

UNIVERSITY OF OXFORD  
DEGREE OF DOCTOR OF PHILOSOPHY  
REPORT OF THE EXAMINERS

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Macroeconomic Modelling of the Labour Market

We are in complete accord that this thesis is of high quality, beautifully written and unquestionably deserving of the award of a D.Phil. The oral examination revealed a candidate who was completely on top of the material, eloquently defending the choices made when constructing the models used in each chapter and well able to set each piece of research in the wider context. The work itself displays a comprehensive grasp of the necessary technology and an ability to extend well known models into new areas, thereby shedding light on a number of issues which had previously been unresolved.

There are four substantive chapters in the thesis, the first three of which develop a variety of Dynamic Stochastic General Equilibrium (DSGE) models whereas the last makes use of a Computable General Equilibrium (CGE) model.

The fundamental structure used in the first three chapters is that of a DSGE model with a Mortensen-Pissarides matching model of the labour market. The purpose of this structure is to investigate how the labour market operates over the cycle when there are workers with different skill levels. The first chapter uses the "simple" Mortensen Pissarides model with a constant and exogenous separation rate. Workers are divided into high skill and low skill and two variants are compared. In the first, firms are partitioned into high skill and low skill firms whereas in the second, high skill workers can work in low skill jobs where they are more productive than low skill workers but less productive than they are in high skill jobs. This allows the author to focus on the role of "overcrowding" in the low skill sector in response to skill biased technical change or increases in the proportion of high skill workers. The modelling here is quite tricky particularly when constructing a matching framework for firms employing two types of workers.

In the second chapter, the author dispenses with two types of worker but utilises the "complex" Mortensen-Pissarides model where we have endogenous separations as a consequence of random productivity shocks. The model also incorporates capital accumulation. This enables the author to study the cyclical properties of job creation and job destruction in response to shocks in the presence of firing costs, unemployment benefits and various types of wage rigidity. The modelling here is a significant advance on the literature and is very elegantly done.

Chapter 3 brings the models of the first two chapters together, so that we have both skilled and unskilled workers alongside endogenous job destruction. The author handles the complexities of the model with a sure touch and he is now able to pursue the cyclical properties of job creation and job destruction in both low skill and high skill sectors as well as analysing the cyclical movements of high skill workers in and out of the low skill sector. Overall, this chapter represents an admirable piece of original research.

In the fourth chapter, the author changes tack and uses a CGE model to analyse the consequences of fuel subsidies for the labour market. The focus is on Iran, where fuel subsidies are huge. The most interesting section is concerned with the consequences of removing the subsidies. Over the long term, the gains are substantial but these take time to come through. Meanwhile, most workers tend to lose out in the short-run. What is more, positive long run effects are largest when the income generated by reducing fuel subsidies is channelled into private sector investment rather than household consumption. Overall, it is clear that even a slow process of subsidy withdrawal is going to be politically very difficult despite the significant overall welfare gains in the long run. As with the other chapters, this is a thoroughly professional piece of research and much impressed the examiner with particular expertise in CGE modelling.

Overall, therefore, a fine D.Phil thesis.

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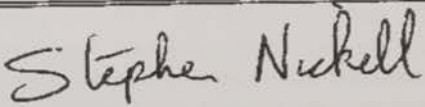
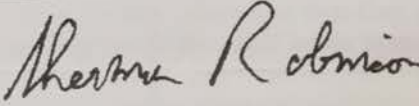
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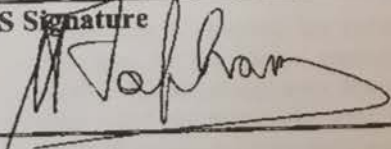
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Supervisor(s)	Dr M Gregory	
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# **Macroeconomic Modelling of the Labour Market**

# **Macroeconomic Modelling of the Labour Market**

Omar AlShehabi

Pembroke College  
University of Oxford

This thesis is submitted for the degree of Doctor of Philosophy at the  
University of Oxford in the subject of Economics



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## Preface

The lessons we learn during a journey often exceed the expected outcomes, and so it proved during the course of this thesis. Beyond its immediate content, I emerged with two great realizations. Firstly, that Economics plays a fundamental role in shaping our world. The structure of our daily routines, jobs, societies, goals and indeed the world we live in are determined to a large extent by our economic activity. Though I had extreme doubts at the beginning and throughout the study, exploring the multiple facets of Economics turned out to be a fruitful and surprisingly enjoyable ride.

Secondly, and probably more importantly, there is much more to studying Economic activity than the Orthodox neoclassical streak which has come to dominate what is nowadays the field of Economics. An in-depth navigation of history, politics, sociology and the many other branches of the social sciences are essential to understanding the societies that we live in. Equally important is an exposure to what have been dubbed “heterodox economics” and the different schools of thought within political economy, areas which unfortunately fail to even receive a mention in most current expositions of Economics. Although models and mathematical formulations are indispensable to a rigorous analysis of the economic world around us, a grasp of the historical context, social norms, and political interactions that shape the economic environment that we live in are just as crucial. Human lives are not static, and the great transformations that societies have undergone cannot be encapsulated simply in mathematical formulae. The late Andrew Glyn provided an enormous wealth of knowledge on this issue, and his encouragement and provoking insights will be greatly missed. Although the focus of this thesis is confined to the study of Walrasian macroeconomic modelling of the labour market, the doors it has opened onto other thoughts and fields necessary to exploring economic and social activity is a deeply cherished experience that will shape my outlook for the rest of time.

With regards to the contents of the thesis, several individuals have been generous in imparting knowledge and advice without which this study would not have seen light. I would like to thank Professor Michel Juillard for advice in programming matters regarding the DSGE models in the first three chapters. The comments of Professor

Simon Wren-Lewis and Dr. Margaret Stevens also proved to be extremely useful. The fourth chapter's study concerning CGE modelling of the Iranian economy was undertaken while working for the World Bank Middle East and North Africa department under the supervision of Anton Dobronogov, whose support is gratefully acknowledged. Hans Lofgren has provided invaluable advice on programming and modelling matters. Special thanks are due to Paul Dorosh for his patient and extensive help during the project.

Ken Mayhew provided great assistance as my college supervisor over the past years at Pembroke College, for which I am grateful. Most of all, I am greatly indebted to my D.Phil. supervisor Dr. Mary Gregory. She has been a constant source of inspiration and knowledge; without her encouragement and guidance this thesis would not have been possible.

Reem Abou El Fadl, Fawaz Bourisly, Fahd Fathi, Daniel Jewel, Darrell McGraw, Shahrzad Sadr, Ala'a Shehabi, Wasma Al Saud, Omar Shweiki and Abdel Razzaq Takriti are irreplaceable friends who have made the past years at Oxford the most defining and enjoyable of my life. A great number of other people have imparted invaluable contributions while completing this study, and overlooking the mention of some of them is inevitable. I can only ask for their pardon and express my sincere appreciation to each person who has offered their assistance in completing this work.

Above all, my deepest gratitude goes to my family. Particularly, my father Hesham, my mother Aisha, my brother Saad, and my Uncles Abdul Hamid and Abdul Aziz have provided endless love and support which I am blessed to have. This thesis is in memory of Abdul Hamid Al Shehabi.

Omar Hesham Abdulmalek Al Shehabi  
Pembroke College  
July 2008

## **Abstract**

This thesis focuses on macroeconomic modelling of the labour market using Dynamic Stochastic General Equilibrium (DSGE) and Computable General Equilibrium (CGE) models. The first three chapters utilize DSGE models calibrated to the Dutch economy. Their main feature is the adoption of the Mortensen-Pissarides matching function approach. The final chapter constructs a CGE model to investigate the effects of fuel subsidies on Iran's labour market.

The first study develops a model that features two types of labour, high versus low skilled, who are differentiated according to educational attainment. The effects of overcrowding, technological change and the unemployment benefit are investigated. While biased technological change and overcrowding hurt low skilled workers, a higher unemployment benefit can help in alleviating these effects.

The subsequent chapter abstracts from educational attainment and features skill differentiation along worker productivity levels. The main feature is the presence of endogenous job destruction, which allows for a rich analysis of job creation and destruction rates. Wage rigidities, unemployment income and firing costs are incorporated. While lower unemployment income and higher firing costs reduce equilibrium unemployment, firing costs and deviations from the Hosios condition are the most important factors in explaining the labour market's cyclical properties.

The third chapter combines the features of the previous two studies to analyze the cyclical dynamics of workers with different educational levels. The analysis focuses on the "overeducated": high skilled workers in simple jobs. They are shown to have unique cyclical properties, where their employment increases in a recession, thus overcrowding low skilled workers.

The final chapter switches focus to CGE modelling. The effects of fuel subsidies on the labour market in Iran are studied. Using a unique Social Accounting Matrix, the results show that reducing fuel subsidies can help in reducing unemployment only if the extra revenue is channelled towards additional Investment.

## **Introduction**

Two approaches have recently come to dominate the macroeconomic modelling of equilibrium within an economy. The Dynamic Stochastic General Equilibrium (DSGE) approach, based on the seminal work by Kydland and Prescott (1982), has become the standard method within which cyclical properties over the business cycle are analyzed. Based on the theory of Walrasian equilibrium, a forward looking rational expectations model is developed and then subjected to shocks to assess the dynamic effects on the economy in the short run.

Computable General Equilibrium (CGE) models form an alternative modelling approach that has also commanded wide application within the literature. Although also based on the theory of Walrasian equilibrium, their focus and nature are different from DSGE models. Geared more towards policy purposes, they tend to take a long-run view of changes in the economy rather than short-run fluctuations. Since the analysis tends to focus on specific policy proposals in a particular country or region, there is considerable disaggregation along economic sectors, with the economic data employed being much richer in detail and scope.

This dissertation will explore both modelling strategies with a particular focus on the labour market. The first three parts develop Dynamic Stochastic General Equilibrium models that make the labour market's business cycle dynamics and steady state properties the centre of attention. In each case, the key feature is the adoption of the Mortensen-Pissarides matching function, where successful matches between workers and firms are a result of the interaction between vacancies and unemployment.

The first study focuses on modelling differences in labour skills defined as educational levels. It introduces two types of workers - high skilled and low skilled - as well as corresponding high skilled and low skilled jobs that they compete for. A worker is defined as high skilled if he has a certain minimum of years of education, while workers are considered low skilled if their years of education fall below the specified minimum. A crucial feature of the study is the presence of overcrowding, where high skilled workers are able to take on low skilled jobs, but the reverse is not possible. The

effects of general productivity shocks, biased technological change, shifts in the labour force composition, and changes in the unemployment income are analyzed.

The second chapter also deals mainly with skills within a DSGE framework, but skills here take on a different meaning. Skills represent workers' productivity on the same job, with different workers having diverging productivity levels. There is a distribution of workers' job productivities, with the firm choosing to terminate jobs where a worker's output falls below a minimum threshold. This modelling strategy allows us to shift the main focus to endogenous job destruction, where the firm's decision to sever a matched job is explicitly derived. A richer analysis of the rates of job creation, job destruction, job turnover, and net employment change is possible. The effects of varying firing costs, unemployment income, and wage rigidities on the business cycle and the steady state are discussed.

Although two stand-alone studies in their own right, the first two sections also serve as building blocks for the third DSGE modelling chapter, where the two features of the first two sections - skill differences both along education as well as productivity levels- are combined into one model. The most important innovation in this analysis is the focus on the labour market cyclical properties of the 'overeducated': high skilled workers employed in low skilled jobs. This is an area which has not been previously addressed in DSGE modelling, and the study makes it possible to investigate job destruction and job creation properties for the overeducated, as well as high skilled and low skilled workers, over the business cycle.

The final chapter takes a different direction to labour market modelling and uses a Computable General Equilibrium approach. The study deals with the specific case of the Islamic Republic of Iran and the relationship between the labour market and crude oil and fuel subsidies in the country. Iran has one of the highest rates of fuel subsidies in the world (estimated at 10% of GDP in 2001) coupled with an acute unemployment problem (World Bank, 2003). Given the huge distortions these subsidies create in the economy, the labour market could potentially be far away from the equilibrium that would obtain in their absence. The complexity and policy relevance of this issue creates an ideal scenario in which to apply a CGE modelling approach.

# I. High Skilled and Low Skilled Labour

## I.1 Introduction

This chapter seeks to develop a set of DSGE models whose main emphasis is the interaction of high skilled and low skilled workers in an economy. The development of these models is motivated by several empirical trends. Firstly, there is a general segmentation of jobs based on levels of education. Jobs in the economy are divided between those that are predominantly undertaken by workers with a basic level of education, while others are overwhelmingly occupied by individuals with higher levels of educational attainment. In the subsequent stylized models, we refer to workers with high levels of education as ‘high skilled’ workers while workers with basic levels of education are referred to as ‘low skilled’ workers.

Secondly, these two groups of workers have diverging experiences within the labour market, with ‘low skilled’ workers generally faring much worse than their ‘high skilled’ counterparts. Low skilled employees experience higher unemployment rates, longer unemployment spells and lower wages. Moreover, they face competition from their high skilled counterparts, with a significant number of high skilled workers taking ‘low skilled’ jobs, a phenomenon dubbed ‘overcrowding’ or ‘overeducation’. The reverse does not hold true however, with low skilled workers generally unable to take on high skilled jobs.

We develop two models in order to assess the importance of these features. What does the segmentation of the labour market entail for unemployment and wages? What if the relative number of high skilled to low skilled workers increases? What consequences arise if more and more ‘high skilled’ workers take over the jobs of ‘low skilled’ workers? What if there is a shock that favours the high skilled sector of the economy? What if a general shock hits the economy? Who stands to lose more? What can we conclude regarding government policy?

## **I.2 Literature Overview**

### **I.2.1 General Framework**

Macroeconomic modelling has been frequently criticized for relying on ad hoc equations and formulations that do not have an analytically rigorous foundation. A disjoint between macroeconomics and the (supposedly) solid theoretical foundations of microeconomics is perceived to exist. This renders macroeconomic modelling susceptible to being attacked for lacking a solid base upon which its theories are grounded. Kydland and Prescott (1982) addressed this problem by providing an applied method of simulating macroeconomic models within a microeconomic foundation, a modelling approach which is dubbed ‘Dynamic Stochastic General Equilibrium’ (DSGE). The main contribution of their formulation lies in providing an analytically tractable method of solving a general model of the economy based on microeconomic principles, with the focus specifically on the dynamics that pertain over the business cycle.

Although their original real business cycle model has been severely criticized, the methods incorporated to solve and simulate models have survived and become standard computational macroeconomics procedures used in academia and policy institutions alike. Canonical papers that incorporate the DSGE framework range from Woodford’s analysis of optimal monetary policy rules (1999) to Eichenbaum’s exposition of the effects of fiscal policy (1990). In short, the DSGE approach has become a widely applied toolkit for analyzing and simulating short run dynamics within an economy.

Standard real business cycle models do not focus explicitly on the labour market, and a rigorous analysis of the dynamics of employment is generally lacking. In its earliest form (e.g. Kydland and Prescott (1982)), the labour market is assumed frictionless and Walrasian in nature, with the dynamics driven by inter-temporal substitution between leisure and employment. This by construction ignores the issue of involuntary unemployment altogether, since unemployment is assumed to arise from the workers’ decision to undertake more leisure and less work. This explanation attracted criticism since it implied that recessions arise because workers become ‘lazy’. No

formal device for the posting of vacancies is posited either. Hence, the dynamics of job destruction and job creation become difficult to assess in such a context.

A model of the labour market which correlates more closely with observed features is needed. A widely applied method for incorporating labour dynamics within DSGE models has become the Mortensen-Pissarides matching function. In this setup, newly created jobs are a product of the number of unemployed workers and the number of vacancies posted through a matching function. Rigidities are thus introduced since not every vacancy results in a job successfully filled, while each vacancy has an associated cost involved. Job searching consequently has associated frictions and expenses.

One of the earlier attempts to include this formulation within a DSGE model is that of Andolfatto (1996), who investigates the effects of incorporating the matching model framework on business cycle properties. Particular emphasis is placed on the dynamic evolution of vacancies, unemployment, real wages and productivity. The study compares the basic real business cycle model and the job search model to empirical data of the United States (U.S.). Andolfatto finds that the matching framework is able to match the observed data more closely and to explain many anomalies within the basic real business cycle model. In particular, his model explained the persistence of unemployment and why adjustment in the economy occurs through changes in the number of employed workers rather than changes in the number of hours worked, a feature that the original real business cycle models remain silent on. Furthermore, the model reports a negative correlation between vacancies and unemployment, the so-called Beveridge curve.

Merz (1995) develops a similar DSGE model that includes searching for jobs by the unemployed, where the probability of an unemployed worker gaining a job depends on his expended effort on search with a corresponding disutility cost incurred. Similar to Andolfatto, Merz's two-sided search model (where costly search is now conducted by both the unemployed and the firm) corresponds more closely to the U.S. empirical data on the labour market than the standard real business cycle model. Labour adjustment occurs at the extensive rather than the intensive margin, while a negative

correlation relationship between unemployment and vacancies over the business cycle is reproduced.

## **I.2.2 Skills Heterogeneity**

In this study the focus aims to take a different path from the above papers. Most of the research in DSGE models incorporating matching frictions assumes a single type of labour. Specifically, no differentiation is made on what is dubbed the ‘skills’ frontier. My aim is to incorporate heterogeneity in skills across the labour force.

What is meant by differences in skills? Studies take divergent approaches to the definition of skills. The most common differentiation is by education. Individuals with a certain level of education are considered to be high skilled, while workers whose qualifications fall below that minimum are identified as low skilled. This is the definition adopted by Rubart (2006) and Acemoglu (1998). Others postulate that there is only an imperfect correlation between skills and education, where higher education acts as an imperfect signalling mechanism for skills. Thus, skill is seen here as an ability that has been developed and influenced by factors other than education (e.g. innate ability). This is the approach taken by e.g. Morato, Fabra, and Planas (2003). Still others define skills by the industry that jobs are concentrated in. Different workers have distinct skills that are suited to diverging industries, and there is no ex ante ranking of the relative qualities of skills. Marimon and Zilibotti (1999) take this approach. Others, such as Lamo, Messina, and Wasmer (2006) similarly assume that there are diverse skills suited for different sectors, but that some skills (e.g. managerial) are more mobile across industries and less rigid than other specific skills that are suited to a particular sector (e.g. coalmining).

There is a common thread running through all of these definitions. A skilled worker is seen as one who is ‘more able’ in a particular field than his counterpart non-skilled worker. Obviously, this ability can be defined by a worker being more suited to a particular job, more mobile across sectors, or more productive than his counterpart. The definition adopted here is that ‘high skilled’ workers have a certain minimum amount of education, while ‘low skilled’ workers do not possess that minimum. There

are several motivations for this. Some jobs require a certain education level as a minimum, and agents who do not fulfil this criterion are not even considered for the job (e.g. academia). Furthermore, there is considerable evidence that workers with higher education levels are more mobile across sectors than workers with lesser educational levels (e.g. Green et al (1999)). The empirical evidence also shows that highly educated workers earn higher wages than their counterparts. Thus, 'high skilled' can be interpreted here as a feature that opens up wider possibilities to its possessor and makes a workers relatively better off than others in the labour market, whether this is through being able to work in a larger variety of sectors or being able to command a higher wage.

Empirical evidence<sup>1</sup> on the properties of the labour market in the United States and Europe in the last two decades of the twentieth century seems to be almost unanimous in confirming that the labour market experiences of skilled and unskilled workers vary considerably, with unskilled workers getting the 'rough-end' of the deal. As Autor et al (1998) point out, there seems to exist a dualism between different skills groups that is based on levels of education. There is one upper tier with high employment levels and low employment variation that also benefits from steady and high wages. The lower tier seems to suffer from lower employment rates, higher employment variation, and lower, less steady wages.

There are, however, significant differences across countries in terms of the experiences of the different skill groups. Mortensen and Pissarides (1999b) point out that in Europe, the wage differential across skill groups has remained remarkably stable, although the unemployment duration has changed markedly, with low skilled workers suffering from longer unemployment spells. Furthermore, the unemployment increase in Europe has mainly concentrated on the low skilled segment of the labour force, with the high skilled segments suffering very little or no increase in unemployment rates. Thus, the main reason for the rise in unemployment in Europe has been an increase in the long term unemployed. Alogoskoufis et al (1995) document that the flow out of unemployment halved, while flows into unemployment remained steady between 1979 and 1988.

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<sup>1</sup> The empirical evidence will focus mainly on Europe and the United States in the last two decades of the twentieth century.

In the U.S., however, there is a different story. Levy and Murnane (1992) and Alogoskoufis et al (1995) show that both the flows out of and into unemployment have been stationary. Instead, the main problem has been a growth in the wage differential both between skill groups and within skill groups. Bound and Johnson (1991) and Katz and Murphy (1992) show that between 1979 and 1987, the average weekly wages of college graduates with 1-5 years work experience increased by 30% relative to high school graduates. This increase in inequality is not only due to an increase in the wages of the skilled, however, as the real wages of the unskilled have also fallen by 20% between 1979 and 1987 (Katz and Murphy (1992)).

### **I.2.3 Theories and Models of Skill Heterogeneity**

What are the reasons for the diverging experiences of differently skilled workers in the economy, and why are there differences in their conditions across countries? Recently, a few papers have attempted to incorporate labour skills in the Mortensen-Pissarides framework. The structure of the models developed in these papers depend crucially on the explanation that the authors think accounts for the experiences of the differently skilled agents in the labour market. Indeed, several hypotheses have been put forward to explain these phenomena. This next part of the literature overview will assess these explanations and the papers that have attempted to model some of them.<sup>2</sup> The focus will be on analyzing the alternative ways of formulating a model depending on the explanation that that one sees as the most relevant.

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<sup>2</sup> One important contending explanation not covered here concerns the effects of trade and competition from other countries on the fortunes of differently skilled workers, an explanation predominant within the International Economics literature (e.g. Wood (1995)). It is argued that the opening up of trade hurts low skilled workers since they face increasing competition from their counterparts in developing countries, where low skilled workers are more abundant. This places downward pressures on their wages and employment levels and negatively affects their overall experience in the labour market. Such an explanation is not covered because, to our knowledge, such a method of modelling has not received attention within DSGE models based on the Moretensen Pissarides matching function. Indeed, this could present an interesting and important contribution to the literature.

## **Mismatch and Specific Skills**

One hypothesis that has been put forward for the differences in labour market experiences is that of job-worker skill mismatch. Skills are too sector specific, and when there is a shift in the sectoral composition of the economy, workers find it hard to adjust to the skill requirements of the new sectors. To take an extreme example, a person might have the necessary skills to be a nuclear physicist, but these skills are not necessarily optimal for being a football player. Lamo, Messina, and Wasmer (2006) provide evidence of this low mobility effect in Poland, while Blanchard and Katz (1992) document low mobility in several U.S. states, most notably Massachusetts.

One modelling structure used to expound this effect is the so-called circle model, initially popularized in the Industrial Organization literature by Salop (1979). Marimon and Zilibotti (1999) utilize this framework, where workers are spaced out along a circle, with the movement around the circle representing different regions of skill requirements. A worker's productivity depends on the distance of his skill-position from that of the firm that would ideally suit his skills. The further a worker's placement is from his ideal job position, the lower his productivity is on his current employment relationship. The purpose of the model is to analyze the effects of unemployment insurance on workers. The model predicts that although unemployment insurance has the expected effect of increasing unemployment, it does however help workers in finding a suitable job. There is a possibility of mismatch between the types of workers and firms, and unemployment insurance helps in creating more suitable matches by supporting an extended period of search for optimal jobs.

The general problem with a circle model is that different labour types *ex ante* have the same probability of acquiring a job, assuming that the number of available jobs in each sector is the same. In other words, any variations in unemployment across sectors arise solely from differences in the number of jobs available in each sector. This construction implicitly assumes that the so called "shift in demand for labour" hypothesis, e.g. from manufacturing to services, is the only reason for changes in unemployment. Although this might be a plausible explanation, no consideration is given to the possibility that qualitative differences in levels of skills, mobility or education might offer a reason for unemployment.

An alternative method of modelling skills differences in a Mortensen-Pissarides framework is through assuming that there are only two types of workers, with one type (the high skilled) possessing a quality lacking in the other. In the skills mismatch scenario, the demarcation between the two types is defined by their mobility across sectors.<sup>3</sup> Thus there are rigid ‘low skilled’ workers, who suffer from low mobility when moving to other job types. Equivalently, there are ‘high skilled’ workers who are assumed to be more mobile between the different sectors. One interesting paper that follows this approach is Lamo, Messina, and Wasmer (2006). There are two sectors in the economy and two types of workers, distinguished by their mobility across sectors. High skilled workers are assumed to be able to work in both sectors, while low skilled workers can find employment in only one. Their modelling analysis is centred on comparing Lithuania to Poland. Lithuania has a labour force that is highly mobile between sectors, due to a general education that is applicable to a wide range of fields. Poland, on the other hand, seems to have a more rigid labour market that is highly specialized and sector-specific. The model reproduces the hypothesis that specificity of human capital has adverse effects on the employment experience of low skilled workers.

The circle and two skill-types frameworks each have their advantages and drawbacks. On the one hand, the circle model is able to show the interactions between several sectors. Furthermore, it does not make the elitist assumption that workers in certain sectors are by nature more highly skilled than others. Instead it is simply assumed that demand shifts from certain areas of the economy towards others. On the other hand, the circle model fails to allow for qualitative differences in levels of skills as an explanation of the diverging experiences of workers. In the absence of external skill-biased shocks, workers of different types would theoretically all have the same employment experience. No space is allowed for the importance of factors such as educational attainment or mobility between sectors on employment status. Any differences that occur are because of an external shock that favours one sector over the

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<sup>3</sup>A further way of modelling skills differences is by assuming that there is a distribution of workers’ productivity. In this framework, skill levels are modelled as productivity levels. All employees work in the same job and industries, except that some workers are more productive than others on the job. This modelling strategy is used in the second part of this thesis, where it will be discussed in more detail.

other. In other words, it is simply a matter of external forces whether workers of certain sectors enjoys an increase in demand to the detriment of others.

The two labour-types model, although limiting the amount of heterogeneity in the setup, allows for interaction between the two types of workers and for differences in fortune due to educational attainment or mobility. Thus, for example, the stock of skilled workers could hypothetically influence the employment status and wage levels of unskilled workers. More possibilities and interactions between the different skill types are allowed for within this framework. Not surprisingly, this framework has proved more popular when modelling skills in the labour market. For these reasons the two skill-types model will be the one adopted in this part of the dissertation, with the distinguishing feature of the two skill types being the level of education.

### **Skill Biased Technological Change**

One of the leading explanations put forward for the diverging experiences of high skilled and low skilled workers in the labour market is skill biased technological change. There has been an asymmetric rise in the demand for skilled workers due to technological innovation that demands a higher skilled labour force (Krugman (1995), and Berman et al (1998)). The argument contends that there has been a significant increase in technology that requires a labour force endowed with a higher level of education, causing the demand for such labour to increase to the detriment of the less demanded unskilled workers.

Rubart (2006) uses the two skill-type framework for the analysis of skill biased technological change. Labour is ex-ante heterogeneous and divided into two different categories of educational attainment, with the labour market and job opportunities for each worker type being completely segmented. Job destruction is assumed to be exogenous. A technological shock that is biased towards skilled labourers is introduced. Rubart's main conclusion is that a skill biased technological shock leads to an increase in demand for high skilled workers, which leads to a greater substitution of low skilled with high skilled workers. This adversely affects the wage and employment levels of the low skilled.

## **Overcrowding of high skilled**

An alternative explanation to an increase in demand for high skilled workers is that of an increase in the supply of high skilled workers. This increase in supply can have several effects: one of them could be that there is an ‘over-crowding effect’, where the increasing number of high skilled workers leads them to take over jobs of the low skilled. There is a burgeoning empirical literature dealing with this phenomenon, commonly referred to as ‘over-education’ (e.g. Hartog, 2000)<sup>4</sup>.

Pierrard and Sneessens (2004) combine both a skill biased technological shock and the ‘crowding out’ hypothesis in a two labour-types Mortensen-Pissarides model calibrated to the Belgian economy. High skilled (more educated) workers are assumed to be able to work in both the low skilled and the high skilled sector. They look at whether over-qualified workers crowding out low skilled workers can be a significant factor in explaining the experiences of each worker type in the labour market. Their model predicts that skill biased technological shocks do play an important role, but that the crowding out effect also has a significant impact.

## **Supply of high skilled workers creates its own demand**

The other possible consequence of increasing the supply of skilled workers is ‘supply creating its own demand.’ Here, the increase in the supply of skilled workers causes firms to decide to open jobs that require higher skills. Hence, the composition of the economy is endogenous. Traditionally, it has been postulated that the increase in demand for high skilled workers has pushed workers to acquire higher skills and education. Here, the mechanism is reversed, and the increase in the supply of high skilled workers is what causes an increase in the number of high-tech jobs, thereby adversely affecting low skilled workers. Beaudry and Green (1998), among others, have recently put forward empirical evidence to support this hypothesis. This is the approach that Acemoglu (1998) employs in his static, non-DSGE model. He hypothesizes that an increase in the supply of high skilled workers causes increasing wage inequality and unemployment for both skills groups.

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<sup>4</sup> A more extensive discussion of the overeducated is given in Chapter 4.

Blazquez and Jansen (2005) combine Acemoglu's idea of endogenous job composition with the crowding out effect in a static non-DSGE model. They reach the surprising conclusion that high skilled workers taking over the jobs of the low skilled is not necessarily detrimental to the latter. This is because, when a significant number of high skilled workers are willing to take low skilled jobs, firms decide to create an increased number of low skilled positions. Some of these low skilled jobs are taken up by low skilled workers, thus reducing their unemployment duration.

Obviously, the model one adopts depends critically on the factors one thinks best explain the diverging experiences of differently skilled workers. Hence, the goal of this study is to develop a Mortensen-Pissarides model that is able to replicate and provide an insight into labour market dynamics while also providing a modelling framework for labour skill heterogeneity that is able to shed light on the labour market experiences of different workers.

This study adopts the two skill-types approach, with the level of education distinguishing the two groups. The model allows us to investigate several of the effects outlined above. Particularly, we are able to analyze the consequences of a general technological change, biased technological change, the role of overcrowding in the labour market due to mismatch between high skilled workers and low skilled jobs, and changes in the relative supplies of high skilled versus low skilled worker groups.

We develop two models in order to assess the importance of these features. What does the segmentation of the labour market entail for unemployment and wages? What if the relative number of high skilled to low skilled workers increases? What consequences arise if more and more 'high skilled' workers take over the jobs of 'low skilled' workers? What if there is a shock that favours the high skilled sector of the economy? What if a general shock hits the economy? Who stands to lose more? What can we conclude regarding government policy?

### I.3 The Models

The main feature of the two models is the presence of two types of labour, high skilled and low skilled, as in the models of Rubart (2006) and Pierrard and Sneessens (2004). ‘High-skilled’ and ‘low skilled’ are defined in terms of education, where high skilled workers have a minimum level of education which low skilled workers lack. As a background, both models in this section assume a capitalist neoclassical economy within a Walrasian equilibrium setting: rational and self-oriented agents with perfect foresight seek to maximize their own utility and profits. Labour, like all other goods in the economy, is a commodity that can be rented out for a price (wages). The models are all real models; there are no nominal (monetary) features. The main focus of the model will be on the labour market. Any complications that do not form part of the central analysis (e.g. habit formation in consumption or monopolistically competitive firms) have been deliberately abstracted from in order to focus specifically on labour market dynamics.

The main difference from a pure Walrasian model is the presence of matching frictions in the labour market and decentralized wage determination via the Nash Bargain. Trade in the labour market is assumed to be decentralized, costly, and time-consuming due to the presence of frictions. The way this friction is modelled is through a matching function. The idea of a matching function is similar to that of a production function, where a successful match is assumed to be the outcome (or output) from the interaction between unemployed workers and vacancies posted by the firm (inputs). In other words, job production and output production are seen as two different markets but with similar postulated generating functions.<sup>5</sup>

We develop two models. In the first model the two labour markets are completely segmented, with high skilled workers working exclusively in high skilled jobs and low skilled workers employed only in low skilled jobs. The second model relaxes this assumption and allows for high skilled workers to work in the low skilled sector, hence

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<sup>5</sup> A common criticism of matching-function models is their "black-box" approach to frictions. These frictions are simply postulated to exist, with no formal model that justifies their particular form, even though one can give a list of factors that might cause these frictions, e.g. performing badly in job interviews, incompatibility between the worker and the firm, etc. For a survey, see Pissarides and Petrongolo (2001).

exhibiting “overcrowding”. The exposition proceeds as follows: First each model’s analytic properties are developed and discussed. After each model has been fully articulated, they are both calibrated to data based on the Dutch economy. The discussion focuses on the steady state results and the effects of introducing shocks. This is followed by a discussion about government policy implications and suggestions for further modifications and research.

Although this chapter also serves as a building block for the fourth chapter in the thesis, it stands alone as a work of research with its own contributions to the current literature. It makes an explicit and detailed comparison between the modelling nature and results of no “overcrowding” (i.e. complete segmentation in the labour market) and the model which includes this feature. Such an in-depth comparative analysis has been lacking in previous studies. The development of the models also takes a different approach, including abstraction from on the job search in order to more clearly focus the discussion on the factors of interest. Finally, the analysis of the results and the static effects of permanent shocks on the labour markets are more detailed in scope and depth than those employed in similar studies.

### I.3.1 Model 1: Labour Markets with Complete Segmentation

The first model features complete segmentation of labour markets. There are two representative intermediate firms, each employing only one type of labour (either high or low skilled). Thus employment of the two labour types is determined via the activities of the intermediate firms. The model serves as an exposition of the standard capital-augmented DSGE model with Mortensen-Pissarides matching functions, since the model in essence represents the basic capital-augmented model but with two labour markets instead of one.

The economy is divided into five sectors: the representative household, two intermediate firms which use labour as input, a final firm which uses intermediate goods and capital as input, and the labour market. Production has been split into intermediate and final firms in order to clearly focus the exposition on the dynamics of the labour market.

#### I.3.1.1 The Labour Market

The frictions in the model occur within the labour market, with only the intermediate firms using labour as a direct input. There are two intermediate firms, one that is high-tech (complex), employing only high-skilled workers, while the other is low-tech (simple), employing only low skilled workers. We normalize the total stock of workers available to one, with  $\gamma$  representing the fraction of high skilled workers and  $1-\gamma$  the fraction of low skilled workers in the economy.  $n^h$ ,  $n^l$ ,  $u^h$ , and  $u^l$  represent the number of high skilled workers employed in the high-tech sector, low skilled workers in employed the low-tech sector, high skilled unemployed workers, and low skilled unemployed workers respectively. The superscripts  $l$  and  $h$  will be used to denote variables in the low-tech and high-tech sectors respectively.

$$n_t^h + u_t^h + n_t^l + u_t^l = 1 \quad (1)$$

$$n_t^h + u_t^h = \gamma \quad (2)$$

$$n_t^l + u_t^l = 1 - \gamma \quad (3)$$

All variables and parameters are normalized in relation to the workers base (i.e. base =1). In each period an intermediate firm is assumed to post a certain number of vacancies, denoted  $v^i$  (where  $i$  denotes the type of labour market  $l$  or  $h$ ). The matching function solves for the total number of new vacancies being successfully filled, or the flow of new matches in a particular period. The function is characterized by the inputs unemployment and vacancies:

$$m_t^i = M^i(u_t^i, v_t^i) \quad (4)$$

The matching functions (whose precise forms will be articulated later on) are assumed to be increasing in their arguments, concave, and homogenous of degree 1. The solution to each matching function  $M^i$  represents the number of successful matches  $m_t^i$ , or new jobs created. Thus it is assumed that newly created matches depend positively on the number of those unemployed, since the more workers are searching for jobs the more likely new jobs will be filled.  $m^i$  also depends positively on vacancies: the more vacancies posted, the more successful matches will result.

The concept of market tightness  $\theta$  closely relates to the matching function.  $\theta^i$  is defined as the proportion of vacancies to unemployment of each skill type and reflects the availability of jobs to those unemployed:

$$\theta_t^i = v_t^i / u_t^i \quad (5)$$

The higher  $\theta^i$  is, the easier it is for an unemployed worker to find a job, while the lower  $\theta^i$  is, the easier it becomes for a firm to fill its posted vacancy (and vice versa). A higher  $\theta^i$  implies that the demand for labour relative to the supply is high.

The probability of a vacancy being successfully filled can be written in terms of the matching function:

$$q_t^i = m_t^i / v_t^i \quad (6)$$

$q^i$  depends positively on the unemployment level (since the higher the unemployment level the higher the number of job seekers for a particular vacancy), and it is inversely proportional to both the number of vacancies (since higher vacancies imply that there is increased competition between firms for job seekers) and market tightness.

Initially, we assume that there is an exogenous rate of job separation in each sector given by  $\tau^i$ . This enables us to derive an equation for the evolution of employment at each intermediate firm

$$n_{t+1}^i = (1 - \tau^i)(n_t^i + q_t^i v_t^i) \quad (7)$$

The above expression is a stock-flow relationship. The next period's stock of employed workers depends on surviving workers from the current period and the flow of successful new matches. Modelling a stock-flow relationship in discrete time requires care. The issue is whether the flow of new hires (i.e.  $q_t^i v_t^i$ ) should be modelled in the same time-period as the total new stock of workers  $n_{t+1}^i$  or whether it should be lagged one period backwards. This study assumes that the stock of successful matches entering next period's production is determined in the current period. Hence the timing might be explained as follows: vacancies are posted at the beginning of the current period  $t$ , and the successful number of matches is known at the end of that same period. The existing workers and successful new matches that have survived firing from period  $t$  are translated into the employment stock at the beginning of period  $t+1$ . This is the method followed by Krause and Lubik (2007), among others.

### I.3.1.2 The Intermediate Goods Firms

There are two representative intermediate firms, one employing high skilled labour only and the other low skilled labour exclusively. Each intermediate firm produces a distinct intermediate good that will be used in the production of final output. These intermediate goods depend only on one factor that each firm can influence: the workers (either high or low skilled). The firms choose their levels of employment only indirectly through their choice of the vacancies posted, which in turn determines the number of workers at the firm through the matching process. No capital considerations enter into the intermediate firm. Each intermediate firm's objective is to maximize its profits from production given the costs it faces. Although at first glance this construction might appear contrived, this division between the two intermediate firms will prove helpful in analyzing the properties of the different labour markets, particularly when overcrowding is introduced in the second model.

Each intermediate firm  $i$ 's output can be presented as follows (where  $i$  represents either the simple ( $l$ ) or complex firm  $h$ ):

$$Q^i = y^i n_t^i \quad (8)$$

$y^i$  stands for the exogenous productivity level in each sector.

Turning to costs, each firm faces two different types of expenditure. The first of these is the wage  $w_t^i$  paid to workers.<sup>6</sup> The second expense is a vacancy cost  $a^i$ , which applies when a firm posts a vacancy. It is necessary that vacancy posting incurs a cost to limit vacancy supply; otherwise firms are able to post as many vacancies as they desire without worrying about associated expenses. Indeed, it is also a natural assumption that posting and maintaining a vacancy is costly, as it involves advertising and recruitment costs. The firm has to allocate funds for expenditure e.g. on letting job seekers know that a vacancy is available and on appropriately screening applicants' qualifications. Vacancies are assumed to have a flat cost rate, and so economies of scales are abstracted from.

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<sup>6</sup> The exact nature of the wage derivation is discussed below in section I.3.1.3.

We can now spell out the firms' maximization problem more clearly. Each firm's objective is to choose the current period vacancy level  $v_t^i$  (the control variable) with the corresponding employment level in the next period  $n_{t+1}^i$  (the state variable), in order to maximize the present discounted value of profits given by:

$$\pi_1^i = E_1 \left\{ \sum_{t=1}^{\infty} B^{t-1} [c_t^i y^i n_t^i - w_t^i n_t^i - a^i v_t^i] \right\} \quad (9)$$

Subject to the evolution of the employment constraint relevant to each firm outlined previously:

$$n_{t+1}^i = (1 - \tau^i)(n_t^i + q_t^i v_t^i) \quad (10)$$

$c_t^i$  in equation (9) above stands for the price the intermediate firm  $i$  receives for its good, which is determined in the final goods firms.

Maximizing the resulting Lagrangian with respect to the above outlined variables yields the following First Order Conditions for each intermediate firm  $i$ :

$$n_{t+1}^i : \lambda_t^i = BE_t [c_{t+1}^i y^i - w_{t+1}^i + (1 - \tau^i) \lambda_{t+1}^i] \quad (11)$$

$$v_t^i : \frac{a^i}{q_t^i} = (1 - \tau^i) \lambda_t^i \quad (12)$$

$$\lambda_t^i : n_{t+1}^i = (1 - \tau^i)(n_t^i + q_t^i v_t^i) \quad (13)$$

$\lambda_t^i$  represents the Lagrangian multiplier on the equation for the evolution of employment, which signifies the expected value of a future employee to the firm. This can be seen in equation (11), where the value of an employee equals the output he will produce minus the wage he will receive in addition to the value he will bring in the subsequent period ( $\lambda_{t+1}^i$ ). In this manner, equation (11) resembles a Bellman equation. Equation (12) equalizes the expected costs of hiring a worker (left hand side of the equation) with the expected benefits that a worker could bring to the firm. Equation (13) is the evolution of employment from one period to another, introduced previously. Since both firm types, as explained above, are mirror images of each other (with the only difference being the type of labour used in production), the above framework applies to each type of firm.

### I.3.1.3 Wage Setting

The standard methodology for determining wages in a Mortensen-Pissarides matching function framework is via Nash Bargaining. Wages are not determined in a pure competitive model, where labourers receive the marginal product of their labour as wages. Rather, the production surplus that accrues from the match is divided between the workers and the firms depending on the bargaining power that either may command. Newly created matches create a surplus that continues if the match is maintained, while this surplus is lost if the match breaks down. The Nash Bargaining formulation spells out how this surplus is to be divided between the workers and the firm.

For each firm  $i$ , the Nash Bargain solves the following problem<sup>7</sup>:

$$\left[ V_t^i - G_t^i \right]^{1-\kappa^i} = \left[ J_t^i - U_t^i \right]^{\kappa^i} \quad (14)$$

$V_t^i$  stands for the value of a filled job to a firm, while  $G_t^i$  is the value of a vacancy to a firm.  $J_t^i$  represents the value of being employed to the worker, while  $U_t^i$  stands for the value of being unemployed. Finally,  $0 < \kappa^i < 1$  represents the worker's bargaining strength in each sector, where a higher value implies a larger share of the production surplus accruing to the worker. The optimal solution of the Nash Bargaining procedure has the following characterization:

$$\kappa^i \left[ V_t^i - G_t^i \right] = (1 - \kappa^i) \left[ J_t^i - U_t^i \right] \quad (15)$$

The free entry condition states that firms will keep posting vacancies until the value of a vacancy is reduced to zero ( $G_t^i = 0$ ). This makes the Nash Bargaining solution become:

$$\kappa^i \left[ V_t^i \right] = (1 - \kappa^i) \left[ J_t^i - U_t^i \right] \quad (16)$$

To derive an explicit formulation for the wage we need to find expressions for  $V_t^i$ ,  $U_t^i$ , and  $J_t^i$ . For this purpose, it is more instructive to construct a Bellman asset equation for the various parties involved.

With respect to each intermediate firm  $i$ , one can write the value of a job filled as:

$$V_t^i = c_t^i y^i - w_t^i + BE_t \left[ (1 - \tau^i) V_{t+1}^i \right] \quad (17)$$

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<sup>7</sup> For more on Nash Bargaining, see Nash (1951).

The value of a job match to the firm in the current period  $V_t^i$  depends on wage costs subtracted from the production revenue (this part comprises the net revenue flow from the asset), in addition to the expected future value of the match (which reflects the change in the stock value of the asset). This future value is determined by the probability of the match continuing  $[(1-\tau^i)]$ .

We now determine the value of employment,  $J_t^i$ , for a worker of each type  $i$ .  $J_t^i$  comprises the wage the worker gains in the current period plus the expected value next period (which depends on the probability of the employment match continuing):

$$J_t^i = w_t^j + BE_t[(1-\tau^i)J_{t+1}^i + \tau^i U_{t+1}^i] \quad (18)$$

$U_t^i$  stands for the present value of unemployment to an unemployed worker of type  $i$ . He gains unemployment income<sup>8</sup>  $w^u$  in the current period plus the expected value next period (which depends on the probability of moving out of unemployment and into employment,  $\theta_t^i q_t^i$ ):

$$U_t^i = w^u + BE_t[\theta_t^i q_t^i (1-\tau^i) J_{t+1}^i + (1-\theta_t^i q_t^i (1-\tau^i)) U_{t+1}^i] \quad (19)$$

If the value functions are replaced in the Nash Bargaining solution, we can derive an explicit characterization of the worker-specific wage:

$$w_t^j = \kappa^i [q_t^i \theta_t^i (1-\tau^i) B V_{t+1}^i + c_t^i y^j] + (1-\kappa^i) [w^u] \quad (20)$$

We now need an expression for  $B V_{t+1}^i$ , the value of an employed worker to the firm in  $t+1$ . This is simply  $\lambda_t^i$ , the Lagrangian multiplier on the equations of the evolution of employment, which represents the expected value of a future job match to the firm. Substituting in equation (12) we arrive at the expression for wages:

$$w_t^j = \kappa^i [a^i \theta_t^i + c_t^i y^j] + (1-\kappa^i) [w^u] \quad (21)$$

A more detailed derivation of the above equation is given in the appendix. The individual wage depends positively on the unemployment benefit, vacancy costs, market tightness, the productivity of a worker of type  $i$ , and the price at which an intermediate good is sold. The effect of an increased worker's bargaining share on wages is by definition positive, since a greater part of the surplus goes to the workers. An increase in the unemployment income gives workers the leverage to demand a higher working wage in order to take up a job. Furthermore, higher vacancy costs imply

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<sup>8</sup> Unemployment income can either be seen as unemployment benefits or non-market returns to unemployment, which would also include other returns such as leisure.

that the firm is willing to offer a higher wage in order to fill the job this current period, and not to incur any further hiring costs in the future. High levels of workers' productivity tend to increase output, which then increases the surplus over which workers and firms bargain, thus generating a higher wage. Similarly, it is obvious that a higher intermediate good price will increase the surplus over which workers and firms bargain. Finally, an increase in market tightness makes it less likely that a firm will fill a vacancy and more likely that an unemployed person will find a job elsewhere, strengthening the workers' hand and causing the bargained wage to increase.

### I.3.1.4 Final Goods Firm

The representative final firm is assumed to operate in a perfectly competitive market and to have a constant returns to scale Cobb- Douglas production function with three inputs, capital and two intermediate goods. There is also an aggregate technology parameter  $Z$ :

$$Q_t^{final} = F^{final}(K_t, Q_t^l, Q_t^h) = ZK_t^{\mathcal{G}} [Q_t^h]^{\alpha} [Q_t^l]^{1-\mathcal{G}-\alpha} \quad (22)$$

where  $\mathcal{G}$  and  $\alpha$  represent the elasticity of final output with respect to capital and the complex intermediate goods respectively. Thus  $\alpha$  determines the percentage by which final output changes if there is a change in the amount of the complex intermediate input.

It is worth spending a few moments analyzing the model's overall setup. In the model as it currently stands, high and low skilled labour are simply different inputs in the (final) production function via their respective intermediate goods. In other words, they play the exact same role as would capital or any other input one might want to include in the production function. Both types of labour are formally completely separate from each other, as each enters the production of its respective intermediate good only. Thus, there is no direct interaction between the two. There is, however, indirect interaction that occurs in the final good sector via the substitution that could happen between the different factors of production. Furthermore, the only difference between the two labour types occurs in the respective elasticities of their intermediate goods,  $\alpha$  and  $(1 - \alpha - \mathcal{G})$ , and their respective labour productivity levels in their sectors,

$y^l$  and  $y^h$ . These elasticities and productivity parameters will crucially determine the different fates of the two types of workers in the labour market, both in terms of the wages they receive and the levels of employment and unemployment they face.

The final firm's decisions are based on standard neoclassical assumptions. The firm has to pay for the foregone costs of the depreciation of capital as well as the rental rate of capital owned by the household. The final firm has to also pay for the costs of the intermediate output that it uses for production. Hence the firm aims to maximize the following profits, subject to its choices of the quantities of the three intermediate inputs:

$$\pi_1^{final} = E_1 \left\{ \sum_{t=1}^{\infty} B^{t-1} [Q_t^{final} - c_t^h Q_t^h - c_t^l Q_t^l - (\delta + r_t) K_t] \right\} \quad (23)$$

$r_t$  is the rental rate of capital that goes to the households,  $\delta$  is the depreciation rate, and the price of final output is normalized to unity.

The first order conditions are:

$$Q_t^h : F^{final}(K_t, Q_t^l, Q_t^h)_{Q_t^h} = \alpha Z K_{jt}^{\beta} [Q_t^h]^{\alpha-1} [Q_t^l]^{1-\alpha-\beta} = c_t^h \quad (24)$$

$$Q_t^l : F^{final}(K_t, Q_t^l, Q_t^h)_{Q_t^l} = (1 - \alpha - \beta) Z K_{jt}^{\beta} [Q_t^h]^{\alpha} [Q_t^l]^{-\alpha-\beta} = c_t^l \quad (25)$$

$$K_t : F^{final}(K_t, Q_t^l, Q_t^h)_{K_t} = \beta Z K_{jt}^{\beta-1} [Q_t^h]^{\alpha} [Q_t^l]^{1-\alpha-\beta} = r_t + \delta \quad (26)$$

Equations(24),(25) and(26) reproduce some of the main features of the neo-classical model: the return to a factor equals its marginal productivity. Thus equation (24) states that the marginal benefit of an extra unit of the complex intermediate goods (left-hand side of the equation) should equal its marginal cost (the price of the intermediate good on the right-hand side of the equation). Equation (25) states a similar result for the simple good. Finally, equation (26) shows that the rental rate going to the households equals the marginal benefit of capital to the final firm. Although capital considerations do not form a central part of the analysis, their inclusion yields several advantages. Introducing capital allows for intertemporal substitution of consumption across time, as without capital the household sector is unable to reallocate consumption from one period to another. Furthermore, it allows for a more realistic calibration of the model when compared to a model that lacks such a feature.

### I.3.1.5 Households

We assume that there is one representative household which includes both labour forces, the high and low skilled. It includes the employed as well as the unemployed from each group. Since there is only one representative household, the welfare and utility of each member of the household is taken into consideration in the maximization problem. Each worker cares about the welfare of all other agents. An employed person, whether high or low skilled, cares just as much about himself as about an unemployed worker. We can add to these as well the fact that a representative household assumes that high skilled and low skilled workers all share the same returns of capital and firm profits.<sup>9</sup>

Assuming a representative household is a pervasive problem within the current DSGE literature, where no mechanism has been developed to introduce household heterogeneity. It is always assumed that the household is composed of a large number of individuals who protect each other against fluctuations in income.<sup>10</sup> For tractability, we stick to the current state of the art and make the assumption that there is one representative household.

Labour (of both types) is supplied inelastically, and unlike in the classical Walrasian models, workers cannot choose the amount of labour time they supply. Thus labour adjustment happens at the extensive (workers are either hired or fired) but not the intensive margin (workers cannot vary the amount of hours they choose to work).

Some members of the household, whether high or low skilled, are employed while others remain jobless. All members of the household are potentially employable and

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<sup>9</sup> A major drawback of models with perfect foresight and rational expectations is that if one assumes that each type of worker is his own household (i.e. low skilled and high skilled workers are each in a separate representative household that maximizes its own utility) then the low-skilled household would choose to own more capital than the high-skilled household. Since low-skilled workers receive a lower wage, they will invest in more capital, since it presents a higher return relative to their wages when compared to high-skilled workers. This obviously runs contrary to the data. One possible alternative is to introduce two households for each of the skill types and assume that only high skilled workers accumulate capital. This, however, is not very insightful, as it requires the extreme assumption that low skilled workers do not accumulate any capital. More seriously, it implies that low skilled workers are unable to allocate their consumption inter-temporally, having to spend all of their income in one period on consumption. Since this framework does not offer any tangible improvements, we stick to the single representative household model.

<sup>10</sup> For more information, see Andolfatto (1996) and Merz (1995).

therefore part of the labour force. Those who are unemployed receive an unemployment income that takes on the same value for all unemployed worker types. This allows us to exogenously vary the unemployment income and assess its impact on the economy.

The household maximizes the following lifetime utility with respect to consumption:

$$H_1 = E_1 \sum_{t=1}^{\infty} B^{t-1} U(C_t) \quad (27)$$

subject to the following budget constraint:

$$C_t + T_t + I_t = \pi_t^{final} + \pi_t^l + \pi_t^h + n_t^l w_t^l + n_t^h w_t^h + (r_t + \delta)K_t + (u_t^h + u_t^l)w^\mu \quad (28)$$

The household maximizes its utility through its choice of consumption, which is funded by the income from wages, unemployment income and returns to capital. The household also has to finance capital investment within the economy, since the household owns all firms. Correspondingly, capital rent  $r_t$  which the household charges the firm, contributes to its income.

Investment is the difference between the stocks of capital between two periods after adjusting for depreciation:

$$I_t = K_{t+1} - (1 - \delta)K_t \quad (29)$$

where  $\delta$  stands for the depreciation rate of capital.

The household's budget also depends on the total wages  $n_t^l w_t^l + n_t^h w_t^h$  generated by members of the household of both types of labour who are employed at the intermediate firm. Members who are currently unemployed receive a total unemployment income of  $(u_t^h + u_t^l)w^\mu$ . This unemployment income is fixed and defined to be a proportion  $b$  of the average earned wages in the steady state, where  $b$  is strictly less than one and  $w^\mu < w^l$  and  $w^h$ :

$$w^\mu = b \frac{w^l n^l + w^h n^h}{n^h + n^l} \quad (30)$$

If this unemployment income is to be interpreted as unemployment benefit, then it has to be financed by the entire household collectively by a tax  $T_t$ . This tax  $T_t$  is by definition equal to total unemployment benefit expenditure  $(u_t^h + u_t^l)w^\mu$ .

$$T_t = (u_t^h + u_t^l)w^u \quad (31)$$

In effect, there is consumption sharing within the model, where employed workers pass on parts of their income to the unemployed so that they can benefit from consumption as well.

If we substitute the investment equation (29) and the tax equation (31) into the budget constraint we end up with:

$$C_t + K_{t+1} - (1 - \delta)K_t = \pi_t^{final} + \pi_t^l + \pi_t^h + n_t^l w_t^l + n_t^h w_t^h + (r_t + \delta)K_t \quad (32)$$

It is worth spending more time on the implications of the unemployment benefit. The unemployment benefit does not enter directly into the household's choices or the budget constraint. It simply acts as a transfer mechanism within the household. It does however play an important role in the wage bargaining process as witnessed in the intermediate firm. The unemployment benefit raises the alternative income to that of working. This strengthens the bargaining position of the workers relative to the firm. Thus we are particularly interested in the effects of the unemployment benefit on wages determined between the workers and the firm and subsequent resulting employment levels.

Alternatively, one can instead view the unemployment income  $w^u$  as the non-market returns a worker would obtain from being unemployed.<sup>11</sup> This could include factors such as leisure as well as other non-market activities that might generate returns for the worker. In this case, taxes would not be subtracted from the budget constraint and it would simply remain as:

$$C_t + K_{t+1} - (1 - \delta)K_t = \pi_t^{final} + \pi_t^l + \pi_t^h + n_t^l w_t^l + n_t^h w_t^h + (r_t + \delta)K_t + w^u (u_t^l + u_t^h) \quad (33)$$

Using either formulation makes no changes on the results, since it does not affect the optimal decisions in the economy. The rest of this study will follow the case where  $w^u$  is treated as unemployment benefit to be financed by taxes, but the results carry over with no distinguishable differences to the case where  $w^u$  is seen as non-market returns.

Maximizing the above problem yields the following condition for consumption:

$$U_{c_t} = BE_t[(1 + r_{t+1})U_{c_{t+1}}] \quad (34)$$

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<sup>11</sup> Den Haan et al (2000) use such an interpretation.

Equation (34) is a standard Euler equation for consumption, where the marginal utility of current consumption is equal to the marginal utility of future consumption discounted by the interest rate and the discount factor  $B$ .

We now can see the role that capital plays in the model. We have previously introduced choice of capital quantity in the final firms sector. Investment in capital across periods also enters the household's budget constraint. By combining these two sectors there is a mechanism for households to reallocate income across periods, which is the primary purpose of introducing capital. Indeed the model resemble a Yeoman Farmer formulation a la Blanchard and Kiyotaki (1987), where the household owns all assets and enterprises in the economy, including capital, intermediate and final firms.<sup>12</sup> Because of this, the household budget constraint equation also closes the model and acts as an aggregate economy-wide accounting condition.

A cautionary note should be mentioned, however. This does not mean that the current setup is equivalent to a single social planner problem, where the social planner maximizes the decisions in the household, the intermediate firms, the final firm, and the labour market sector. The main difference between a social planner problem and this model is the presence of decentralized bargaining over wages. Indeed, as we will explain later, the two versions (the social planner problem and decentralized bargaining over wages) are only equivalent under very strict and specific conditions.<sup>13</sup>

### I.3.1.6 Specifying Functional Forms

To complete the model, we need to specify the functional forms of the two matching functions,  $M_t^l$  and  $M_t^h$ . The forms adopted are Cobb-Douglas:

$$M^l(u_t^l, v_t^l) = g^l (u_t^l)^{1-\xi^l} (v_t^l)^{\xi^l} \quad (35)$$

$$M^h(u_t^h, v_t^h) = g^h (u_t^h)^{1-\xi^h} (v_t^h)^{\xi^h} \quad (36)$$

A Cobb-Douglas function is the most widely used formulation and is in line with the empirical findings of many papers e.g. Blanchard and Diamond (1989).<sup>14</sup>

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<sup>12</sup> Indeed this also explains why the household discount factor  $B$  is also equal to that of the firms.

<sup>13</sup> Specifically the Hosios condition. See Hosios (1990).

<sup>14</sup> For more information, see Pissardies (2000). pp. 34-36.

The household utility function is assumed to be log linear:

$$U(C_t) = \ln C_t \quad (37)$$

Before moving on to discuss the calibration and the steady state properties of the model, it is more instructive to develop the analytic properties of the second model. This will allow us to explicitly compare the differences arising between the two models.

### I.3.2 Model 2: Introducing Overcrowding

The second model we develop has one distinctive feature that makes it differ from the previous one. Although there is separation between the two types of labour, high skilled workers can now take jobs in the simple sector, while low skilled workers are confined to jobs in the simple sector only.

High skilled workers can end up in either a simple or complex job, and the arrival of either job opportunity is assumed to be random. A high skilled worker would always rather take a simple job than not have a job at all. High skilled workers who do end up in a simple job, however, are still available in the vacancy market for complex jobs. Thus a high skilled worker in a simple job can still take up a post in a complex job. Furthermore, a high skilled worker always prefers a complex job to a simple job (this will be evident in the model, as a complex job will always offer a higher wage), and the job arrival rate for unemployed high skilled workers or high skilled workers employed in simple jobs is assumed to be the same.

#### I.3.2.1 The Labour Market

As expected, the labour market takes a more complicated form now. We have the following characteristics:

$$n_t^l = n_t^l + n_t^{lh} \quad (38)$$

$$n_t^h + u_t^h + n_t^{lh} = \gamma \quad (39)$$

$$n_t^l + u_t^l = 1 - \gamma \quad (40)$$

The notation has changed slightly.  $n_t^l$  now stands for total workers employed in the simple sector, whether they are high-skilled or low skilled.  $n_t^l$  stands for low skilled workers in simple jobs, while  $n_t^{lh}$  stands for the high skilled in simple jobs.  $n_t^h$  continues to stand for workers in the complex sector (who are all high-skilled).  $\gamma$  is once again the proportion of high skilled workers in the economy, and correspondingly  $1-\gamma$  is the proportion of low skilled workers in the economy.

Matching functions change to take account of the new feature of the model:

$$m_t^l = M^l(u_t^l + u_t^h, v_t^l) \quad (41)$$

$$m_t^h = M^h(u_t^h + n_t^{lh}, v_t^h) \quad (42)$$

The pool from which simple intermediate firms can potentially have a successful match is now both the high skilled and the low skilled unemployed. Complex firms can hire workers from the unemployed high skilled and the high skilled employed in simple jobs.

We also now have several forms of  $\theta^i$ , the market tightness:

$$\theta_t^l = v_t^l / (u_t^l + u_t^h) \quad (43)$$

$$\theta_t^h = v_t^h / (u_t^h + n_t^{lh}) \quad (44)$$

$$\theta_t^{ll} = v_t^l / u_t^l \quad (45)$$

$$\theta_t^{lh} = v_t^l / u_t^h \quad (46)$$

Market tightness in the entire simple job market  $\theta_t^l$  is not only a function of the low skilled unemployed but also the high skilled unemployed. Similarly, the market tightness for the complex job market  $\theta_t^h$  is a function of unemployed high skilled workers and high skilled workers employed in simple jobs.  $\theta_t^{ll}$  reflects the simple jobs market tightness for the low skilled, while  $\theta_t^{lh}$  reflects the market tightness for unemployed high skilled workers in the simple jobs market.

Correspondingly, we can define the different probabilities of a successful job match,  $q^i$ , as follows:

$$q_t^l = m_t^l / v_t^l \quad (47)$$

$$q_t^h = m_t^h / v_t^h \quad (48)$$

$$q_t^{ll} = \frac{u_t^l}{u_t^l + u_t^h} q_t^l \quad (49)$$

$$q_t^{lh} = \frac{u_t^h}{u_t^l + u_t^h} q_t^l \quad (50)$$

$q_t^l$  gives the probability of a successful match in the overall market for simple jobs, while  $q_t^h$  is the corresponding variable for the complex jobs market.  $q_t^{ll}$  represents

the probability of a successful match in the simple goods market but only for low skilled workers, while  $q_t^{lh}$  gives the probability of a successful match in the simple goods market for high skilled workers.

The employment dynamics for each of the worker groups becomes:

$$n_{t+1}^l = (1 - \tau^l)(n_t^l + q_t^l v_t^l) \quad (51)$$

$$n_{t+1}^{lh} = (1 - \tau^{lh} - \theta_t^h q_t^h)(n_t^{lh} + q_t^{lh} v_t^l) \quad (52)$$

$$n_{t+1}^h = (1 - \tau^h)(n_t^h + q_t^h v_t^h) \quad (53)$$

Equation (52) here is the most interesting and needs the most explanation, as the other two are similar to the ones obtained in the first model. Equation (52) shows that there is an extra source of job termination  $\theta_t^h q_t^h$  for high skilled workers in simple jobs above and beyond the usual exogenous rate of separation  $\tau^{lh}$ . This additional term reflects the fact that some high skilled workers employed in the simple job sector leave to complex jobs.

### I.3.2.2 The Intermediate Goods Firms

The two intermediate firms are no longer symmetrical as in the first model, since high skilled labourers can now work in both complex and simple jobs. Each firm has to be examined individually.

#### I.3.2.2.1 The Complex Intermediate Goods Firm

The complex firm's problem is exactly similar to the first model, since it only employs high skilled workers. Its output is given by:

$$Q_t^h = y^h n_t^h \quad (54)$$

The firm maximizes:

$$\pi_1^h = E_1 \left\{ \sum_{t=1}^{\infty} B^{t-1} [c_t^h y^h n_t^h - w_t^h n_t^h - a^h v_t^h] \right\} \quad (55)$$

This is subject to the evolution of employment constraint given in equation(53):

$$n_{t+1}^h = (1 - \tau^h)(n_t^h + q_t^h v_t^h) \quad (56)$$

The first order conditions for the firm are:

$$n_{t+1}^h : \lambda_t^h = BE_t [c_{t+1}^h y^h - w_{t+1}^h + (1 - \tau^h) \lambda_{t+1}^h] \quad (57)$$

$$v_t^h : \frac{a^h}{q_t^h} = (1 - \tau^h) \lambda_t^h \quad (58)$$

$$\lambda_t^h : n_{t+1}^h = (1 - \tau^h)(n_t^h + q_t^h v_t^h) \quad (59)$$

### I.3.2.2.2 The Simple Intermediate Goods Firm

The main difference between the first and the second model occurs here. To recap, simple intermediate firms can hire both low skilled and high skilled workers. The output of the simple jobs firm becomes:

$$Q^l = y^l (\Xi n_t^l + n_t^h) \quad (60)$$

$y^l$  stands for the exogenous productivity level on simple jobs, while  $\Xi$  represents the relative productivity of low skilled to high skilled workers on simple jobs.

We now turn to the costs which the simple firm faces. The first of these is the wage  $w_t^l$  paid to each of the high skilled or low skilled workers,  $w_t^h$  and  $w_t^l$  respectively. The second firm expenditure is the vacancy cost  $a^l$ , which is assumed to apply equally to high skilled and low skilled workers.

Thus the simple jobs' firm's objective is to choose the current period vacancy level  $v_t^l$  and the next period's employment level of each worker type  $n_{t+1}^l$  and  $n_{t+1}^h$  in order to maximize the present discounted value of profits:

$$\pi_1^l = E_1 \left\{ \sum_{t=1}^{\infty} B^{t-1} [c_t^l y^l (\Xi n_t^l + n_t^h) - w_t^l n_t^l - w_t^h n_t^h - a^l v_t^l] \right\} \quad (61)$$

subject to the evolution of employment constraints given in equations (51) and(52):

$$n_{t+1}^l = (1 - \tau^l)(n_t^l + q_t^l v_t^l) \quad (62)$$

$$n_{t+1}^h = (1 - \tau^h - \theta_t^h q_t^h)(n_t^h + q_t^h v_t^l) \quad (63)$$

Maximizing subject to the constraints yields the following First Order Conditions:

$$n_{t+1}^l : \lambda_t^l = BE_t [c_{t+1}^l y^l \Xi + (1 - \tau^l) \lambda_{t+1}^l - w_{t+1}^l] \quad (64)$$

$$n_{t+1}^h : \lambda_t^h = BE_t [c_{t+1}^l y^l + (1 - \tau^h - \theta_{t+1}^h q_{t+1}^h) \lambda_{t+1}^h - w_{t+1}^h] \quad (65)$$

$$v_t^l : \lambda_t^h = \frac{1}{q_t^h (1 - \tau^h - \theta_t^h q_t^h)} [a^l - \lambda_t^l q_t^l (1 - \tau^l)] \quad (66)$$

$$\lambda_t^l : n_{t+1}^l = (1 - \tau^l)(n_t^l + q_t^l v_t^l) \quad (67)$$

$$\lambda_t^h : n_{t+1}^h = (1 - \tau_t^h - \theta_t^h q_t^h)(n_t^h + q_t^h v_t^l) \quad (68)$$

As usual,  $\lambda_t^i$  above represents the Lagrangian multiplier on the equation for evolution of employment, which signifies the current value of a future employee of each type to the firm. This can be seen in equations (64) and (65), where the extra value

of an employee equals the output he will produce minus the wage he will receive in addition to the value he will bring in the subsequent period (the last expression in the equation). Equation (66) outlines the relationship between the values of hiring the two different types of employees, whether high skilled or low skilled. It is worth noting the difference between this equation and the corresponding equation (12) derived in the first model, where the Lagrangian multiplier here no longer depends only on vacancy costs and the probability of employment, but also on the Lagrangian multiplier of the other labour type. This reflects the fact that there are two types of workers that the vacancies are open for. Equations (67) and (68), as explained earlier, give the evolution of employment of each type from one period to another.

### I.3.2.3 Wage Setting

#### I.3.2.3.1 The Complex Intermediate Goods Firm

Once again a Nash Bargain with Bellman asset equations is used to derive the wages. Thus, for the complex firm, the Nash Bargaining solution (after applying the free entry condition) is of the following form:

$$\kappa^h [V_t^h] = (1 - \kappa^h) [J_t^h - U_t^h] \quad (69)$$

As in the previous model,  $V_t^h$  stands for the value to the firm of a job filled.  $J_t^h$  represents the value which the worker receives from being employed, while  $U_t^h$  stands for the value of being unemployed. Finally,  $\kappa^h$  represents the worker bargaining power in the solution, where a higher value implies a higher share of the production surplus accruing to the worker.

For the complex firm, the value of a job filled is:

$$V_t^h = c_t^h y^h - w_t^h + BE_t [(1 - \tau^h) V_{t+1}^h] \quad (70)$$

The formulation for  $V_t^h$  is exactly similar to that in the first model. The value of a job match to the firm in the current period  $V_t^h$  depends on wage costs subtracted from the production revenue in addition to the expected future value of the match.

The value of employment for a worker in a complex job,  $J_t^h$ , is also similar to the one developed in the first model:

$$J_t^h = w_t^h + BE_t [(1 - \tau^h) J_{t+1}^h + \tau^h U_{t+1}^h] \quad (71)$$

The situation is no longer similar in  $U_t^h$ , the present value of unemployment to an unemployed high skilled worker:

$$U_t^h = w^u + BE_t \left[ \begin{aligned} & (1 - \tau^h) \theta_t^h q_t^h J_{t+1}^h + (1 - \tau^{lh} - \theta_t^h q_t^h) \theta_t^{lh} q_t^{lh} J_{t+1}^{lh} \\ & + \langle 1 - (1 - \tau^h) \theta_t^h q_t^h - (1 - \tau^{lh} - \theta_t^h q_t^h) \theta_t^{lh} q_t^{lh} \rangle U_{t+1}^h \end{aligned} \right] \quad (72)$$

The main difference now arises from the fact that an unemployed high skilled worker has a chance of being employed in both the complex sector ( $\theta_t^h q_t^h J_{t+1}^h$ ) and the simple sector ( $\theta_t^l q_t^l J_{t+1}^l$ ).<sup>15</sup>

If the value functions are replaced in the Nash Bargaining solution, we arrive at the following expression for wages at the complex sector:

$$w_t^h = \kappa^h [a^h \theta_t^h + c_t^h y^h] + (1 - \kappa^h) [w_t^u] + \frac{(1 - \kappa^h) \kappa^{lh}}{(1 - \kappa^{lh})} \left[ (1 - \tau^{lh} - \theta_t^h q_t^h) q_t^{lh} \theta_t^{lh} \lambda_t^{lh} \right] \quad (73)$$

As in the first model, the complex sector wage depends positively on the unemployment income, hiring costs, market tightness, the productivity of the high skilled worker and the price at which the intermediate good is sold. However, there is an additional term to reflect the enticement that the complex firm has to pay in order to differentiate itself from the simple firm in which the high skilled worker may also choose to work (the final term in the equation). Unemployed high skilled workers have a higher reservation wage now because of the possibility of being employed in the simple sector.

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<sup>15</sup> It should be apparent that events  $V_{t+1}^h$  and  $V_{t+1}^l$  are mutually exclusive when a high skilled worker is unemployed, and hence  $P[V_{t+1}^h \cap V_{t+1}^l] = 0$ . In other words, in one period, an unemployed high skilled worker can only take up a complex or a simple job, but not the two together.

### I.3.2.3.2 The Simple Intermediate Goods Firm

There are two wages that the simple intermediate firm pays out: one for the low skilled workers and one for the high skilled workers.

#### The Low Skilled worker

The low skilled worker's wage derivation is very similar to that in the first model, since the low skilled worker is only involved in one labour market. The Nash Bargaining solution is:

$$\kappa^H [V_t^H] = (1 - \kappa^H) [J_t^H - U_t^L] \quad (74)$$

For the simple firm, the value of a job filled is:

$$V_t^H = \Xi c_t^L y^L - w_t^H + BE_t [(1 - \tau^H) V_{t+1}^H] \quad (75)$$

This is almost exactly like the first model, the only difference being the addition of  $\Xi$  to introduce differences in the relative productivity between high and low skilled workers on the simple job.

The value of employment for a low skilled worker,  $J_t^H$ , is also similar to the one developed in the first model:

$$J_t^H = w_t^H + BE_t [(1 - \tau^H) J_{t+1}^H + \tau^H U_{t+1}^L] \quad (76)$$

Similarly for  $U_t^L$ :

$$U_t^L = w^H + BE_t [(1 - \tau^H) \theta_t^H q_t^H J_{t+1}^H + (1 - (1 - \tau^H) \theta_t^H q_t^H) U_{t+1}^L] \quad (77)$$

Substituting the value functions into the Nash Bargaining solution gives us a similar solution to that which was generated in the first model:

$$w_t^H = \kappa^H [q_t^H \theta_t^H (1 - \tau^H) \lambda_t^H + \Xi c_t^L y^L] + (1 - \kappa^H) [w_t^H] \quad (78)$$

The only difference from the first model is that  $\lambda_t^H$  will take on a different value from  $\lambda_t^L$  in the previous model as shown in equation(66). The simple sector can now choose high or low skilled workers, and the difference in  $\lambda_t^H$  reflects this.

## The High Skilled Worker

The Nash Bargaining solution is:

$$\kappa^{lh} [V_t^{lh}] = (1 - \kappa^{lh}) [J_t^{lh} - U_t^{lh}] \quad (79)$$

The value of a job filled for the firm is:

$$V_t^{lh} = c_t^l y^l - w_t^{lh} + BE_t [(1 - \tau^{lh} - \theta_t^h q_t^h) V_{t+1}^{lh}] \quad (80)$$

The interesting addition here is  $\theta_t^h q_t^h$ , which is subtracted to reflect that some high skilled workers will leave the simple sector to the high skilled sector. Otherwise the derivation closely resembles the Bellman equation from the previous model.

The value of employment for a high skilled worker in a simple job is:

$$J_t^{lh} = w_t^{lh} + BE_t [(1 - \tau^{lh} - \theta_t^h q_t^h) J_{t+1}^{lh} + (1 - \tau^h) \theta_t^h q_t^h J_{t+1}^h + (\tau^{lh} + \tau^h \theta_t^h q_t^h) U_{t+1}^h] \quad (81)$$

Once again  $\theta_t^h q_t^h$  is inserted to reflect the fact a high skilled worker might leave a simple job for a complex job. Finally, the expression for the value of being unemployed for a high skilled worker was introduced previously:

$$U_t^h = w^u + BE_t \left[ \begin{aligned} &(1 - \tau^h) \theta_t^h q_t^h J_{t+1}^h + (1 - \tau^{lh} - \theta_t^h q_t^h) \theta_t^{lh} q_t^{lh} J_{t+1}^{lh} + \\ &(1 - (1 - \tau^h) \theta_t^h q_t^h - (1 - \tau^{lh} - \theta_t^h q_t^h) \theta_t^{lh} q_t^{lh}) U_{t+1}^h \end{aligned} \right] \quad (82)$$

If the value functions are replaced in the Nash Bargaining solution, we arrive at the following expression for wages:

$$w_t^{lh} = \kappa^{lh} [c_t^l y^l + (1 - \tau^{lh} - q_t^h \theta_t^h) \lambda_t^{lh} q_t^{lh} \theta_t^{lh}] + (1 - \kappa^{lh}) [w^u] \quad (83)$$

The most important new term in the above expression is  $q_t^h \theta_t^h$ , showing that some overeducated workers will leave the simple firm to the complex sector. Furthermore, the new value of  $\lambda_t^{lh}$ , as shown in equation (66), will reflect the fact that the simple sector can now choose between high or low skilled workers.

If we compare the low skilled workers' wages (78) with the corresponding expression for the overeducated (83), we can determine the factors that might cause these two wages to differ in value. An important parameter is the relative productivity of low skilled workers to the overeducated in simple jobs  $\Xi$ . If this parameter is less than one, then the wages of the low skilled would decline, all else being equal. The

lower is the relative productivity of low skilled workers, the lower are the wages they receive.

On the other hand, the fact that an overeducated worker might leave the simple sector to complex jobs adversely affects his wage, which is shown by the presence of  $q_i^h \theta_i^h$  in equation (83) above. Since simple firms recognize that high skilled workers have a higher probability of quitting due to opportunities in the complex sector, they offer lower wages. Finally, the overeducated and low skilled workers each have distinct market tightness ( $\theta^h$  and  $\theta^l$ ), probabilities ( $q^h$  and  $q^l$ ), and Lagrangian multipliers  $\lambda_i^h$  and  $\lambda_i^l$ . The combined effects of these factors will play a crucial role in determining the relative wages of each type of worker, whether low or high skilled, in the simple sector.

### I.3.2.4 Final Goods Firm and Households

There are no substantive additions in the rest of the exposition when compared with the first model. The same assumptions and characteristics that applied to the final firm and the household are reproduced here with the only difference being that the budget constraint of the household takes account of the overeducated workers' income  $n_t^{lh} w_t^{lh}$ :

$$C_t + T_t + I_t = \pi_t^{final} + \pi_t^l + \pi_t^h + n_t^{ll} w_t^{ll} + n_t^{lh} w_t^{lh} + n_t^h w_t^h + (r_t + \delta)K_t + (u_t^h + u_t^l)w^u \quad (84)$$

### I.3.2.5 Specifying Functional Forms

To complete the model once again we specify the functional form of the two matching functions,  $M_t^l$  and  $M_t^h$ :

$$M^l(u_t^l, u_t^h, v_t^l) = g^l (u_t^l + u_t^h)^{1-\xi^l} (v_t^l)^{\xi^l} \quad (85)$$

$$M^h(u_t^h, n_t^{lh}, v_t^h) = g^h (u_t^h + n_t^{lh})^{1-\xi^h} (v_t^h)^{\xi^h} \quad (86)$$

Notice the difference in the matching functions here from the first model, where the pool of available workers that is entered in each function has changed. In  $M_t^h$ , it is  $u_t^h + n_t^{lh}$ , and in  $M_t^l$  it is  $u_t^l + u_t^h$ . The household utility function is exactly like it was in the first model and takes a log-linear formulation.

## **I.4 Simulations**

### **I.4.1 Methodology and Model Solving**

The models are solved and simulated using standard methods for simulating non-linear rational expectations models as developed originally by Kydland and Prescott (1982).<sup>16</sup> The first order conditions for the labour market, the intermediate firms, the final firms, and the household sector along with the equations for the average and minimum wage are solved for the steady state, where time and expectation operators are dropped. These equations are linearized using the methods of Taylor approximation. They are then simulated over several periods in Matlab using the software Dynare<sup>17</sup> in order to obtain the models' simulation properties.

Calibration is the methodology adopted to derive the models' properties, conduct impulse response analysis to shocks, and determine steady state effects. Simply put, it involves choosing the best estimates available for the parameters in the model using the available empirical research and then solving the model based on these parameter values. It is the most widely applied method within DSGE models.

There are several motivations for using calibration in such models. Most importantly, it allows us to investigate whether the model is able to replicate empirical regularities witnessed in the economy in question. Furthermore, calibration provides an analytically tractable method of solving and simulating non-linear models that are not otherwise solvable in closed form.

Calibration does have some drawbacks, however. In particular, calibration does not rely upon a solid econometric foundation, which renders performing consistent estimates and constructing statistical inference difficult. It also relies on using parameter estimates from diverging sources. However, calibration remains the most

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<sup>16</sup> For more information, see Sims (2002).

<sup>17</sup> See Juillard (2001).

widely applied procedure within DSGE models. As a result we have chosen calibration as our preferred method of simulation.

## I.4.2 Calibration parameters

The parameters used in calibration are chosen to reproduce the labour market properties of the Dutch economy in the mid 1990s due to the availability of the relevant data. Where possible, the parameters are chosen to reflect existing empirical estimates for the Dutch economy. Otherwise they have based on those used in previous papers with similar models. The parameters outlined below apply to both models unless otherwise mentioned.

The model used as a reference is the second model with overcrowding effects, as it allows for richer analyses of the labour market. Each period represents one quarter. The discount parameter  $B$  is 0.99, representing a quarterly real interest rate of 0.01 and an annual rate of 0.04. The capital depreciation rate  $\delta$  is set at 0.025, implying a ten year lifetime for a particular unit of capital. High skilled workers are defined as workers with an education level of upper secondary school or more. The proportion of high skilled workers in the labour force  $\gamma$  is set at 0.71, the value reported by OECD (1998) for the year 1995 in the Netherlands<sup>18</sup>. The productivity on simple and complex jobs  $y^h$  and  $y^l$  are initially normalized to one in each of the separate sectors. The job destruction rates for complex and simple jobs are set at a quarterly rate of  $\tau^h=0.03$  and  $\tau^l=0.05$  respectively. Thus simple jobs are less stable than their complex counterparts, and are more likely to be severed.

Turning to the matching function, the elasticity of new matches with respect to vacancies  $\zeta^h$  and  $\zeta^l$  are set at 0.4 in both models, implying an elasticity of matches with respect to vacancies of 0.4 and of 0.6 with respect to unemployment. This is a commonly used value in matching-function models and equal to the estimates of Van Ours (1991) for the Netherlands. We also set the wage bargaining strength of the workers,  $\kappa^h$ ,  $\kappa^{lh}$ ,  $\kappa^{ll}$ ,  $\kappa^l$  at the same level as the elasticity of new matches with respect to unemployment (0.6). This is to satisfy the Hosios condition, which states that the wage

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<sup>18</sup> See OECD (1998) p. 43, Table A1.1

bargaining strength of workers should equal the job matches elasticity with respect to unemployment in order for the outcome of the decentralized economy to equal that of the social planner's problem. If this condition is not met, then the model's outcome is socially inefficient.<sup>19</sup>

The vacancy costs are assumed to be double for complex jobs when compared to simple jobs, where  $a^h = 0.35$  and  $a^l=0.175$ . Total costs per quarter ( $a^h v_t^h + a^l v_t^l$ ) represent 1.7% of final output, a figure similar to that used by Andolfatto (1996). Turning to the final firm, the elasticity of final output with respect to capital  $\varrho$  is set at a standard 0.33, and the elasticity of the complex sector's input in the final firm is  $\alpha = 0.5$ . These parameters are based on those of Pierrard and Sneessens (2004), and they imply that the elasticity of the final output with respect to the complex intermediate input is higher than that of the simple input. Thus the complex sector is more productive than the simple sector. The value of the average replacement ratio  $b$ , the parameter determining unemployment income, is set at  $b=0.52$ , in accordance with the reported OECD (2002b) value for the Gross replacement ratio in Netherlands in 2002.

The relative productivity of low skilled workers to high skilled workers in simple jobs  $\Xi$  is initially set to 1. This is to identify any differences other than relative productivities that might have an influence on the characteristics of each type of workers in the simple sector.

There are two more parameters that need to be deduced,  $m^h$  and  $m^l$ , the parameters in the matching functions. These are chosen so as to reproduce the employment rates for each skill group in the Dutch Economy in the 1990s, which are roughly 4% ( $u^h$ ) and 8% ( $u^l$ ), and reasonable probabilities of matching rates,  $q^h$  and  $q^l$ . Thus  $m^h=0.6$  and  $m^l=0.7$ .

The parameters used in the first model are exactly those described above for the model with overcrowding. This will obviously produce slightly differing results, particularly in the steady state unemployment, wages, and employment levels. The main

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<sup>19</sup> For more information, see Hosios (1990). A more in-depth discussion of the Hosios condition is given in the next chapter. It should be noted that the Hosios condition holds only in the first model and not the second. This is because there is an externality in the second model by dint of the fact that high skilled workers are able to work in the simple sector. For the Hosios condition to hold, each labour market has to be self contained with only low (resp high) skilled workers being employed in low (resp high) skilled jobs.

purpose of this chapter, however, is to compare the two models, and thus the second model is used as the reference for the properties of the Dutch economy, while the first model is used as a comparison to the second model. Thus, in order to compare the models to each other as accurately as possible, the parameters are chosen to be equivalent.

It should be noted here that the main purpose of this chapter is neither to reproduce exactly the characteristics of the Dutch economy, nor to analyze what happened in the Dutch economy over the specified period. If this were the point, then the models should have been complicated significantly by adding other factors, such as monetary factors, monopolistic competition, and fiscal and monetary rules, in order to have ensure a more complete representation of the economy. This would have obscured significantly the main focus of this study, the two-tiered labour market.

The purpose here is more theoretical. As explained previously, given that there is general segmentation between the two labour forces, and given that there is overcrowding of high skilled workers in the simple sector, what do these two general features imply for the labour markets? What are the consequences when the phenomena of skill-biased technological change versus general aggregate (unbiased) technological change are introduced? What if the composition of the labour force change, and what do these issues entail for government policy?

## I.5 Results

We start by analyzing the steady state results, followed by the effects of permanent shocks on the economy equilibrium; we conclude by looking at some government policy implications.<sup>20</sup>

### I.5.1 Steady State Results

The steady state values obtained for each model are reproduced below:

**Table 1**  
**Steady State Results**

	c	K	Q <sup>f</sup>	N <sup>h</sup>	N <sup>l</sup>	q <sup>h</sup>	q <sup>l</sup>	urate <sup>h</sup>	urate <sup>l</sup>	overall urate	w <sup>l</sup> /w <sup>h</sup>	w <sup>h</sup>	w <sup>l</sup>	\$ <sup>h</sup>	\$ <sup>l</sup>	\$ <sup>l,h</sup>	\$ <sup>k</sup>	\$ <sup>total</sup>
<b>model2</b>	1.22	15.26	1.62	0.67	0.27	0.62	0.82	0.037	0.077	0.048	0.82	1.18	0.97	1.15	0.94	1.09	0.54	1.63
	N <sup>h</sup>	N <sup>h</sup> /n <sup>l</sup>	q <sup>h</sup>	q <sup>l</sup>	w <sup>h</sup>	w <sup>l</sup>	w <sup>high</sup>	w <sup>l</sup> /w <sup>h</sup>	w <sup>h</sup> /w <sup>l</sup>	w <sup>l</sup> /w <sup>high</sup>								
	0.01	0.04	0.44	0.38	0.86	0.97	1.18	0.82	0.88	0.82								
	c	K	Q <sup>f</sup>	N <sup>h</sup>	n <sup>l</sup>	q <sup>h</sup>	q <sup>l</sup>	urate <sup>h</sup>	urate <sup>l</sup>	Overall urate	w <sup>l</sup> /w <sup>h</sup>	w <sup>h</sup>	w <sup>l</sup>	\$ <sup>h</sup>	\$ <sup>l</sup>	\$ <sup>l,h</sup>	\$ <sup>k</sup>	\$ <sup>total</sup>
<b>model1</b>	1.22	15.21	1.62	0.68	0.27	0.58	0.56	0.048	0.061	0.052	0.84	1.17	0.99	1.14	0.97	1.09	0.53	1.63

Key model 2 (overcrowding):

$$\text{\$}^h: \text{average labour-status related high skilled labour income} = (n^{lh} * w^{lh} + n^{lh} * w^h + (0.71 - n^{lh} - n^h) * w^u) / (0.71)$$

$$\text{\$}^l: \text{average labour-status related low skilled labour income} = (n^{ll} * w^{ll} + (0.29 - n^{ll}) * w^u) / (0.29)$$

$$\text{\$}^{l,h}: \text{average labour-status related labour income} = (0.29 * \text{\$}^l + 0.71 * \text{\$}^h)$$

$$\text{\$}^k: \text{total capital income} = (\delta + r) * K$$

$$\text{\$}^{\text{total}} = \text{\$}^k + \text{\$}^{l,h} + \pi^h + \pi^l + \pi^{\text{final}}$$

$$w^l: \text{average low-tech sector wages} = (n^{lh} * w^{lh} + n^{ll} * w^{ll}) / (n^{lh} + n^{ll})$$

$$w^{\text{high}}: \text{average high-skilled workers wages} = (n^{lh} * w^{lh} + n^h * w^h) / (n^{lh} + n^h)$$

$$n^{lh} / n^{ll}: \text{overcrowding in the simple sector}$$

Key model 1:

$$\text{\$}^h: \text{average labour-status related high skilled labour income} = (n^{lh} * w^h + (0.71 - n^h) * w^u) / (0.29)$$

$$\text{\$}^l: \text{average labour-status related low skilled labour income} = (n^{ll} * w^l + (0.29 - n^{ll}) * w^u) / (0.29)$$

$$\text{\$}^{l,h}: \text{average labour-status related labour income} = (0.29 * \text{\$}^l + 0.71 * \text{\$}^h)$$

$$\text{\$}^k: \text{total capital income} = (\delta + r) * K$$

$$\text{\$}^{\text{total}}: \text{total household income} = \text{\$}^k + \text{\$}^{l,h} + \pi^h + \pi^l + \pi^{\text{final}}$$

<sup>20</sup> The results presented here are robust in the sense that moderate changes in the parameters' selection do not change the qualitative results. A more extensive robustness analysis is outlined in the subsequent chapters.

The symbols stand for the same variables as those developed in the model; a few require explanation. In the second (overcrowding) model,  $w^l$  stands for the wages received by the low skilled workers in the simple sector.  $w^j$ , on the other hand, stands for the overall wage in the simple sector. The two are related but slightly different. The simple sector wage  $w^j$  is a weighted average of the wages of all those that work in the simple sector. It is mainly composed of low skilled workers' wages, but also includes the wages of high skilled workers in simple jobs. Since only low skilled workers are employed in the simple sector in model 1,  $w^j$  stands for both the low skilled workers and the simple sector wage. There is also the overall high skilled workers' wages in the overcrowding model,  $w^{high}$ , which is a weighted average of the wages of all high skilled workers whether in low-tech or high-tech jobs. The high-tech sector wage  $w^h$ , on the other hand, shows wages of high skilled workers in the high-tech sector only.

Of all these different variables, which are the most important for the analyses? Each in our opinion is helpful in analyzing the overall picture, but the main focus will be on the difference between the wages of low skilled workers (in the simple sector)  $w^l$  and of high skilled workers in the complex sector  $w^h$ . After all, in both models, these are the 'natural sectors' of each type of worker. The complex sector is the 'target job' of high skilled workers, and where the vast majority of them are employed. Indeed, one can view simple sector jobs as 'second rate solutions' for high skilled workers, and are only taken because they are better than having no work and receiving unemployment income. Thus, although comparing the other wages is important, one must not lose sight of the central point of analysis here: the fate of high skilled versus low skilled workers.

Similarly, this translates into the three ratios in the second model: one that is a ratio of all low-sector wages and high tech sector wages  $w^l/w^h$ , another ratio of the low skilled workers wages and the wages of high skilled workers in the complex sector  $w^l/w^j$ , and finally the ratio of low skilled workers to the overall high skilled wage  $w^l/w^{high}$ . All of these ratios are of interest, but once again the main focus will be on the ratio of low skilled workers' wages to the complex sector wages. Indeed, as the results show, all three ratios have similar values and move in a similar direction and in similar magnitudes when one considers steady state static changes in the model. One final ratio of interest is the ratio between the wages of high skilled workers in the simple sector

and the wages of low skilled workers also employed in the simple sector. This ratio enables us to identify which type of worker is paid most in the low-tech sector.

$\$^l$  refers to (pre-tax) average labour related income received by low skilled workers, while  $\$^h$  refers to the equivalent for high skilled workers. Both are weighted averages of wages and unemployment income to each labour skill group, and they are intended to give a rough indication of the income received by an average worker of each type, regardless of employment status. A caveat should be immediately entered here. The numbers for these variables should be interpreted with extreme caution. Firstly, they exclude the income received from capital, encapsulated in  $\$^k$ . This however might not be particularly grave in the case of low-skilled workers, since, as we mentioned previously, low-paid agents in the economy (which are here the low skilled workers) generally own the least amount of capital and do not receive much capital income.<sup>21</sup> Another caveat is that, as mentioned earlier, there is only one household that maximizes for all workers and all income. These figures are included however because they provide a rough indication of the status of the average labour income received by each group.

We can now proceed to analyze the steady state results. In the model with overcrowding, our reference model, the unemployment rates are 4% and 8% for high and low skilled workers respectively, the values reported by OECD (1998) for the Dutch economy in 1995. The crowding out value (the ratio of high skilled workers in simple jobs to low skilled workers on simple jobs) is 4%, which falls short of the range found by Hartog (2000) for EU countries (10%-30%). Our model will naturally underestimate overeducation, however, since it only measures the overcrowding of upper secondary and university educated workers in jobs requiring below upper secondary education. It does not measure, for example, the incidence of overeducation among university degree holders in jobs only requiring an upper secondary school degree (i.e. it does not measure overeducation within the broadly defined high skill sector). The ratio of low skilled workers' wage to the complex sector wage,  $w^l/w^h$ , is similar to the 1995 Netherlands values obtained by the OECD (1998) for the ratio of the earnings of workers with below an upper secondary degree to those with an upper

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<sup>21</sup> Firms' profits income (which can be deduced from the total income  $\$^{\text{total}}$ ) are also excluded, but they are negligible due to the neo-classical setup of the model.

secondary education.<sup>22</sup> The ratio remains the same when comparing all simple sector workers to complex sector workers or when we compare low skilled workers' wages to all high skilled workers in both sectors. The probabilities of filling a simple and complex job ( $q^l$  and  $q^h$ ) in the model are similar to those obtained in the empirical estimates of Van Ours and Ridder (1991). They find that the average probability of filling a vacancy is 0.7, with the probability decreasing in levels of educational attainment. Our results reflect this.

It should be reiterated that one should not read too much into the exact values obtained by the model in relation to existing empirical values, since this is not the main purpose of the model. The models are more oriented towards qualitative theoretical findings than towards reproducing exact empirical finding. These qualitative findings hold regardless of the exact parameter values employed in the model, as they were reproduced even when using differing parameter values. The fact that the model does fit empirical findings to a large extent, however, is worthy of note.

One surprising result is that high skilled workers in simple jobs receive a lower wage than low skilled workers in simple jobs. High skilled workers have a high probability of leaving simple sector jobs for complex firms, and firms know this. This makes high skilled workers less valuable to simple firms than low skilled workers. There is a higher probability of high skilled workers leaving the low-tech jobs, thus making the simple firms incur vacancy costs they would not have otherwise faced. This relates to our postulation earlier that simple jobs are only 'stop-gap' solutions for high skilled workers. Low-tech firms realize this, which reflects in the lower wages they offer to these workers. This stands at odds with the empirical data, which shows that overeducated workers should receive at least as much as their low skilled counterparts (Hartog, 2000; Sicherman, 1991). Furthermore, it can cause problems with the interpretation of the model. If high skilled workers in simple jobs receive wages that are lower than their low skilled counterparts, then would not high skilled workers try to conceal their skill status? If so, how is the firm to distinguish between high skilled and low skilled workers? This problem can be easily avoided, however, by increasing the relative productivity of overeducated workers on simple jobs when compared to low skilled workers, which will be discussed below in section I.5.2.3.

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<sup>22</sup> See OECD (1998) p. 358, Table F7.1.

Comparing the first (no-overcrowding) model to the reference overcrowding model, one notices in the former a higher overall unemployment rate for higher skilled workers and a lower unemployment rate for low skilled workers. This is expected, since there is no overcrowding present in the perfectly segmented market of the first model. By the same token, wage ratios  $w^l/w^h$ ,  $w^l/w^h$ , and  $w^l/w^{high}$  are also all lower in the overcrowding model when compared with the ratio  $w^l/w^h$  in the first model. In the perfectly segmented model, low skilled workers no longer compete with high skilled workers in the simple sector, thus obtaining a higher wage and lower unemployment levels. High skilled workers, on the other hand, now only have the complex sector in which to work. This increases their unemployment rate and also decreases their bargaining leverage with complex firms. These features also explain the increase of the wage ratio of low skilled workers to high skilled workers in the perfectly segmented model. The overall unemployment rate is lower in the overcrowding model, meaning that the increase in high skilled unemployment in the first model exceeds the rise in the unemployment of the low skilled workers in the overcrowding model.

Although the overall high skilled unemployment rate has increased in the perfectly segmented model, the number of high skilled workers in complex jobs has actually increased (albeit very slightly) when compared to the second model. The explanation is that complex firms no longer have to compete with simple firms for high skilled workers. The overall increase in the high skilled unemployment rate, however, means that the loss of employment due to the absence of overcrowding is higher than the gain in employment due to high skilled firms hiring more.

The probability of filling a simple vacancy,  $q^l$ , decreases in the first model, while the probability of filling a complex job  $q^h$  shows only a slight decline. We can postulate that in the case of simple jobs, this is due to the shrinking pool of unemployed workers from which the firm can hire in the perfectly segmented model. It comprised both high and low skilled workers in the overcrowding model but only low skilled workers in the first model, thus decreasing the probability of filling a vacancy. Furthermore, as mentioned previously, the steady state value of employed low skilled workers has increased in the perfectly segmented model, which means the low skilled market is tighter and the probability of filling a simple job is lower. In the complex sector case,

employment levels in the high tech sector have increased in the perfectly segmented model, and so this makes the residual pool from which the firm can hire smaller, thus reducing the probability of successfully filling a vacancy.

Thus the first main conclusion we draw from the above analysis is that introducing the possibility of overcrowding unambiguously hurts low skilled workers. They are faced with higher unemployment rates and lower wages because of the competition from high skilled workers. High skilled workers, on the other hand, have new employment opportunities that decrease their unemployment rate and also increase the wages they receive on complex jobs. This is because there is an extra source of competition for complex firms, and hence they have to offer higher wages.

## I.5.2 Static Effects of Shocks

**Table 2**

### Static Effects of Shocks

#### Model 2

$Z=1.05$     $y^l=1.05$     $y^h=1.05$     $\gamma=0.76$     $\alpha=0.55$     $b=0.57$     $\Xi = 0.95$

% change in							
c	7.71	1.27	3.78	0.79	6.56	-0.09	-1.26
k	7.67	1.27	3.77	0.81	6.40	-0.20	-1.25
$Q^f$	7.67	1.26	3.76	0.81	6.40	-0.20	-1.25
$n^h$	0.16	0.03	0.08	6.39	0.64	-0.20	-0.07
$n^l$	0.20	0.04	0.10	-16.48	-3.51	-0.44	0.03
urate <sup>h</sup>	-1.56	-0.27	-0.79	-1.10	2.72	2.67	0.27
urate <sup>l</sup>	-2.44	-0.42	-1.23	-10.97	42.05	5.29	-0.31
overall urate	-1.96	-0.34	-0.99	-8.95	20.82	3.88	0.00
$w^h$	7.55	1.24	3.71	-5.04	16.17	0.11	-1.17
$w^l$	7.77	1.28	3.81	16.95	-20.17	0.23	-1.58
$w^l / w^h$	0.21	0.03	0.10	23.15	-31.28	0.11	-0.41
$\$^h$	7.61	1.25	3.74	-1.64	16.03	0.24	-1.16
$\$^l$	7.85	1.29	3.85	7.23	-19.35	0.54	-1.55
$\$^{h,l}$	7.67	1.26	3.76	0.58	7.19	0.32	-1.26
$\$^k$	7.67	1.27	3.77	0.81	6.40	-0.20	-1.25
$\$^{total}$	7.66	1.26	3.76	0.63	6.93	0.13	-1.26
$n^h$	-6.94	-1.18	-3.47	56.69	-52.61	6.76	3.96
$n^h / n^l$	-7.12	-1.22	-3.57	87.61	-50.89	7.23	3.94
$w^h$	7.53	1.24	3.70	15.17	-15.08	2.27	2.62
$w^l$	7.79	1.28	3.82	16.46	-19.93	0.27	-1.46
$w^{high}$	7.58	1.25	3.72	-4.90	16.25	0.11	-1.15
$w^l/w^h$	0.23	0.04	0.11	22.64	-31.08	0.15	-0.29
$w^l/w^{high}$	0.20	0.03	0.10	22.47	-31.12	0.16	-0.32
$w^h / w^l$	-0.23	-0.04	-0.11	-1.52	6.37	2.04	4.26

## Model 1

$$Z=1.05 \quad y^l=1.05 \quad y^h=1.05 \quad \gamma=0.76 \quad \alpha=0.55 \quad b=0.57$$

% change in						
c	7.76	1.28	3.81	0.31	6.92	-0.15
k	7.72	1.27	3.79	0.31	6.81	-0.24
$Q^f$	7.72	1.27	3.79	0.31	6.81	-0.24
$n^h$	0.14	0.02	0.07	6.76	0.44	-0.20
$n^l$	0.18	0.03	0.09	-16.48	-3.07	-0.37
urate <sup>h</sup>	-2.84	-0.49	-1.43	5.19	-8.74	3.97
urate <sup>l</sup>	-2.77	-0.48	-1.40	-14.13	47.27	5.64
overall urate	-2.81	-0.48	-1.42	-1.41	10.38	4.54
$w^h$	7.63	1.26	3.74	-6.00	17.01	0.08
$w^l$	7.58	1.25	3.72	19.96	-21.73	0.29
$w^l / w^h$	-0.04	-0.01	-0.02	27.63	-33.11	0.21
$\$^h$	7.70	1.27	3.78	-2.94	17.05	0.23
$\$^l$	7.66	1.26	3.76	9.55	-21.10	0.52
$\$^{h,l}$	7.69	1.27	3.77	0.26	7.27	0.30
$\$^k$	7.72	1.27	3.79	0.31	6.81	-0.24
$\$^{total}$	7.69	1.27	3.77	0.28	7.11	0.10

Results report percentage change in values from the base model.

We now focus on the steady state effects of altering the values for seven key parameters: the aggregate productivity level in the final good sector  $Z$ , the productivity level on complex jobs  $y^h$ , the productivity level on simple jobs  $y^l$ , the relative productivity of low skilled workers to high skilled workers in simple jobs  $\Xi$  (which only applies in the second model), the proportion of all workers that are high skilled  $\gamma$ , the elasticity of substitution on the complex input good in the final sector  $\alpha$ , and finally the replacement ratio in the unemployment income  $b$ . Each of the above is increased by 0.05 in absolute terms and the resulting values are then discussed.

### **I.5.2.1 Increasing the aggregate productivity $z$**

As expected, increasing the aggregate productivity  $Z$  causes an increase in all wages, all employment levels and consumption in both models. The results are much more pronounced on wages than on employment, however. This means that most of the gains accruing from the added aggregate productivity are passed on as wage rises through the Nash bargain rather than increased employment. Since all wages increase in roughly similar percentage terms, the various wage ratios under consideration remain quite constant.

Capital accumulation also increases markedly, reflecting the fact that rises in aggregate productivity are also passed on as higher returns to capital. Average income of high skilled workers, low skilled workers, capital, and final output increase significantly and in similar percentage terms due to the increase in wages and capital accumulation.

The overcrowding change is countercyclical and quite noticeable at  $-7\%$ . Although the percentage changes of the high and low unemployment rates are quite similar, the absolute number of new high skilled workers in the complex sector is much higher than the number of low skilled employed workers in the simple sector simply because there are twice as many high skilled as low skilled workers. This increase in the sheer numbers of high skilled workers in the complex sector pulls away some high skilled workers from the simple sector, causing the number of high skilled workers on simple jobs and overcrowding to decline.

### **I.5.2.2 Increasing the productivity in the simple versus complex sector**

Increasing  $y^l$  or  $y^h$  is one way of introducing biased technological change. Interestingly enough, increasing the productivity in either the simple or the complex sector produce very similar results. The directions of change are exactly the same, but the values of the percentage changes are different. As expected, the changes are higher when the productivity in the complex sector is increased, since complex intermediate goods have a higher elasticity in the final sector. More surprisingly, the directions of

changes are exactly like those that occurred when we introduced aggregate productivity changes in I.5.2.1.

How does this work? As is well known, in a Cobb-Douglas framework factor-augmenting and output-augmenting technological changes have similar effects. Thus the changes from increasing productivity in an input sector or overall productivity in the final output are similar. Indeed, although the increase in productivity occurs in only one input sector here, the benefits are distributed to inputs in the other sector as well, since the productivity increase in one sector ultimately increases productivity and output in the final sector. In other words, the biased technological change here does not come at the expense of harming the other type of workers. In fact, it actually indirectly benefits them by increasing the output capabilities of the final good.

### **I.5.2.3 Changing relative productivity in the simple sector $\Xi$**

Decreasing the relative productivity of low skilled workers compared to the overeducated in the simple sector  $\Xi$  changes the relative wages of the two workers. The wages of the overeducated increase when compared to their low skilled counterparts. Indeed for a value of  $\Xi=0.85$ , the wages of the overeducated overtake the low skilled workers' wages, in line with empirical findings. Thus the main anomaly of the base model is solved. This seems like a reasonable assumption if one postulates that productivity should increase with the skill level of the worker. Thus higher wages are due to higher productivities. As mentioned previously, however, there is an additional element influencing the wages of the overeducated. This is the quit rate from the simple to the complex sector, which (adversely) affects their wages in the lower skilled jobs.

#### **I.5.2.4 Varying the Elasticity of the Final Output with Respect to the Intermediate Inputs**

Another method of introducing biased technical change is varying the elasticity of final output with respect to the two intermediate goods. This reflects back as a biased technical change on the workers in each intermediate firm, since they are the ones producing the intermediate goods.

We model this by increasing the elasticity on complex inputs from 0.5 to 0.55. This means that the elasticity on simple intermediate inputs,  $(1 - \alpha - \beta)$ , decreases correspondingly by 0.05. The effects of such a change are completely different from the technological change effects outlined earlier. Indeed, the importance of the overcrowding effect comes to the forefront here.

First let us examine the completely segmented model. Here, the increased productivity of the complex good (and hence of high skilled workers) pushes up their wages and decreases their unemployment rates, with the proportional increase in wages more noticeable. Conversely, the relative decrease in productivity of simple goods pushes up employment rates for low skilled workers very drastically and decreases their wages, with wages decreasing proportionally more. The overall unemployment rate increases, reflecting that the increase in low skilled unemployment rates is much higher than the decrease in that of high skilled workers. Low skilled average income decreases and that of high skilled workers increases. However, average overall labour-state related income increases, and so does final output.

In the alternative model, the results are different due to the overcrowding effect. There is a decrease in the probability of finding a job in the simple market. Thus, some of the high skilled workers who were employed there leave the sector, either to unemployment or to work in the high skilled sector, where the probability of finding a job increases. Indeed the percentage drop in high skilled workers employed in the simple sector is at a staggering 51%. Although the number of high skilled workers employed in the complex sector increases, the rise is nowhere near enough to offset the drop in the number of  $n^{\text{th}}$  workers. Consequently, in stark contrast to the first model, the

overall high skilled unemployment rate actually increases. Wages in the high skilled sector increase significantly, just as in the first model. The unemployment rate increases and wage rate decreases for low skilled workers for similar reasons to the first model.

High skilled income increases considerably here as well, suggesting that the increase in complex wages more than offsets the increase in high skilled unemployment in the overcrowding model. Similar to the model 1, low skilled labour income falls, while total income and final output increase, reflecting that the increase in income of high skilled workers more than offsets the decrease in income of low skilled workers.

The increase in the productivity of complex goods in the final sector has two important consequences. First, unlike the other productivity increases outlined in previous sections, this biased increase comes at the expense of the productivity of simple sector goods, and  $(1-\theta-\alpha)$  decreases in both models. The gains from the increase in productivity are no longer shared among all sectors and workers, and the simple good sector ends up losing considerably.

Secondly, overcrowding plays a very important role here. The biased technological change impacts upon high skilled workers employed in the simple sector in an immensely negative manner, and the change in their employment causes overall high skilled workers unemployment to actually increase.

What does this increase in  $\alpha$  signify in a real-life situation? Recall that the final good produced stands for a representative final good. One can interpret it as representing a basket of goods in the economy. A rise in  $\alpha$  means that the economy embodies complex goods more intensively. Thus if the economy is made up more and more of high skilled intensive goods, low skilled workers tend to lose out, and high skilled workers tend to gain more. Whether this change in the composition of the economy towards more high-tech goods is driven by a change in demand preferences or because of changes in producers supply is left to the reader's imagination, but in either case one can represent this through an increase in  $\alpha$ .

### **I.5.2.5 Increase in the proportion of high skilled workers $\gamma$**

Increasing the proportion of high skilled workers also has significant consequences, and once again overcrowding causes different effects in our two models. In the perfectly segmented first model, there is a higher pool of high skilled workers for the complex sector to choose from, loosening the labour market. Unemployment rates in that sector are driven up (even though the absolute number of high skilled workers employed increases) and wages offered decrease. The decrease in the number of low skilled workers tightens the labour market in the simple sector, pushing up their wages and lowering the unemployment rate. The wage ratios  $w^l/w^h$ ,  $w^l/w^h$ , and  $w^l/w^{high}$  increase due to the combination of these effects. High skilled average income decreases slightly due to the lower wages offered. Low skilled average income experiences the opposite and increases substantially. Total income and final output also register rises.

In the second model with overcrowding the picture changes dramatically. Once again, the labour market is looser in the complex sector. Now, however, more high skilled workers are driven towards the simple sector. Their absolute number  $n^h$  increases dramatically and so does overcrowding. This lowers the overall high skilled unemployment rate, a result in stark contrast to the first model. The increase in competition from high skilled workers makes the decrease in the unemployment rates and the increase in the wages for low skilled workers much less dramatic. This reflects as a less marked rise in the wage ratios  $w^l/w^h$ ,  $w^l/w^h$ , and  $w^l/w^{high}$  than in the first model. Both average incomes for high skilled workers and low skilled workers increase here, unlike in the first model.

### **I.5.2.6 Increasing the replacement ratio $b$**

Before discussing increasing the replacement ratio (and hence unemployment income), a few caveats have to be noted. Firstly, the setup implicitly assumes lump sum taxes for the redistribution of unemployment benefit. Thus there are no distortionary effects on the choices of labour supplied by the household, an obviously a limiting assumption. Secondly, the entire household subsidizes the unemployment income,

which is obviously not reflective of actual scenarios. These caveats notwithstanding, it is still interesting to investigate what happens when the replacement ratio is changed.

The effects in both models are very similar. As expected, all unemployment rates increase. Wages for high skilled workers in the complex sector are relatively unaffected, while those for low skilled workers and the simple sector in general increase more noticeably. The wages of low skilled workers are closer in value to the unemployment income, and thus changes in the replacement ratio affect their wages more significantly than their high skilled counterparts. This shows that unemployment benefits are more influential in the simple sector and on low skilled workers than in the complex sector. This makes the wage ratios  $w^l/w^h$ ,  $w^l/w^h$ , and  $w^l/w^{high}$  increase. Thus unemployment benefits are beneficial for low skilled workers wages but detrimental to their unemployment rates. However, the labour average income for low skilled workers (which includes both unemployment benefits and wage income) increases, while it remains relatively static for high skilled workers. Notwithstanding the caveats noted previously about this measure of income, it does seem that unemployment benefits helps those who are low skilled (and consequently indirectly those who are most at risk and who are at the bottom ladder in the economy). Of course, these measures of income do not take into account capital and firms' profits' income (but as mentioned previously these profits are close to zero). Indeed capital accumulation and capital income does decrease slightly in both models, showing that capital amounts are adversely affected by the increase in unemployment benefits. However, total income and final output remain relatively static. Thus modest rises in unemployment income results in a more equitable distribution of income and helps those who benefit the least and who are most at risk in the economy, especially if we were to assume that higher skilled workers pay the necessary taxes, without drastically affecting overall income and output in the economy.

It remains for us to investigate the dynamic effects of transitory shocks on the economy and its business cycle. The models as they are set up, however, are not conducive to the examination of the business cycle properties of the labour market. In particular, job destruction is taken to be exogenous, and hence no analysis is possible on that frontier. A detailed discussion of the business cycle dynamics will therefore be left to the subsequent two chapters, when endogenous job destruction is introduced.

## I.6 Government Policy Implications

What does all of the above imply for government policy? Two general principles guide our view on this. Firstly, the government should be concerned with overall wellbeing in the economy, reflected in indicators such as overall income to the household. Secondly, the government should also be particularly concerned with the least fortunate and those most at risk. Namely, these are the low skilled workers in the simple sector, since changes in the economy hit them the hardest, and they already receive the lowest share of the revenue in the economy.

Let us first deal with changes that had similar effects in both models. An increase in aggregate productivity or in productivities that affect one sector without hindering the other sector are beneficial to all sectors and all types of workers. Thus technological innovation that affects both sectors or one sector without compromising the other are beneficial for the economy and to both types of workers and should be encouraged.

Now we turn to an increase in  $\alpha$ , which as we mentioned earlier can be interpreted as the economy and the goods produced in it becoming more reliant and intensive in high skilled workers. An increase in the productivity or technology that affects the high-tech sector at the expense of the simple sector unambiguously harms the simple sector and its workers. In particular, workers in the simple sector stand to lose in both unemployment levels and wages. What happens to high skilled workers depends if overcrowding plays an important role or not. In both cases, wages of high skilled workers and the complex sector increase dramatically. If there is overcrowding,  $u^h$  actually increases, while if there is no overcrowding,  $u^h$  decreases.

If government policy is mainly geared towards helping the least fortunate in the economy, one might jump to the conclusion that the government should try and discourage innovation and productivity gains in the high-tech complex sector when it comes at the expense of the simple sector. This seems counter-intuitive and runs into the danger of advocating Luddism<sup>23</sup>. This is especially the case when one notices that in

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<sup>23</sup> Luddism refers to a social movement which believes that technological advancements are undesirable and detrimental to human society. The movement originated with the English textile workers in the Industrial Revolution (the so-called “Luddites”) who protested against the tumultuous social changes

both models consumption, final sector output and total income all increase. Another much more fruitful suggestion is that redistribution, through for example higher unemployment benefit and other redistributive means (since the unemployment income in our model effectively works as a redistributive lump sum transfer in the economy), can help in addressing the imbalance of fortunes experienced in the economy. In this way, the benefits of the technological change remain and some of this surplus is redistributed to those who are less fortunate. Thus one suggestion could be that government redistribution should increase when biased technological progress that benefits the complex sector and harms the simple sector increases.

An increase in the share of high skilled workers in the labour market increases the wages and labour status related income of low skilled workers. It also increases the labour status related income of high skilled workers and the overall income of the household. Thus, if our criteria for government policy is helping the least fortunate in the economy and increasing overall income, then it is clear that the government should pursue policies that increase the proportion of high skilled workers in the economy.

Turning to unemployment income, an increase in  $b$  causes wages to increase primarily in the simple sector but causes all unemployment rates to increase. Low skilled average income increases however, which includes the income of unemployed workers on benefit, while total income and final output are largely unaffected. This suggests that reasonable levels of unemployment benefit are not necessarily harmful to the overall economy and indeed can be beneficial to those most adversely affected in the economy. This obviously no longer holds when unemployment benefit increases are drastic to the point where they approach wages offered in the economy. Furthermore, our model abstracts from the distortionary effects of unemployment income on job search intensity by the unemployed, which could be adversely affected by the higher replacement ratio.

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caused by the Industrial Revolution. They perceived these social changes to be a result of technological advancements, and hence destruction of machinery was a common feature of Luddism. For more on Luddism, see Binfield (2004).

## I.7 Conclusion

Our goal in this chapter was to construct models that focused on different skill levels, defined across educational attainment. We calibrated two models that explicitly compared two completely segmented labour markets with the case where high skilled workers could take on both simple and complex jobs. Within this setup, we investigated the effects of overcrowding, aggregate productivity shocks, biased technological shocks, changes in the labour force composition, and changes in the unemployment income.

Aggregate technological increases or biased technological changes that do not affect the other sector adversely are beneficial to all agents in the economy, including low skilled and high skilled workers. Biased technological changes that benefit the high tech sector while adversely affecting the simple sector, however, result in diverging fortunes for high skilled versus low skilled workers. High skilled workers tend to gain in terms of wages while low skilled workers tend to lose in terms of wages and unemployment. Here, overcrowding effects come to the fore, causing very different effects from those in a perfectly segmented market. This is particularly evident in the unemployment rate of high skilled workers, which increases when overcrowding is present and decreases in a perfectly segment labour market. The government policy implication of these results is that some of the benefits accruing to the complex sector should be redistributed to low skilled workers to alleviate some of the adverse effects they face.

Overcrowding effects also play an important role when the labour force composition changes. An increase in the relative number of high skilled workers causes the unemployment rate for high skilled workers to increase in the perfectly segmented model, while  $u^h$  decreases when there is overcrowding. In both models, wages offered to the complex sector decrease, while unemployment rates in the simple sector decrease and wages increase. Low skilled labour's income increases and so does overall income. These results suggest that the government should pursue a policy of increasing the proportion of high skilled workers in the economy.

Finally, modest increases in the unemployment benefit cause increases in the unemployment rates of both worker types. However, low skilled workers' wages and average income rise, while overall income in the economy is not significantly affected. This suggests that reasonable levels of redistributive taxation can help those worst off in the economy (low-skilled workers).

Some caveats about the model and the conclusions should be noted. Firstly, the models do not include many economy-wide features such as money, fiscal policy, monetary policy and monopolistic goods. The models do not purport to be a realistic representation of the economy and the goal is not to reproduce accurately all of the economy's features. Its main emphasis is on the labour market, and this is what the construction and analysis is centred around. A more important limitation is that there is one representative household. This entails the household caring for both low skilled and high skilled workers, maximizing in conjunction their capital and their consumption. This is obviously limiting, and a more advanced treatment should address this issue.

An interesting development is to place the two-skilled Morten-Pissarides analysis within an open economy model that incorporates the effects of trade. This would allow for an investigation of the effects of global competition on the fortunes of the differently skilled workers, an important addition that currently has not received attention within the literature.

Finally, one might consider including endogenous job destruction in the models. At the moment, the rate of separation of jobs is assumed to be constant and exogenous. Explicitly making the firm take the decision of firing employees would be an improvement in theoretical modelling. Furthermore, it would allow us to examine variables such as job destruction and job creation rates, which are excluded in the present model due to the assumption of exogenous job destruction. This would allow for a fruitful discussion of the cyclical properties of the model. This is the main focus of the next chapter.

## II. Endogenous Job Destruction and Skills as Productivity<sup>24</sup>

We shift focus in this chapter from differences in skills in terms of education to differences in skills defined as productivity levels. To begin with, we abstract from the main feature of the previous chapter of modelling two distinct labour markets (a feature which will be incorporated in the subsequent chapter). There is now only one type of intermediate firm and only one type of labour market. Each worker, however, has a distinct productivity level when employed on his job. This allows us to explicitly analyze the choice of a firm to continue or destroy a job, unlike in the first chapter where separation rates were exogenous. Following a shock to the economy, firms may no longer find maintaining certain jobs profitable, and may therefore decide it worthwhile to terminate the posts. Endogenous job destruction is introduced within the model by assuming that each job match within the firm has an associated idiosyncratic productivity level. The firm has to decide on the minimum level of idiosyncratic productivity that would make a job match viable. If the idiosyncratic productivity of a particular match fails to reach that level, then the firm will decide to terminate the job.

This allows for a richer analysis of the dynamics of job destruction rates (jdr), job creation rates (jcr), job turnover rates (jt) and change in net employment rates (net). Furthermore, it permits us to analyze the effects of firing costs, also absent in the first chapter. Since job separation was exogenous in the first chapter, there were few unique insights offered by modelling firing costs.

We also introduce the possibility of wage rigidities to look at their effects on the model's key variables. Wage rigidities have recently garnered attention for their potential importance in explaining the cyclical data of the labour market. We model wage rigidities using two formulations to assess whether their introduction has any important consequences for the business cycle properties of the model.

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<sup>24</sup> This chapter presents an updated and revised version of the author's thesis submitted for the degree of M.Phil. in Economics at the University of Oxford in May 2005 under the title "*Matching Functions as a Source of Unemployment in a Dynamic Stochastic General Equilibrium Model*"

## II.1 Literature Overview

Job creation and job destruction rates have generated a lot of interest in the labour market literature, encouraged by the pioneering work of Davis et al (1996) for the manufacturing sector of the U.S. economy. The labour market, even if it remains steady in terms of the overall number of workers employed, is constantly in a state of flux due to the existence of job creation and destruction. The job creation rate (jcr) is defined as the total number of new jobs created as a proportion of total employment in firms that have witnessed a net increase in the number of workers employed. This definition does not include replacements for pre-existing jobs. Similarly, the job destruction rate (jdr) is defined as the number of jobs destroyed as a proportion of the total number of jobs in firms witnessing an overall decrease in employment, where separations that have been replaced are not included in the count. A closely related definition is that of net employment change, defined as the difference between the job creation and the job destruction rate over all firms in the economy. Job turnover (sometimes called job reallocation) in turn is the sum of the job destruction and job creation rates for the whole economy.

Job destruction and job creation rates are remarkably similar across OECD countries, with each averaging around 10% annually in the 1990s.<sup>25</sup> Furthermore, jdr is found to be countercyclical, decreasing substantially in a boom. There is a consensus on the other hand that jcr is procyclical, showing a rise during an upturn. A corollary to this is that there is broad agreement that jdr is negatively correlated with net employment change (net), with the opposite holding true for jcr.

However, there are several contentions within the literature regarding the other cyclical properties of jdr and jcr. One of the main controversies centres on their relative volatilities. Several authors (Blanchard and Diamond (1989), Bleakley et al (1999)) report that the counter cyclicity of jdr is much more pronounced than the procyclicity of jcr in the United States, with the amplitude of the former dominating its counterpart. Thus, a recession is highlighted by an increase in firings rather than by a

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<sup>25</sup> For an extensive summary of the relevant literature to jcr and jdr, see Dale-Olsen (2007), Davis et al (1999) and Boeri (1996).

decrease in hirings. Others, such as Shimer (2005), find  $jdr$  in the U.S. to be extremely stable over the business cycle, with most of the adjustment occurring via  $jcr$ . This disagreement extends across countries as well as within the same country. Boeri (1996) reports that  $jcr$  is more volatile than  $jdr$  in France and Germany, while the opposite holds true in the United States.

Even though there is disagreement over which of the two is more dominant, it seems that both have an important role to play over the business cycle (Yashiv, 2007a). The table below produces some cyclical properties for the Dutch economy over the business cycle according to Broersma and Gautier (1997).

**Table 3**  
**Empirical Cyclical Properties of the Dutch Economy**

Variables	$jcr$	$jdr$	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	Corr( $jcr, net$ )	Corr( $jdr, net$ )	AR(1) $jcr$	AR(1) $jdr$
Value	6.59	7.86	.19	.30	.41	-.88	0.76	0.84

Annual data for the Dutch Economy for the period 1979-1993 (the period for AR(1) is 1980-1993). Source: Broersma and Gautier(1997).  $\sigma^i$ =standard deviation of  $jcr$ ,  $jdr$ .  $jdr$ = job destruction rate.  $jcr$ =job creation rate.  $net$ = net employment change. AR(1)= First order autoregression. Corr(.)=correlation

$Jcr$  shows a positive correlation with  $net$  over the business cycle, while the reverse holds true when comparing  $jdr$  and  $net$ . Both  $jcr$  and  $jdr$  are highly persistent, with the latter showing a higher first order autocorrelation. Furthermore,  $jcr$  and  $jdr$  are both quite volatile, with  $jdr$  having a comparatively a higher standard deviation than  $jcr$ . As mentioned previously however, this last point is not an agreed upon within the literature. In another study, Broersma et al (2000) find job creation to be more volatile than  $jdr$  in the Netherlands, with job reallocation in turn being procyclical with  $jcr$  as its main driving force. What matters however is that in either case both are found to be volatile and seem to play a role in fluctuations over the business cycle.

The question now centres on how  $jcr$ ,  $jdr$ ,  $jt$ ,  $net$  and their cyclical properties are to be modelled in DSGE models in a way that can shed light on their dynamics and steady states over the business cycle. One approach introduces endogenous job destruction in models based on the Mortensen-Pissarides matching function. As Pissarides (2000) points out, without this feature models by assumption generate a constant rate of job destruction, and thus the channel of changes in employment occurs

only through job creation. This feature does not correlate with the empirical findings discussed above, which suggest that both job creation and job destruction respond to shocks. Hence it seems extremely plausible that changes in the rate of job destruction play an important factor in explaining labour market dynamics.

Recently, a small stock of models have emerged that attempt to incorporate endogenous job destruction within a DSGE framework. Den Haan, Ramey and Watson (2000) develop a model featuring endogenous job destruction that investigates the effects of incorporating costly capital adjustment and irreversible investment on unemployment fluctuations. Firms explicitly decide when to terminate certain unproductive job matches, thus generating endogenous job destruction. They also have to choose the amount of capital employed before knowing the nature of shocks that hit the economy, thus generating sunk costs associated with capital. They are able to show that their model can fit the observed dynamic properties of vacancies, unemployment, job destruction and job creation quite well. Furthermore, they illustrate that job destruction, when combined with costly capital, can play an important part in propagating shocks throughout the economy. Their model however abstracts from firing taxes and an assessment of the importance of labour market institutions such as the unemployment benefit, as well as the impact that rigid wages might have on the model.

Krause and Lubik (2007) study the effects of incorporating monetary shocks and wage rigidities within an endogenous job destruction model similar to that of Den Haan et al (2000), choosing to omit capital from the setup. Their model finds reproducing the Beveridge curve observed in the data difficult when endogenous job destruction is included in the model. Most importantly, their simulation also fails to produce the empirically observed negative correlation between job destruction and job creation rates, with both rates showing countercyclical properties. This result obtains irrespective of whether wage rigidities are included in the model.

The first aim of this chapter is to follow in the above papers' footsteps and develop a model that can provide insights into the dynamics of  $jdr$  and  $jcr$  over the business cycle. The second goal is to investigate the effects of wage rigidities as well as different labour market institutions on labour market properties. This is driven by recent observations on the well-documented differences in unemployment rates and labour

market business cycle properties between the United States and Europe. As Blanchard and Wolfers (2000), Nickell (1997), and Bertola et al (2001) point out, in addition to having diverging unemployment rates, it seems that European and the United States' economies generate different responses to extremely similar macroeconomic shocks. They conclude that different labour market institutions in each country amplify similar shocks into different effects. This chapter plans to analyze the effects of the labour market institutions of unemployment income and employment protection, as well as wage rigidities, on labour market properties.

It is well documented that the United States has considerably lower unemployment rates than some European counterparts. In addition, the United States has significantly lower unemployment benefits and employment protection than those prevalent in Europe. Can these differing labour market institutions explain the divergence in unemployment rates? Blanchard and Wolfers (2000), Nickell (1997), and Bertola et al (2001) offer the unemployment benefit as the most relevant institutional factor in the determination of employment. They suggest that firing costs play no important role in explaining differences in the unemployment rates. Ljungqvist (2002) reaches a different conclusion, proposing that firing costs and unemployment benefits have the most effect on unemployment, with both increasing the unemployment rate.

Cahuc and Zylberberg (1999), on the other hand, propose that employment protection can potentially increase employment levels. Mortensen and Pissarides (1999b) concur with their analysis. Thus there seems to exist divergent opinions within the literature on the effects of different institutional parameters. The consensus is that unemployment benefits play an important role in explaining unemployment levels (they seem to increase them). The evidence is more mixed on firing costs. Some authors argue that firing costs play no important factor in explaining unemployment differences, while others claim that the costs have a negative effect on employment, still more suggest that the costs have a positive effect.

A closely associated issue is the effects of the different institutional parameters on job turnover and their business cycle properties. As Messina and Valanti (2007) point out, job turnover is in general significantly more countercyclical in the United States than in Europe, with job turnover found to be even procyclical in certain European countries.

Institutional parameters could play an important role in explaining these differences. They propose that higher firing costs in Europe could be one of the possible explanations. In addition to reducing both job destruction and job creation rates' absolute levels, higher firing costs mute the effects of job destruction as a channel of changing employment over the business cycle. Thus job destruction becomes less volatile, with job turnover in turn becoming less countercyclical.

Another important feature that can help explain cyclical properties of the labour market are wage rigidities. Wage rigidities were introduced to solve the so called "unemployment volatility puzzle"<sup>26</sup> present in models that use the Mortensen-Pissarides framework. Shimer (2005) noticed that unemployment and vacancies are too unresponsive to shocks when compared to empirical data. He postulates that the cause of this is the Nash Bargaining formulation of wage determination present in these models. Wages are renegotiated in every period, creating a direct link between output and wage changes. This leads wages to be too responsive and correlated with output while quantity variables instead are only very weakly variable, contrary to what the empirical data indicates. Shimer suggests that sluggish wages could be an answer to this problem.

Hall (2003) proposes a tractable yet fruitful way of modelling wage rigidities. Wages are influenced by what he calls "wage norms". These wage norms are taken as references by those involved in wage determination in an economy, and hence they impose constraints on the values wages can take in a specific period. Such a wage norm could be the average prevailing wage in the economy. What matters is that the wage norm acts as a reference which imposes a limit on the possible values that wages currently being negotiated can obtain.

Wage rigidities have generated a huge debate within the recent literature.<sup>27</sup> Some have pointed out that flexible wages are not the source of the unemployment volatility problem, and indeed making them rigid is not the answer to it either (Pissarides, 2007). Most of this debate has focused on models with constant job destruction. This study aims to look at the effects of wage rigidities on a model incorporating endogenous job

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<sup>26</sup> The term is taken from Pissarides (2007).

<sup>27</sup> See Pissarides (2007) and Mortensen and Nagypal(2005) for a review.

destruction along the lines of Den Haan et al (2000). In addition to investigating the unemployment volatility puzzle spelled out above, we aim to analyze what wage rigidities imply for the cyclical properties of  $jcr$  and  $jdr$ . We model wage rigidities through both a Hall formulation and a simpler more conventional setting, where only a fraction of wages are negotiated in a particular period. Krause and Lubik (2007), in their New Keynesian model with endogenous job destruction, find that although wage rigidities modelled along Hall's formulation help in magnifying the relative volatility of unemployment and vacancies in their model, such wage rigidities do not help in explaining the cyclical properties of  $jcr$  and  $jdr$ , particularly the empirically observed negative correlation between the two.  $Jcr$  turns out to be countercyclical.

We trace the reason for such a perverse response for  $jcr$  to the exaggerated "echo" effect in such models. As Fujita (2004) points out, in response to a negative shock, both vacancies and job creation by firms initially decrease. However, the increasing unemployment rate increases the probability of filling a vacancy, which causes  $jcr$  to consequently rise. Vacancies in turn lack persistence and revert quickly towards their equilibrium levels, contrary to the data. This causes  $jcr$  to be countercyclical overall. We aim to investigate whether such a conclusion extends to a real model augmented with capital, wage rigidities, unemployment income, and firing costs.

Following on from Shimer's contribution, Hagedorn and Manovskii (2008) show that a high level of unemployment income in a model abstracting from endogenous job destruction can also assist in explaining the high volatilities of unemployment and vacancies in the data. A high unemployment income means that the alternate worker payoff from unemployment rises substantially, thus increasing the volatility of unemployment and vacancies. Our analysis takes a different approach. In addition to shedding light on such an effect, we are more interested at looking at the effect of varying unemployment income on the cyclical properties of  $jcr$  and  $jdr$ .

There have been extremely few papers analyzing the effects of the institutional parameters of firing costs and unemployment benefit on the labour market in a DSGE framework that incorporates a Mortensen-Pissarides matching function with endogenous job destruction. One exception is the paper by Joseph et al (2004), which analyzes the effects of the above factors within a setting of endogenous job destruction

and unemployed (job) search effort. They find that unemployment benefits have a significant negative impact on unemployment levels, while firing costs do not seem to have a significant effect. The main drawback of their model is the assumption of a uniformly distributed idiosyncratic productivity threshold, which seems unrealistic. They also do not investigate the effects of sluggishly adjusting wages, choosing instead to employ a minimum wage construction. Furthermore, their analysis does not focus on which of the parameters are most important in generating the correlation properties of  $jdr$  and  $jcr$ .

Thus, our general objective is to construct a real capital-augmented DSGE model that incorporates Mortensen-Pissarides matching functions and endogenous job destruction of the type developed by Den Haan et al (2000). We aim to analyze the cyclical properties of job destruction and job creation and to point out what might be important factors in addressing these features. Furthermore, we seek to investigate the effects of wage rigidities and institutional parameters, namely firing costs and unemployment income, on the cyclical properties of  $jdr$  and  $jcr$ .

This study offers several contributions to the existing literature. The combination it employs of wage rigidities, unemployment income and firing costs is unique, as no other study we know of utilizes the same combination within an endogenous destruction DSGE framework. We extend Krause and Lubik's (2007) conclusion that a New Keynesian model with endogenous job destruction along the lines of Den Haan et al (2000) fails to produce a negative correlation between  $jcr$  and  $jdr$ , with  $jcr$  being countercyclical. These conclusions carry over to our real model augmented with capital. The echo effect is too strong and vacancies are not persistent enough. We also show that introducing wage rigidities, although helpful in increasing the relative volatilities of unemployment and vacancies, does not help in improving the cyclical properties of  $jcr$  and  $jdr$  over the business cycle. This holds for both a Hall wage norm and a simpler formulation of wage rigidities.

Furthermore, we show that this same conclusion applies to increasing unemployment income. Although the relative volatilities of unemployment and vacancies are improved, a more central conclusion is that this does remedy the deficiencies with regards to the cyclical properties of  $jcr$  and the persistence of

vacancies. Most importantly, however, we show that introducing firing costs assists significantly in explaining the procyclicality of  $jcr$ , the negative correlation of  $jdr$  and  $jcr$ , and the persistence of vacancies. It also decreases the countercyclicality of job turnover, a result in line with Messina and Valanti's (2007) findings that higher firing costs in European countries explain the lower countercyclicality of job turnover when compared with the U.S. Finally, an interesting result is that the more the elasticity of matching (with respect to unemployment) in the matching function differs from the workers' bargaining share in the Nash Bargain, or the more we deviate from the Hosios condition, the more the cyclicity of  $jcr$  and the persistence of vacancies match that of the data.  $Jcr$  becomes more procyclical and negatively correlated with  $jdr$ , while vacancies exhibit persistence, in line with empirical results.

## II.2 The Model

In this section, the job search model used for analysis is constructed. The model is developed from Krause and Lubik (2007) and Den Haan et al (2000). Some of the properties and discussion relevant to the model are very similar to those expounded in the first chapter, and for brevity's sake these will not be repeated here.

### II.2.1 The Labour Market

There is now only one type of workers in the labour market. Let the total stock of workers available be normalized to one, with  $n$  representing the number of workers employed and  $u$  the number of workers unemployed:

$$n_t + u_t = 1 \quad (87)$$

All variables and parameters are normalized in relation to the workers' base (i.e. base =1). In each period firms are assumed to post a certain number of vacancies, denoted  $v_t$ . The matching function is characterized by the inputs unemployment and vacancies:

$$m_t = M(u_t, v_t) = g u_t^{1-\xi} v_t^\xi \quad (88)$$

The matching function is assumed to take a Cobb-Douglas form, is increasing in its arguments, concave, and homogenous of degree 1.  $m_t$  is the number of successful matches, or new jobs created.  $g$  is a scaling parameter.

Market tightness,  $\theta_t$ , is defined as:

$$\theta_t = v_t / u_t \quad (89)$$

The probability of a vacancy being successfully filled is the number of new matches divided by vacancies::

$$q_t(\theta_t) = m_t / v_t \quad (90)$$

Overall job separations at the firm are determined by two factors: Similar to the first chapter, there still exists the exogenous separation rate  $\tau^{ex}$ . The second factor is the endogenous separation rate  $\tau^{en}(\zeta_{it})$ , which is determined by the idiosyncratic

productivity threshold  $\zeta_{it}$  chosen by the firm (the concept of which will be developed shortly). This is the crucial addition in endogenous job destruction models. Job termination occurs exogenously and endogenously, with the firm choosing the number of jobs to be terminated in the latter. Hence the overall separation rate at firm  $i$  is given by:

$$\tau_{it} = \tau^{ex} + (1 - \tau^{ex})\tau^{en}(\zeta_{it}) \quad (91)$$

Combining the overall separation rate given by equation (91) and the total number of new hires outlined in equation (88) we arrive at the expression for the evolution of employment at a particular firm  $i$ :

$$n_{it+1} = (1 - \tau_{it+1})(n_{it} + q_{it}v_{it}) \quad (92)$$

This is the employment evolution equation similar to that derived in the first chapter but with  $\tau$  including endogenous job destruction. The timing issue faced in the first chapter regarding stock-flow relationships arises here again.<sup>28</sup> We follow the same framework adopted previously and assume that the stock of workers in  $t+1$  equals the number of existing workers and new hires in period  $t$  that have survived firing at the beginning of period  $t+1$ .

In this model, the job destruction level is defined as the jobs that the firm actively decides to destroy, which does not occur because of exogenous worker separations. Thus, we can write gross job destruction as:

$$j_{it+1}^{desgross} = \tau_{it+1}n_{it} - \tau^{ex}n_{it} \quad (93)$$

The second term is subtracted because, in our model, it represents exogenous worker separations and not conscious job destruction by the firm.

If we divide the job destruction level by  $n_{it}$  we arrive at the job destruction rate:

$$j_{it+1}^{des} = \tau_{it+1} - \tau^{ex} \quad (94)$$

Turning to job creation, the job creation level is defined as the total number of successful matches at a firm minus the number of creations to replace exogenous worker separation. The job creation level is represented as:

$$j_{it+1}^{cregross} = (1 - \tau_{it+1})q_{it}v_{it} - \tau^{ex}n_{it} \quad (95)$$

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<sup>28</sup> See Section I.3.1.1

$\tau^{ex} n_{it}$  has been subtracted once again because it does not represent actual jobs created but jobs filled to replace the workers' exogenous separations that occur. Dividing through by  $n_{it}$  yields the job creation rate:

$$j_{it+1}^{cre} = (1 - \tau_{it+1}) \frac{q_{it} V_{it}}{n_{it}} - \tau^{ex} \quad (96)$$

Our focus will primarily be on job creation and job destruction rates rather than their levels

We are now able to define the rates of net employment change and job turnover over the whole economy:

$$net_{t+1} = j_{t+1}^{cre} - j_{t+1}^{des} \quad (97)$$

$$jt_{t+1} = j_{t+1}^{cre} + j_{t+1}^{des} \quad (98)$$

Net employment change represents the overall change in the number of jobs in the economy, or overall jcr subtracted from overall jdr. Job turnover refers to the turnover in the overall number of jobs in the economy, whether created or destroyed, or equivalently the sum of jcr and jdr.

## II.2.2 The Intermediate Goods Firm

The intermediate goods firm uses labour only as an input, similar to the previous chapter. The intermediate firm's production function takes on the form:

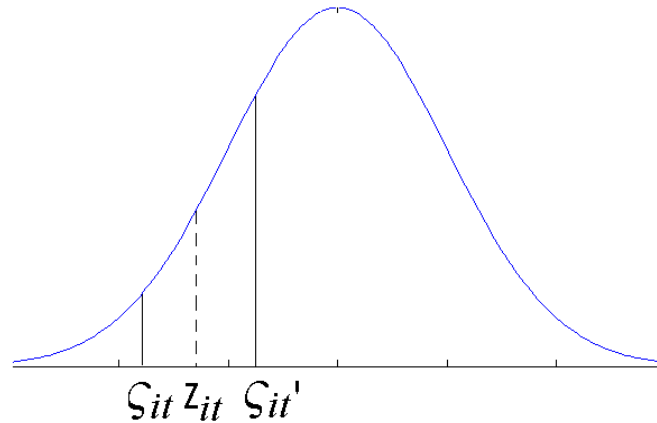
$$Q_{it} = n_{it} \int_{\zeta_{it}}^{\infty} z \frac{f(z)}{1-F(\zeta_{it})} dz = n_{it} G(\zeta_{it}) \quad (99)$$

Production at firm  $i$  is a function of the number of workers employed multiplied by the expected productivity of the workers. The production function is similar to that in the first chapter except for one crucial difference: the presence of a job-specific idiosyncratic productivity level,  $z_{it}$ , which is assumed to vary from one job relationship to another within the firm. In other words, each worker has a particular productivity level  $z_{it}$  that is drawn from a distribution, with different workers having divergent productivities in the jobs they should perform. The firm has an idiosyncratic productivity threshold  $\zeta_{it}$  below which the firm no longer finds a particular production match profitable, thereby choosing to sever the employment relationship. The idiosyncratic productivity of a particular firm-worker match takes on a random value each period<sup>29</sup>, but the distribution of the idiosyncratic productivities is assumed not to change. What changes is the firm's chosen level of  $\zeta_{it}$ . For example, the firm could encounter a negative external shock, which, all other things being equal, tends to lower the firm's production. To compensate for this negative shock, the firm would require a higher minimum idiosyncratic productivity  $\zeta_{it}$  in order for a specific worker's job to be profitable. If the worker's productivity  $z_{it}$  no longer reaches this minimum, then the job relationship is ended.

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<sup>29</sup> This assumption is common in the literature in order to make the derivations tractable (e.g. Den Haan et al (2000), Krause and Lubik (2007), and Joseph et al (2004)). As Den Haan et al (2000) point out, this assumption does not affect the general results of the model when compared with more persistent idiosyncratic productivity levels (i.e. when the productivity level of a particular worker in a particular period is related to his productivity in previous periods). The model's derivation is thus greatly simplified without affecting the overall results.

**Figure 1**  
**Idiosyncratic Productivity Distribution**



The above figure illustrates a bell-shaped distribution for the idiosyncratic productivities. At  $\zeta_{it}$ , the worker's productivity  $z_{it}$  is still profitable for the firm. However, at  $\zeta_{it}'$ , the worker no longer satisfies the minimum productivity requirement for the firm, and consequently the job is severed.

$G(\zeta_{it})$  in equation (99) above represents the expectation of  $z_{it}$  conditional on  $\zeta_{it}$ . Given the threshold level chosen by the firm and the distribution of productivity shocks,  $G(\zeta_{it})$  signifies the average value of  $z_{it}$  expected by the firm to materialize.

We can now expound on the relationship between endogenous job separation,  $\tau_{it}^{en}$ , and the idiosyncratic productivity threshold  $\zeta_{it}$ .  $\tau_{it}^{en}$  is uniquely determined by  $\zeta_{it}$ :

$$\tau_{it}^{en} = F(\zeta_{it}) \quad (100)$$

The endogenous job separation depends on the probability that  $z_{it}$  falls below the determined idiosyncratic productivity threshold, in which case the job is severed. Correspondingly, the overall separation rate becomes:

$$\tau(\zeta_{it}) = \tau^{ex} + (1 - \tau^{ex})F(\zeta_{it}) \quad (101)$$

Turning to costs, the firm faces several different types of expenditure. The first of these is the total wage bill  $W_{it}$ :

$$W_{it} = n_{it} \int_{\zeta_{it}}^{\infty} w_{it}(z) \frac{f(z)}{1 - F(\zeta_{it})} dz = n_{it} w_{it}^{av} \quad (102)$$

$w_{it}(z)$  is the individual wage bill for a particular worker, which will depend on the idiosyncratic productivity that the particular job relationship possesses.  $w_{it}^{av}$ , on the

other hand, reflects the expected wage that the firm anticipates paying, where this expectation takes into account all the possible idiosyncratic productivity levels and their respective probabilities. The expected and individual wages will for the moment be treated as known, but an explicit derivation will be constructed later.

The second cost a firm is assumed to face is a flat vacancy cost  $a$ , similar to that introduced in the first chapter. The final cost the firm pays is a flat firing cost  $\Omega$ , which only applies when a relationship, whether endogenously or exogenously, is severed. This cost can reflect any expense that arises from the severance of the relationship. This can include employment protection costs such as strikes, demonstrations, or no-fault individual severance payment. More importantly, it also includes costs associated with the severance of any job such as bureaucratic costs and procedures and the lost knowledge, experience, or training forgone when a worker leaves the firm. This is why the firing costs apply to both exogenous and endogenous separations.

In summary, the firm's objective is to choose the idiosyncratic productivity threshold  $\zeta_{it+1}$ , the vacancy level  $v_{it}$  and the corresponding employment level  $n_{it+1}$ , in order to maximize the present discounted value of profits given by :

$$\pi_{it}^{\text{intermediate}} = E_1 \left\{ \sum_{t=1}^{\infty} B^{t-1} [c_{it} Q_{it} - W_{it} - a_i v_{it} - \Omega \tau_{it+1} (n_{it} + q_{it} v_{it})] \right\} \quad (103)$$

(where  $c_{it}$  is the price the intermediate firm receives for its good)

Subject to the evolution of employment constraint outlined previously:

$$n_{it+1} = (1 - \tau_{it+1})(n_{it} + q_{it} v_{it})$$

Maximizing with respect to the above outlined variables subject to the constraint yields the following First Order Conditions:

$$n_{t+1} : \lambda_t = BE_t \left( c_{t+1} G(\zeta_{t+1}) - \frac{\partial W_{t+1}}{\partial n_{t+1}} - \Omega \tau_{t+2} + (1 - \tau_{t+2}) \lambda_{t+1} \right) \quad (104)$$

$$\begin{aligned} \zeta_{t+1} : (\lambda_t + \Omega) \frac{\partial \tau_{t+1}}{\partial \zeta_{t+1}} v_t q_t + n_t \\ = BE_t \left[ n_{t+1} c_{t+1} \frac{\partial G(\zeta_{t+1})}{\partial \zeta_{t+1}} - \frac{\partial W_{t+1}}{\partial \zeta_{t+1}} \right] \end{aligned} \quad (105)$$

$$v_t : \frac{a}{q_t} + \Omega \tau_{t+1} = (1 - \tau_{t+1}) \lambda_t \quad (106)$$

$$\lambda_t : n_{t+1} = (1 - \tau_{t+1})(n_t + v_t q_t) \quad (107)$$

Assuming symmetry, we have dropped the  $i$  subscripts for each individual firm.  $\lambda_t$  represents the Lagrangian multiplier on the equation for evolution of employment, which signifies the expected value of a future employee to the firm. This can be seen in equation (104), where the expected value of an employee equals the output he will produce minus the wage he will receive in addition to the value he will bring in the subsequent period ( $\lambda_{t+1}$ ). Equation (106) equalizes the expected costs of hiring a worker (left hand side of the equation) to the expected benefits that a worker could bring to the firm. Equation (107) gives the evolution of employment from one period to another. Finally, equation (105) highlights the expected benefits and costs of a change in the idiosyncratic productivity threshold. A change in the idiosyncratic productivity threshold causes a change in the benefits to the firm that arise from changes in employment (left hand side of the equation), while it also changes the production capability and wages faced by the firm (right hand side of the equation).

The most crucial decision for the firm is deciding the level of the idiosyncratic productivity shock below which the firm finds it necessary to terminate an existing job. By rearranging and substituting between the above first order conditions, we arrive at an expression for  $\zeta_t$ :

$$\zeta_t = \left\{ w(\zeta_t) - \frac{a}{q(\theta_t)} - \Omega \right\} c_t^{-1} \quad (108)$$

A more detailed and explicit derivation of the above formula is given in the appendix. This expression closely resembles the usual formulation for wages in a neoclassical economy. The real minimum wage after subtracting associated expected costs of vacancies and firing equals the productivity of the worker. Once an expression has been derived for the minimum wage offered  $w_t(\zeta_t)$ , we can arrive at an explicit formulation for the idiosyncratic productivity threshold.

### II.2.3 Wage Setting

As is usual, firms and workers are assumed to determine wages through Nash Bargaining. The optimal solution of the Nash Bargaining procedure has the following characterization:

$$\kappa V_t = (1 - \kappa) J_t - U_t \quad (109)$$

In terms of the match creation and destruction relationships, whenever  $V_t$  is above zero, the firm finds the match profitable and the job is created. Conversely, whenever  $V_t$  falls below zero, a firm does not find a match profitable and the job is destroyed. From the workers point of view, whenever  $U_t$  is less than  $J_t$ , the worker finds garnering a job worthwhile and an employment relationship is continued.

With respect to the firm, one can write the marginal benefit of an existing job with a known particular idiosyncratic productivity  $z_t$  as :

$$V_t = c_t G(\zeta_t) - w_t - \Omega \tau_{t+1} + BE_t \left[ (1 - \tau_{t+1}) \int V_{t+1} \frac{f(z)}{1 - F(\zeta_{t+1})} dz \right] \quad (110)$$

With respect to the workers, the value of an existing  $J_t$  takes the form:

$$J_t = w_t + BE_t [(1 - \tau_{t+1}) \int J_{t+1} \frac{f(z)}{1 - F(\zeta_{t+1})} dz + \tau_{t+1} U_{t+1}] \quad (111)$$

$U_t$  stands for the present value of unemployment to an unemployed worker:

$$U_t = w^u + BE_t \left[ \theta_t q_t (1 - \tau_{t+1}) \int J_{t+1} \frac{f(z)}{1 - F(\zeta_{t+1})} dz + (1 - \theta_t q_t (1 - \tau_{t+1})) U_{t+1} \right] \quad (112)$$

These value functions are similar to the ones developed in the previous chapter, with the only difference being the presence of firing costs and the integral over the possible productivities' range of the workers to reflect the presence of varying levels of productivity.

If the value functions are replaced in the Nash Bargaining solution, we can derive an explicit characterization of the worker-specific wage:

$$w_t^{ind} = (1 - \kappa) w^u + \kappa c_t z_t + \theta_t a - (1 - q_t \theta_t) \Omega \tau_{t+1} \quad (113)$$

A more detailed derivation of the above equation is given in the appendix. The individual wage depends positively on the unemployment income, hiring costs, market tightness, the intermediate good price and idiosyncratic productivity shocks, while it depends negatively on firing costs. The only addition here when compared with the previous chapter is the presence of firing costs. Firing costs reduce the wage because the firm has to incur a potentially extra expense in hiring the worker (since there is a probability that he might be fired in the future). The firm partially passes this cost on to the worker, with the portion passed on depending on the relative bargaining power between the two parties  $\kappa$ .

Correspondingly, the minimum wage paid at the idiosyncratic productivity threshold is:

$$w_t(\zeta_t) = (1-\kappa)w^u + \kappa c_t \zeta_t + \theta_t a - (1-q_t \theta_t) \Omega \tau_{t+1} \quad (114)$$

With the binding constraint that this minimum wage does not fall below the unemployment income level. From the individual wage we can find the expected average wage paid by the firm using equation (102):

$$w_t^{av} = (1-\kappa)w^u + \kappa \left[ c_t \int_{\zeta_{it}}^{\infty} z \frac{f(z)}{1-F(\zeta_{it})} dz + \theta_t a - (1-q_t \theta_t) \Omega \tau_{t+1} \right] \quad (115)$$

Replacing the equation for the minimum real wage and the expected wage in the equation derived for  $\zeta_{it}$  earlier, one finds a formulation for idiosyncratic productivity threshold:

$$\zeta_t = \left\{ w^u + \frac{1}{1-\kappa} \left( \kappa \theta_t a - (1-q_t \theta_t) \Omega \tau_{t+1} - \frac{a}{q(\theta_t)} - \Omega \right) \right\} c_t^{-1} \quad (116)$$

The idiosyncratic productivity threshold depends positively on the unemployment income and the workers share in the wage bargaining solution. Higher unemployment income and a higher employee's share in the bargaining procedure  $\kappa$  makes workers demand a higher wage in order to work, as explained above. A higher wage, in turn, imposes an extra cost on the firm, which again raises the minimum individual productivity level at which an employment relationship is profitable.

The effect of a higher  $c_t$  is to lower the level of  $\zeta_t$ , since a higher intermediate good price implies that production revenue increases, which lowers the level of the

idiosyncratic productivity at which the job no longer becomes profitable for the firm. Furthermore, an increase in the firing cost lowers the level of  $\zeta_t$ , since a rise in firing costs makes laying off a worker more expensive. Hence the firm decides to revise downwards its value of  $\zeta_t$  in order to avoid paying extra firing expenses.

The effect of a higher  $\theta_t$  is ambiguous. On the one hand, an increase in  $\theta_t$  (market tightness) implies that there is a relative abundance in vacancies and a low probability of filling a vacancy. This raises the bargained wage and the level of  $\zeta_t$  at which a firm is forced to sever a job, since the firm needs a high enough productivity to justify the higher wages (a situation which the first occurrence of  $\theta_t$  reflects). On the other hand, an increase in  $\theta_t$  signifies that the pool of unemployed workers has grown relatively smaller, and hence there are less people from which one can produce a successful matching process. This makes the firm lower its value of  $\zeta_t$ , since there is a decreased probability  $q(\theta_t)$  of a successful new match in the labour market and thus higher expected vacancy costs, which is reflected in the term  $\frac{a}{q(\theta_t)}$ .

## II.2.4 Wage Rigidities

Shimer (2005) argues that one of the main drawbacks of models incorporating wage determination through a Nash Bargaining solution is that wages tend to be much more volatile and procyclical than empirical evidence would suggest, while unemployment and vacancies exhibit much less movement in the models than in the data.<sup>30</sup> Shimer contends that the main reason for this is the Nash Bargaining assumption itself. According to Shimer, this assumption implies that any increase in output is then directly divided between the workers and firms, meaning that any output rises feed directly into wages. In order to resolve this anomaly, Hall (2003) proposes a form of a wage norm, where wages in the current period are influenced by the “wage norm” which agents use as a reference when they are determining wages. Thus the wage norm places a form of rigidity on the values that wages in the can take. A simple example of such a setup is where the determined wage is a weighted average of a notional wage and the wage norm.:

$$w_t = \chi w_t^{notional} + (1 - \chi) w_t^{norm} \quad (117)$$

Although the efficacy of wage rigidities in Mortensen-Pissarides DSGE models has been hotly disputed by others, Hall’s formulation has garnered attention for its neat formulation of modelling wage rigidities.<sup>31</sup> We employ a version of Hall’s wage rigidities by assuming that the wage norm is equal to the average wage prevalent in the steady state<sup>32</sup>, while the notional wage is equal to the wage calculated according to the Nash bargaining solution (as in the previous section). Hence the individual idiosyncratic wage below which a job is severed in the current period becomes:

$$w_t(\zeta_t)^{rigid} = \chi \left[ (1 - \kappa) w^u + \kappa \left[ c_t \zeta_t + \theta_t a - (1 - q_t \theta_t) \Omega \tau_{t+1} \right] \right] + (1 - \chi) w \quad (118)$$

and the average wage becomes:

$$w_t^{av} = \chi \left\{ (1 - \kappa) w^u + \kappa \left[ c_t \int_{\zeta_{tr}}^{\infty} z \frac{f(z)}{1 - F(\zeta_{it})} dz + \theta_t a - (1 - q_t \theta_t) \Omega \tau_{t+1} \right] \right\} + (1 - \chi) w \quad (119)$$

Where  $1 - \chi$  denotes the weight placed on the norm.

<sup>30</sup> See Hall (2003) for a further discussion of such models.

<sup>31</sup> See Pissarides (2007) for an overview.

<sup>32</sup> Krause and Lubik (2003) employ a similar wage norm.

We also employ a simpler wage rigidities formulation, where it is assumed that only a certain fraction of wages are adjusted in each period. In this case, the idiosyncratic wage remains unchanged from the previous section in equation (120), while the average wage becomes a weight of wages negotiated in the current period and the previous period's average wage: .

$$w_t^{av} = \chi \left\{ (1-\kappa)w^u + \kappa \left[ c_t \int_{\zeta_t}^{\infty} z \frac{f(z)}{1-F(\zeta_{it})} dz + \theta_t a - (1-q_t \theta_t) \Omega \tau_{t+1} \right] \right\} + (1-\chi)w_{t-1}^{av} \quad (121)$$

The main drawback of such a formulation is that it posits no particular reason for the existence of the wage rigidity, and as Hall has pointed it out, it invokes an efficiency which rational agents can easily avoid. There is space for mutual improvement which the agents (firm and worker) do not take up. This problem does not exist in Hall's formulation, as the rigidity per se does not arise from agents failing to renegotiate their wages when appropriate but from the fact that the wage norm acts as an anchor that dampens the response of wages. Indeed, wages are renegotiated every period in Hall's formulation, but the change in the wage is made less dramatic. However, such a simple formulation has wide applicability in the literature and it is worthwhile exploring whether either formulation has differing effects on the cyclical properties of the model. For the baseline model,  $\chi$  will be set to one (in other words, wage rigidities will be shut down). Subsequently,  $\chi$  will be varied in order to assess whether the model's performance changes under either type of wage rigidities.

## II.2.5 Final Goods Firm and Households

The final goods firm is similar to that in the previous chapter. Each final firm  $j$ 's production function is assumed to exhibit constant returns to scale (taking on a Cobb-Douglas functional form) with the inputs of capital and the amount of intermediate goods. There is also an aggregate technology term  $Z_t$ .

$$Q_j^{final} = Z_t K_{jt}^{\theta} Q_{jt}^{1-\theta} \quad (122)$$

Hence the firm aims to maximize the following profits:

$$\pi_{j1}^{final} = E_1 \left\{ \sum_{t=1}^{\infty} B^{t-1} [Z_{jt} K_{jt}^{\theta} Q_{jt}^{1-\theta} - c_{jt} Q_{jt} - (\delta + r_t) K_{jt}] \right\} \quad (123)$$

Subject to the intermediate output production constraint:

$$Q_t = n_t \int_{\zeta_t}^{\infty} z \frac{f(z)}{1-F(\zeta_t)} dz = n_t G(\zeta_t)$$

The household maximizes the following lifetime utility with respect to consumption:

$$H_1 = E_1 \left\{ \sum_{t=1}^{\infty} B^{t-1} U(C_t) \right\} \quad (124)$$

subject to the following budget constraint:

$$C_t = \pi^{final} + \pi^{intermediate} + n_t w_t^{av} + (r_t + \delta) K_t + u_t w^u - T_t - I_t \quad (125)$$

and the evolution of capital over time:

$$I_t = K_{t+1} - (1 - \delta) K_t \quad (126)$$

As in the previous chapter, one can interpret  $w^u$  as non-market returns to unemployment or as the unemployment benefit. In the previous case, the justification would be that non-market unemployment returns include leisure and any other income an unemployed worker might generate.<sup>33</sup> Under such an interpretation, taxes  $T$  would not be subtracted in the budget constraint. This does not result in any distinguishable difference in the results for equal values of  $w^u$ . Consequently, we focus the results on the case of interpreting  $w^u$  as unemployment benefit, with the results carrying over to the case of non-market returns.

<sup>33</sup> Den Haan et al (2000) use such an interpretation.

## II.2.6 Specifying Functional Forms

The household utility function is log linear in form, as in the previous chapter. Finally, in order to model shocks within the economy, the (log of the) aggregate technology level is assumed to follow a first order autoregressive (AR (1)) process:

$$\log(Z_t) = \Psi \log(Z_{t-1}) + \varepsilon_t \quad (127)$$

## II.3 Calibration Parameters

As in the previous chapter, the parameters in calibration have been chosen in order to reproduce the recent quarterly cyclical properties of the Dutch economy. In areas where the first and second chapter models are identical, similar parameters to those used in the first chapter are chosen for the sake of consistency.

With regards to the idiosyncratic productivity level, it is assumed to be normally, independently and identically distributed (i.i.d) with mean  $\mu=1$  and a standard deviation of  $\sigma = 0.4$ . The i.i.d. assumption does run counter to the original ideas of Mortensen and Pissarides, who postulate that the shocks should show persistence. However, as Den Haan et al (2000) demonstrate, models of the type investigated in this chapter are robust to the different distribution specifications and the assumption of i.i.d does not render any significant difference. Some authors, such as Joseph et al (2004), have opted to use a uniform distribution to model the idiosyncratic productivity level. This is an extreme assumption; all levels of idiosyncratic productivities, however diverse, are unrealistically equally probable. Hence we choose to employ a normal distribution.

The value  $\sigma = 0.4$  is chosen in order to reproduce average quarterly job destruction and job creation rates for the Dutch economy. The OECD (1996) and Broersma and Gautier (1997) calculate the annual job destruction rate to be around 8%, and so we choose calibration parameters that yield a quarterly job destruction and creation rates of around 2%. Furthermore, the OECD (1996) and Broersma and Gautier (1997) calculate that job turnover (the change in the number of *job positions* at firms when comparing two periods as a ratio of total employment) comprises one third to one half of total worker turnover (total number of times *workers* have changed jobs divided by the employment level). The difference between the two represents job churning, or job changes in a firm that are needed simply to maintain employment levels at their original level. Based on this, we set the exogenous separation rate to be 0.03.

Vacancy costs, which are usually estimated to be small, are set at 0.3, making total vacancy costs (number of vacancies multiplied by an individual vacancy's cost) equal to 1.1% of final output, a figure similar to that used by Andolfatto (1996). With

regards to the matching function, the parameter  $m$  is chosen to equal 0.7 in order to obtain an unemployment rate of 5.5%, the unemployment rate of the Netherlands in the mid 1990s. To begin with, firing costs and wage rigidities are set at 0. These baseline values will subsequently be varied in order to assess the effects on cyclical properties. For the sake of continuity, the rest of the parameters are identical to those used in the first chapter. Particularly, the matching elasticity with respect to unemployment and the worker's bargaining strength are both set at 0.6 in order to satisfy the Hosios condition. The unemployment income is set at 1.05, or 0.52 of the average wage in the economy, in line with the gross replacement ratio reported by the OECD (2002b) for the Netherlands in 2002.

With regards to the external productivity  $Z_t$ , the error term  $\varepsilon$  is assumed to be normally distributed with mean  $u_\varepsilon=0$  and a standard deviation of  $\delta_\varepsilon= 0.04$  to produce realistic cyclical properties for  $jdr$  and  $jcr$  in the economy, a figure similar to Joseph et al (2004). Furthermore,  $\Psi$  is chosen to equal 0.95, a widely used figure in DSGE models to reflect the persistence of productivity shocks. As will be evident, the main thrusts of the results do not change for a wide range of values for these parameters. Thus, it is worth noting that although the model has been calibrated to Dutch data, it can be easily adjusted to fit other countries' properties.

## II.4 Results

We begin by giving a general description of the dynamics that occur within the steady state equilibrium, where wage rigidities and firing costs are shut down. We then study the impulse response to a unit aggregate productivity shock for the base model, and investigate its cyclical properties. The values of  $\gamma$  (wage rigidities), firing costs, and unemployment income are then varied in order to determine their effects on the cyclical properties and the steady state levels. We report results with a smoothing Hoderick-Prescott (hp) filter of 1600.

### II.4.1 Steady State Results

**Table 4**

**Steady State Results**

c	jcr	jdr	K	n	$Q^{final}$	u	v	$w^{av}$
2.19	0.022	0.022	27.36	0.945	2.91	0.055	0.112	2.02

We first begin by giving a short description of the steady state. At equilibrium the employment and unemployment level remain steady at 0.94 and 0.06 respectively, but there are other dynamics taking effect within. In particular, there is a constant flow of workers in and out of employment, with the job destruction rate equalling the job creation rate at equilibrium (both 2.2%). Job destruction occurs when a particular firm is downsizing its employment and no longer finds certain jobs profitable, while job creation occurs when a firm decides that increasing its employment stock is worthwhile. At equilibrium, in order for the employment rate to be steady, these two flows over the economy should equal each other. Furthermore, there is also a constant flow of investment within the model, where the depreciation rate of capital and the discount rate have to be factored in to replenish lost capital.

## II.4.2 Base Model Cyclical Properties

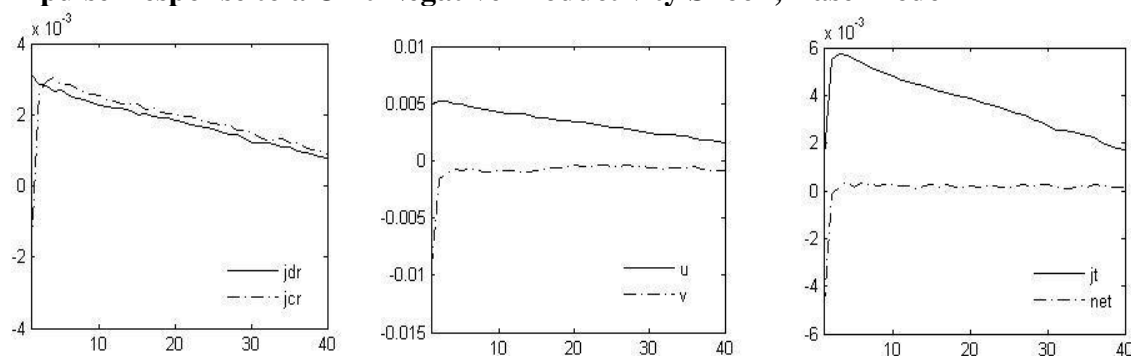
For the base model firing taxes continue to be set to 0 and  $\chi$  (the parameter governing wage rigidities) at one, which will be subsequently varied to assess their importance to the model. The model is subjected to a negative external productivity shock. We focus on certain results that are most important when dealing with job flow dynamics, particularly the job destruction rate (jdr), job creation rate (jcr), job turnover (jt) and net employment change (net).

**Table 5**  
**Cycle Properties of Base Model(Quarterly Data)**

<b>Variables</b>	$\sigma^{jdr}/jcr$	$\sigma^{jdr}/jdr$	$\sigma^{v/u}/\sigma^{Q^{final/n}}$	AR(1) jcr	AR(1) jdr	AR(1) u	AR(1) v
Value	0.22	0.18	2.19	0.48	0.72	0.75	-0.01
<b>Variables</b>	Corr(jdr, jcr)	Corr(jcr, net)	Corr(jcr, Z)	Corr(jdr, net)	Corr(jdr, Z)	Corr(jt, Z)	Corr(u, v)
Value	0.42	0.66	-0.42	-0.40	-1.00	-0.81	-0.27

H-P Filtered quarterly results for variables of interest in the base model in response to a unit negative aggregate productivity shock. jcr and jdr in  $\sigma^{jcr}/jcr$  and  $\sigma^{jdr}/jdr$  are the steady state values.  $\sigma^{v/u}/\sigma^{Q^{final/n}}$  refers to the ratio of the (Log of) the standard deviations of tightness ( $\theta$ ) to productivity ( $Q^{Final/n}$ ).

**Figure 2**  
**Impulse Response to a Unit Negative Productivity Shock; Base Model**



On the y axis, the figures report absolute deviations from steady state values. The x axis indicates number of periods (quarters) after the shock.

By calibration choice, the volatilities of jcr and jdr fall within the ranges found in the data. The model reports that jcr is more volatile than jdr. As mentioned previously, this is a matter of debate in the literature. For example, as shown in Table 3, Broersma and Gautier (1997) report that jdr is more volatile than jcr, while in a later study Broersma et al (2000) report that jcr is more volatile. In either case, our model is able to

reproduce movement in both variables, which tallies with empirical findings.  $Jdr$  is more persistent than  $jcr$ , in accordance with the data (e.g. Table 3 reporting Broersma and Gautier's results, 1997). Furthermore,  $jcr$  is positively correlated with  $net$ , while the reverse holds true for  $jdr$ , in line with their results. Job turnover in turn is found to be strongly countercyclical.

The negative correlation between unemployment and vacancies, the so called Beveridge curve, is  $-0.27$ . The ratio of the (log of) the standard deviation of market tightness to labour productivity is  $2.19$ , confirming Shimer's critique of models that incorporate the Mortensen-Pissarides matching function. Unemployment and vacancies are too unresponsive to shocks. Shimer reports that the ratio is higher than  $10$  in U.S. data.

The most glaring failure in the results is the counter cyclicity of  $jcr$  ( $\text{corr}(jcr, Z)$ ). There is a consensus in the literature that  $jdr$  should be countercyclical (which our model reproduces) but that  $jcr$  should be procyclical. Our model finds a negative correlation between final output and  $jcr$ . This is also reflected in  $jcr$  and  $jdr$  being positively correlated, while empirical studies suggest that the opposite should be the case. In our model, although  $jcr$  decreases in the initial period after a shock, it then increases considerably above its steady state level and remains there (Figure 2). Thus although the initial decline contributes to the increase in employment, it is mainly  $jdr$  that propagates the shock and explains the persistence in the change in employment.

This behaviour of  $jcr$  is due to the so-called 'echo effect'.<sup>34</sup> In response to a negative shock, firms initially decrease vacancies and thus job creation. However, as unemployment increases in the economy, the labour market tightness decreases and the probability of filling a vacancy rises. This causes the job creation rate to move above its equilibrium value. Matching models with endogenous job destruction magnify such an effect. This is also reflected in the lack of persistence ( $AR(1)$ ) of vacancies, unlike what is suggested by the data, a feature expounded on by Fujita (2004) in his real non-capital augmented model. Since the job creation rate rebounds to above its equilibrium level, firms quickly adjust their vacancy postings. Our results are also in line with those reported by Krause and Lubik (2007) who find that both  $jcr$  and  $jdr$  are countercyclical

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<sup>34</sup> For more on the echo effect, see Fujita (2004) or Den Haan et al (2000).

and are positively correlated to each other in their New Keynesian model. The fact that our model is able to reproduce the results of these studies in a real capital-augmenting model shows that the results are robust to different formulations of models with endogenous job destruction. We now turn to varying the levels of wage rigidities, unemployment income and firing costs to analyze whether they have any effects on these results.

### II.4.3 Introducing Wage rigidities

In the following sections, the effects of varying wage rigidities, firing costs and unemployment income are outlined. We begin by introducing wage rigidities using both a Hall and a simpler formulation.  $\chi$ , the parameter governing the degree of wage rigidity in each formulation, is varied in order to assess the impact of introducing wage rigidities. All other parameters are kept at the base model values.

**Table 6**  
**Properties of Introducing Wage Rigidities**

Hall Setting, $\chi=0.5$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	$\sigma^{vu}/\sigma^{Q_{hmal}/n}$	AR(1) jcr	AR(1) jdr	AR(1) u	AR(1) v
Value	0.29	0.23	7.38	0.44	0.72	0.74	-0.02
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(u,v)
Value	0.41	0.68	-0.36	-0.39	-0.99	-0.76	-0.21
Hall Setting, $\chi=0.3$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	$\sigma^{vu}/\sigma^{Q_{hmal}/n}$	AR(1) jcr	AR(1) jdr	AR(1) u	AR(1) v
Value	0.37	0.29	12.03	0.41	0.72	0.72	-0.04
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(u,v)
Value	0.42	0.69	-0.36	-0.37	-0.99	-0.75	-0.19
Hall Setting, $\chi=0.1$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	$\sigma^{vu}/\sigma^{Q_{hmal}/n}$	AR(1) jcr	AR(1) jdr	AR(1) u	AR(1) v
Value	0.56	0.43	19.20	0.39	0.73	0.69	-0.06
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(u,v)
Value	0.46	0.68	-0.39	-0.34	-0.99	-0.76	-0.11

Alternative Setting, $\chi=0.5$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	$\sigma^{v/u}/\sigma^{Q^{final}/n}$	AR(1) jcr	AR(1) jdr	AR(1) u	AR(1) v
Value	0.26	0.19	2.72	0.30	0.67	0.67	-0.06
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(u,v)
Value	0.29	0.76	-0.33	-0.40	-1.00	-0.75	-0.39
Alternative Setting, $\chi=0.3$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	$\sigma^{v/u}/\sigma^{Q^{final}/n}$	AR(1) jcr	AR(1) jdr	AR(1) u	AR(1) v
Value	0.34	0.22	4.00	0.20	0.61	0.61	-0.05
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(u,v)
Value	0.16	0.82	-0.30	-0.44	-0.98	-0.73	-0.51
Alternative Setting, $\chi=0.1$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	$\sigma^{v/u}/\sigma^{Q^{final}/n}$	AR(1) jcr	AR(1) jdr	AR(1) u	AR(1) v
Value	0.67	0.43	9.86	0.24	0.63	0.66	-0.01
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(u,v)
Value	0.15	0.82	-0.31	-0.45	-0.95	-0.73	-0.58

H-P Filtered cyclical results for variables of interest.

The effects of introducing wage rigidities, regardless of the formulation used, are mixed. The most obvious change is the main reason that Shimer proposed the introduction of wage rigidities: to remedy the problem of the lack of volatility of market tightness in such models. The relative volatility of tightness to productivity does increase under both settings, with Hall's formulation of the wage performing best. This is expected since in this case the wage norm is fixed and lacks movement of its own, which by nature makes wages more rigid. Job destruction and job creation also become more volatile in both formulations of wage rigidities. Thus wage rigidities can potentially help in solving the "unemployment volatility puzzle" expounded by Shimer.

More importantly for our purposes, the other problems of the model remain. Jcr remains countercyclical and positively correlated with jdr, and vacancies still lack persistence. This is in line with the results of Krause and Lubik (2007) in their new Keynesian model with no capital augmentation. Thus we extend their results to show that even in a real model augmented with capital wage rigidities cannot help in explaining the cyclicity of jcr over the business cycle, while we also emphasize that vacancies remain impersistent.

## II.4.4 Unemployment Income

Examining unemployment income variations has a double objective. Firstly, the effects of varying the unemployment income on the business cycle properties will be examined, similar to the case of wage rigidities. The other aim is to examine the effects of changes in unemployment income on steady state levels, particularly unemployment and job creation and destruction rates. Differing levels of unemployment income have been proposed as a potential explanation for diverging unemployment levels in Europe and the United States. It is our objective to see what changing unemployment income entails for our model's steady state values. All other parameters, including wage rigidities, are at the base model values.

**Table 7**

**Properties of Varying the Unemployment Income (Quarterly Data)**

$w^U = 0.95$ equilibrium values: $u = 0.046$ $jcr,jdr: 0.014$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	$\sigma^{v/u}/\sigma^{Q^{final}/n}$	AR(1) jcr	AR(1) jdr	AR(1) u	AR(1) v
Value	0.22	0.16	1.95	0.40	0.72	0.74	-0.03
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(u,v)
Value	0.37	0.72	-0.33	-0.39	-1.00	-0.74	-0.45
$w^U = 1.15$ equilibrium values: $u = 0.070$ $jcr,jdr: 0.032$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	$\sigma^{v/u}/\sigma^{Q^{final}/n}$	AR(1) jcr	AR(1) jdr	AR(1) u	AR(1) v
Value	0.22	0.19	2.50	0.53	0.72	0.76	0.06
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(u,v)
Value	0.45	0.63	-0.41	-0.41	-1.00	-0.80	-0.13
$w^U = 1.70$ equilibrium values: $u = 0.318$ $jcr,jdr: 0.195$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	$\sigma^{v/u}/\sigma^{Q^{final}/n}$	AR(1) jcr	AR(1) jdr	AR(1) u	AR(1) v
Value	0.18	0.14	6.02	0.45	0.68	0.80	0.13
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(u,v)
Value	0.19	0.75	-0.18	-0.51	-0.99	-0.69	-0.41

H-P Filtered quarterly results for variables of interest. Base model unemployment income is 1.05 (0.52 of base model steady state wage).

Similar to varying wage rigidities, the most noticeable change in cyclical properties due to varying unemployment income is reflected on the ratio of the standard deviation of market tightness to productivity, which increases considerably. This is in line with the predictions of Shimer and the results of Hagedorn and Manovskii (2008), who identify varying non-working alternative income as a way of increasing the relative volatility of unemployment and vacancies when compared to productivity. The reason for this is that the elasticity of substitution between market tightness and productivity increases. However, as Mortensen and Nagypal (2005) stress, one needs an extremely high value of non-employment income to generate volatilities that match the data. Indeed the difference between the income that a worker receives when working and not working has to be almost zero. This seems extremely unrealistic. In essence, the model collapses to that of the standard real business cycle of Kydland and Prescott. A high rate of substitution between employment and unemployment states is needed to generate the desired volatilities. This is one of the main criticisms of the original real business cycle models and a large impetus for adopting the Mortensen-Pissarides matching function framework. Introducing such a high value for unemployment income brings us back to the original problem of the standard real business cycle models.<sup>35</sup>

There are no other significant changes in the cyclical properties of the model. Indeed, more importantly for our purposes,  $jcr$  remains countercyclical, while vacancies still lack persistence. The echo effect remains strong. Thus a main contribution of our analysis is that varying unemployment income, although it might help in increasing the fluctuations of unemployment and vacancies, does not help in explaining the cyclical properties of  $jcr$  and  $jdr$  in a model with endogenous job destruction along the lines of Den Haan et al (2000).

Turning to changes in the steady state levels, increasing (resp. decreasing) the unemployment income causes a sharp rise (resp. fall) in the unemployment levels. Increasing unemployment income also increases both the job destruction and job creations rates significantly. This is in line with empirical findings (e.g. Nickell, 1997). An increase in the unemployment income raises the non-employment income of workers, the wage the firm has to offer for employed workers, while also raising the idiosyncratic productivity threshold at which a firm destroys a job. Thus a higher

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<sup>35</sup> For more on this see Mortensen and Nagypal (2005).

equilibrium jdr (jcr) arises from the higher idiosyncratic productivity threshold as well as a higher unemployment figure.

## II.4.5 Firing costs

The firing cost analysis will focus on the cyclical properties effects as well as the resultant changes in steady state unemployment, jcr and jdr levels. All other parameter values, including the unemployment income and wage rigidities, are unchanged from the base model.

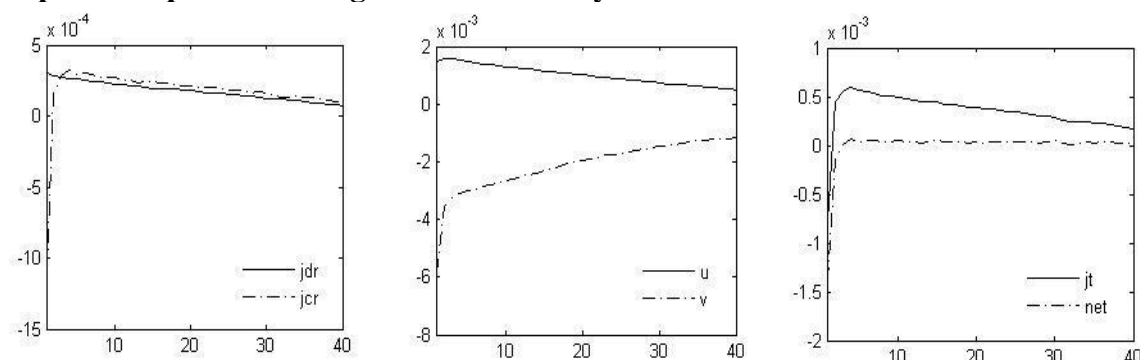
**Table 8**

### Properties of Introducing Firing costs (Quarterly Data)

$\Omega = 0.2$ equilibrium values: $u = 0.046$ jcr,jdr: 0.012							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	$\sigma^{v/u}/\sigma^{Q^{final}/n}$	AR(1) jcr	AR(1) jdr	AR(1) u	AR(1) v
Value	0.23	0.17	2.19	0.36	0.72	0.75	0.05
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(u,v)
Value	0.29	0.76	-0.25	-0.40	-1.00	-0.69	-0.57
$\Omega = 0.4$ equilibrium values: $u = 0.040$ jcr,jdr: 0.006							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	$\sigma^{v/u}/\sigma^{Q^{final}/n}$	AR(1) jcr	AR(1) jdr	AR(1) u	AR(1) v
Value	0.29	0.14	2.18	0.20	0.72	0.76	0.22
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(u,v)
Value	0.09	0.88	-0.04	-0.40	-1.00	-0.48	-0.77
$\Omega^U = 0.6$ equilibrium values: $u = 0.036$ jcr,jdr: 0.003							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	$\sigma^{v/u}/\sigma^{Q^{final}/n}$	AR(1) jcr	AR(1) jdr	AR(1) u	AR(1) v
Value	0.42	0.13	2.18	0.07	0.72	0.76	0.35
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(u,v)
Value	-0.15	0.96	0.19	-0.41	-1.00	-0.10	-0.86

H-P Filtered quarterly results for variables of interest.

**Figure 3**  
**Impulse Response to a Negative Productivity Shock**       $\Omega = 0.6$



On the y axis, the figures report absolute deviations from steady state values. The x axis indicates number of periods (quarters) after the shock.

The most significant effect of introducing firing costs is the fact that  $jcr$  becomes less countercyclical, in line with empirical evidence. The positive correlation between  $jcr$  and  $jdr$  decreases as well. Indeed, for a high enough firing tax ( $\Omega=0.6$ ), the correlation between job creation and job destruction becomes negative and job creation becomes procyclical. Vacancies also become more persistent. Consequently, the negative correlation between unemployment and vacancies, or the Beveridge curve, becomes much more pronounced. Such a value (and indeed possibly higher values) for employment protection seems reasonable in our model. Indeed Mortensen and Pissarides (1999b) estimate firing costs in Europe to be as much as three times as high as hiring costs.

Another important effect of increasing firing costs is that job turnover becomes less countercyclical. This is in line with the results reported by Messina and Valanti (2007), who empirically show that firing costs play an important part in explaining why job turnover is less countercyclical in European countries (where higher employment protection prevails) than in the United States. Thus it seems that firing costs are significant in explaining the cyclical properties of  $jcr$  and  $jdr$  while also shedding light on cyclical differences between Europe and the United States.

What explanations underline such results? The key feature is that firing costs introduce a cost to destroying jobs, while in the baseline model costs only applied to vacancies' postings. This made job destruction the dominant form of adjusting

employment numbers in the baseline model. Thus even though job creation was countercyclical and positively correlated with job destruction we still witnessed an overall decrease in employment. When firing costs are introduced, job destruction is no longer costless and the dominant form of adjustment. This can be seen in the significant decrease in the relative volatility of  $jdr$  to  $jcr$ . Since hiring is relatively less costly when employment protection is introduced,  $jcr$  is activated as a channel of enabling employment change. Vacancies in turn become more persistent and the echo effect is reduced, in line with empirical data.

Investigating the second aim, increasing firing costs has the surprising result of decreasing unemployment levels. Both  $jdr$  and  $jcr$  steady state levels decrease significantly as well. The key to this phenomenon lies in the relative tradeoffs introduced by higher firing costs. On the one hand, firing costs increase the costs to firms of having a high level of employment, as higher firing costs have to be paid in the event of redundancy even if the separation occurs because of the exogenous separation rate. This effect tends to reduce the employment level chosen by the firm.

On the other hand, high firing costs lead the firm to have increasing disincentives against making employees redundant. The firm now would prefer to keep previously unprofitable jobs rather than terminate them, an activity it would have chosen under lower firing costs. This corresponds to what is known in the literature as ‘labour hoarding.’ This second effect seems to dominate the first effect, concurring with the results of Mortensen and Pissarides (1999b). Both effects explain why  $jcr$  and  $jdr$  steady state levels decrease substantially. Given the higher costs of hiring and firing due to the presence of termination costs, it makes sense for the firm to minimize such activities as much as possible.

## II.5 Robustness and the Hosios Condition

DSGE models notoriously suffer from a lack of specific criteria on parameter selection, and it is possible that the results could change depending on the parameters employed. Thus as a robustness check we vary the values of parameters to examine whether this has any effects on the results. We vary the distribution of the idiosyncratic productivity  $z$ , hiring costs  $a$ , the matching function elasticity with respect to unemployment  $(1-\xi)$  and the workers bargaining strength in the Nash solution  $\kappa$ .

Increasing the standard deviation of the normal distribution of the idiosyncratic productivity causes  $jcr$  and  $jdr$  equilibrium levels to increase and equilibrium unemployment to consequently rise. Increasing  $(1-\xi)$  and  $\kappa$  simultaneously to the same levels (to preserve the Hosios condition) causes  $jcr/jdr$  to increase while  $jdr$  becomes relatively more volatile than  $jcr$ . Unemployment consequently increases. Increasing vacancy costs leads to a reduction in equilibrium  $jcr/jdr$  while unemployment increases.

The most important result, however, is that the main insights of the model do not change for a wide range of these parameters. Job creation remains countercyclical and positively correlated with output, while vacancies remain impersistent. Neither wage rigidities or increasing unemployment income help in solving this matter, although they do increase the relative volatilities of  $jcr$ ,  $jdr$  and market tightness.

There is one interesting case, however, where the results do change. This is when the elasticity of the matching function with respect to unemployment  $(1-\xi)$  and the workers' wage bargaining strength  $\kappa$  deviate from one another. In other words, we are interested in the case where the Hosios condition is not satisfied. What matters is not whether  $\kappa$  or  $(1-\xi)$  take on high or low values, since as we explained previously this does affect the results, but the degree of difference between the two. This can be either when  $\kappa$  or  $(1-\xi)$  takes on the higher value when compared to the other. In both cases  $jcr$  becomes procyclical and negatively correlated with  $jdr$ , while vacancies show more persistence.

**Table 9**

**Properties of Deviating from the Hosios Condition (Quarterly Data)**

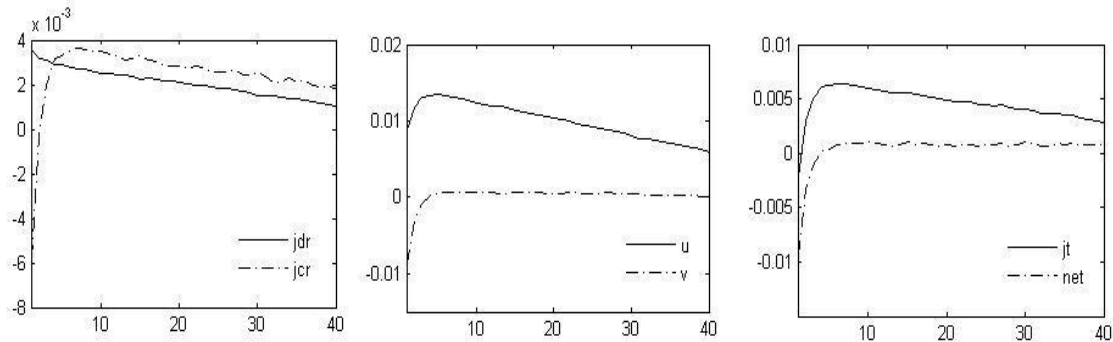
(1-ξ) = 0.2    κ= 0.8    equilibrium values:    u = 0.128    jcr,jdr: 0.043							
<b>Variables</b>	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	$\sigma^{v/u}/\sigma^{Q_{fmal}/n}$	AR(1) jcr	AR(1) jdr	AR(1) u	AR(1) v
Value	0.18	0.10	2.48	0.42	0.70	0.85	0.30
<b>Variables</b>	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(u,v)
Value	-0.10	0.88	0.13	-0.56	-1.00	-0.40	-0.09
(1-ξ) = 0.7    κ= 0.3    equilibrium values:    u = 0.025    jcr,jdr: 0.001							
<b>Variables</b>	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	$\sigma^{v/u}/\sigma^{Q_{fmal}/n}$	AR(1) jcr	AR(1) jdr	AR(1) u	AR(1) v
Value	0.81	0.24	2.06	-0.20	0.72	0.59	0.38
<b>Variables</b>	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(u,v)
Value	-0.01	0.96	0.04	-0.30	-1.00	-0.25	-0.98

H-P Filtered quarterly results for variables of interest. All other parameters are unchanged from base model.

**Figure 4**

**Impulse Response to a Negative Productivity Shock**

**(1-ξ) = 0.2    κ= 0.8**



On the y axis, the figures report absolute deviations from steady state values. The x axis indicates number of periods (quarters) after the shock.

The Hosios condition is required so that a decentralized equilibrium’s welfare equals that of the social planner. In matching models with a Nash Bargaining formulation, the free entry condition for the firm implies that the expected costs of a vacancy equal the benefits for the firm. This however does not take into account externalities that go beyond the particular firm in question. The opening of a vacancy at an individual firm creates two externalities, one positive and one negative. On the positive side, the presence of a new vacancy increases the probability that workers are matched to a firm. On the other hand, this new vacancy reduces the probability that another vacancy is successfully filled. Hence the externalities work through the market

tightness. When the Hosios condition is satisfied, these externalities are equal to each other and they are cancelled out.

When the Hosios condition is not satisfied, however, this amplifies onto market tightness, which in turn ramifies onto the “echo” effect expanded on above. Following a negative shock, vacancies no longer revert quickly to their equilibrium values. This is because the job creation rate does not surge as dramatically as the base model to a level higher than the steady state value. The larger the deviation from the Hosios condition, the more externalities there are to vacancy postings, which makes vacancies more persistent, leading to a lower echo effect and a more cyclical  $jcr$ .

It is an empirical matter, however, to determine whether such a case is a realistic scenario. It should be stated that there is no strong empirical or theoretical justification for setting the two parameters equal to each other except to satisfy the Hosios condition, so conceivably there is no reason to assume that the parameters cannot be different. As Pissarides (2000) points out, the bargaining process happens in a different environment from the matching technology. Although most empirical estimates place  $(1-\xi)$  to be between 0.4-0.7, the values employed by DSGE models have varied significantly. For example, as Hagedorn and Manovskii (2008) point out, figures employed have ranged from 0.72 (Shimer, 2005) to 0.235 (Hall, 2003). Empirical estimates suggest that the workers bargaining strength is higher in Europe than the United States, but it is unlikely that the bargaining strength is extremely high. Hence although deviation from the Hosios condition can be one reason that explains the data, it is an open question whether such a scenario is supported by empirical evidence.

Thus both firing costs and deviations from the Hosios condition are possible solutions to the dilemma of Mortensen Pissarides models with endogenous job destruction along the lines of Den Haan et al (2000). Although the first has been supported empirically, the empirical case for the second has not been established.

## II.6 Conclusion

The main purpose of this chapter was to construct a theoretical DSGE model based on the Mortensen-Pissarides matching function that incorporates endogenous job destruction. In order to assess its viability, the model was simulated and compared to the cyclical properties observed empirically over the business cycle, particularly those of the job destruction and job creation rates. An analysis of the features within the model that are most important in generating these results was sought.

The second aim of this chapter was to provide a taxonomy of the steady-state and cyclical effects of wage rigidities, firing costs and unemployment income, with the goal of analyzing whether any of these factors can contribute to explaining varying cyclical properties in different economies.

With regards to the first aim, the base model does relatively well in explaining the relative persistence of job destruction and job creation rates, with  $jdr$  being more persistent than  $jcr$ . It also shows that both  $jcr$  and  $jdr$  are volatile, reproducing well the fact that both have an important role to play over the business cycle. The model's main failing lies in the counter-cyclicality of  $jcr$  and its positive correlation with  $jdr$ , a feature previously elaborated on by Krause and Lubik (2007) in a New Keynesian monetary model with no capital. Our contribution lies in extending this result to a real model augmented with capital.

Introducing wage rigidities has disappointing results. In line with Shimer's (2005) hypothesis it does increase the relative volatility of market tightness to productivity. More importantly for our concerns however, it fails to improve the procyclicality of  $jcr$  or produce a negative correlation between  $jcr$  and  $jdr$ . Vacancies remain impersistent. This is in line with Krause and Lubik's findings (2007) in their New Keynesian model with endogenous job destruction. We again show that this result extends to capital augmented non monetary models with endogenous job destruction, and the results hold for two different wage setting formulations.

In the same manner, increasing unemployment income increases the relative volatility of market tightness relative to productivity, as Shimer (2005) predicts. However an extremely high value of unemployment income is required for realistic volatilities. As Mortensen and Nagypal (2005) point out, this seems implausible. More importantly for our concerns, we show that increasing the unemployment income does not improve the performance of a model with endogenous job destruction in terms of the cyclical properties of  $jcr$  and the persistence of vacancies.  $Jcr$  remains countercyclical and positively correlated with  $jdr$ , while vacancies lack persistence. Thus a higher unemployment income cannot explain the cyclical properties of  $jcr$  and  $jdr$  over the business cycle in a model with endogenous job destruction.

A higher unemployment income, however, has significant effects on unemployment levels, which rise considerably, an expected result in line the empirical literature. A higher unemployment income reduces the cost of unemployment to workers but also increases the wage that the firm has to pay to entice employees to work. This leads to unemployment increasing substantially, with equilibrium  $jcr$  and  $jdr$  values showing a considerable rise as well. The conclusions on unemployment income, however, have to be judged against the results reached in the first chapter, where reasonable increases in unemployment income were shown to aid the income of the least well off in society (low skilled workers), even if overall unemployment rates increase.

One of the most important parameters affecting the model is the strength of firing costs. Introducing firing costs results in a negative correlation between  $jcr$  and  $jdr$  as well as a procyclical  $jcr$ . Thus firing costs seem to play a very important role in explaining business cycle dynamics. Furthermore, job turnover becomes much less countercyclical when firing costs are introduced, in line with Messina and Valanti's (2007) findings that firing costs explain why job turnover shows less counter-cyclical in Europe than in the United States. In the model with no firing costs, firms relied on costless separations as the main mechanism of adjusting employment, allowing  $jcr$  to even become countercyclical. This is no longer so when firing costs are included. Firing costs introduce a new expense to separations, which makes firms rely relatively more on  $jcr$  as a mechanism of adjusting employment rates.

We also show that deviations from the Hosios condition can help in explaining the procyclicality of  $jcr$  and the persistence of vacancies. Increasing the difference between the values of the elasticity of the matching function with respect to unemployment compared to the workers wage bargaining strength reduces the echo effect and makes  $jcr$  more procyclical. Vacancies also become persistent. Whether such a scenario can hold in the real world is an empirical matter that is not resolved.

In terms of steady state levels, firing costs decrease  $jcr$ ,  $jdr$ , and interestingly, unemployment as well. Firing taxes have two opposing effects. On the one hand increasing  $\Omega$  causes a rise in employment levels (labour hoarding) because dismissals become more expensive. On the other hand, having high levels of employment increase the probability of at least one worker being fired, making it likely that the firm will pay a higher firing bill. The first factor, labour hoarding, dominates the second. The increased costs of both new matches and separations force the firm to choose lower steady state levels of  $jcr$  and  $jdr$ .

There are several areas where the model could be developed and further research could shed extra light. Firstly, it is possible that an alternative way of modelling firing costs could reach different conclusions. For example, instead of a constant flat rate, firing costs could be made to depend on the productivity of the worker. The more productive the worker, the more costly it is to fire him. This could conceivably create a direct link between firing costs and the cost of job destruction.

As in the first chapter, the model used has been purposefully simplified in order to develop a clear understanding of the effects of the variables that interest us. Although the simplification has helped in pinpointing the dynamics of several factors, the model consequently neglects other factors of potential importance. A further modification could be to introduce features that have been abstracted from in the model.

For example, the model lacks money and bonds markets. Bonds can introduce an important way for households to transfer income from one period to another. Furthermore, monetary policy could potentially play an important role in the economy, with monetary shocks being another interesting perturbation to explore. Introducing a nominal element in the model would also allow the analysis to incorporate nominal

price rigidities into the model. This could be done through modelling firms as monopolistic competitors (e.g. through a Dixit-Stiglitz function formulation), in contrast to the current model which does not introduce any sort of price differentials.

Another interesting addition could be combining endogenous job destruction with job differentiation along education and job complexity lines. Workers with different levels of education may have diverging labour market properties over the business cycle. This is the feature we explore in the next chapter.

### **III. Skills and the Business Cycle: A DSGE Model Analysis**

In this chapter, the two main features of the first and second chapter are integrated into one model. Job skills are differentiated by having two intermediate firms (one high skilled and one low skilled), and within each intermediate firm job matches have different idiosyncratic productivity levels. This analysis gives rise to several new features of interest. As we witnessed in the previous two chapters, both overcrowding and endogenous job destruction impart important insights into labour market behaviour. Combining the two allows us to see whether the interaction between them can offer any new additional insights.

To begin with, this analysis will allow us to examine the business cycle properties of the job destruction and job creation rates for both high skilled and low skilled workers and different job complexity levels. Such a construction improves the performance of the model with regards to the cyclical properties when compared to the previous chapter. The most important feature, however, is the properties of job destruction and job creation over the business cycle for “the overeducated”: high skilled workers in simple jobs. As we shall see, they experience unique cyclical properties over the business cycle that differ markedly from the other types of workers. The increasing prevalence of this phenomenon in OECD economies raises the need for an analysis of such cyclical properties. To our knowledge, this is the first study that examines such a question.

### III.1 Literature Overview

The overeducated, or workers who hold qualifications deemed to be in excess of what their job requires, are generally shown to experience unique conditions within the labour market.<sup>36</sup> Empirical evidence shows that they receive wages below those of workers with similar educational levels but employed in jobs that suit their level of qualifications (Green et al, 1999). The overeducated also exert a negative influence on lower skilled workers; low skilled workers face direct competition with the overeducated, which increases their chances of ending up in unemployment and lowers their earned wages.

The question of whether overeducated workers receive higher wages than their low skilled counterparts on similar jobs has not been resolved. Most studies show that there is a positive return to being overeducated (Hartog, 2000; Sicherman, 91). However, Gautier et al (2002), in a widely referenced study using Dutch data, show that this is not the case, with no tangible return in terms of wages to overeducation.

For our purposes, the most relevant empirical evidence relates to flows into the labour market differentiated across job skills and worker educational levels. Empirical research on such an issue is limited, and whatever available evidence there is, is inconclusive. Studies have taken different approaches to the question. Some have looked at differences in labour market flows across different job skill categories (usually defined in terms of blue collar versus white collar workers). Yet others have looked at different wage level categories and corresponding  $jdr/jcr$  levels, while a very limited number of studies have attempted to investigate flow levels for workers with different educational qualifications.

One line of research that could shed light on this study is an analysis of flow rates for different wage categories, since it could be assumed that wages increase with levels of education or job skills. Most of these studies (e.g. Davis et al (1996)) show that  $jdr/jcr$  levels decrease with higher wages. In terms of studies that focus on different job skill levels, most, albeit not all, show that workers in lower skilled jobs (such as low

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<sup>36</sup> For a comprehensive review of overeducated workers see Borghans and de Grip (2000).

level blue collar positions) have higher separation, job turnover, worker flow, and churning rates than workers in complex jobs. Thus, simple jobs are more precarious than their complex counterparts.

Based on data from the state of Maine in the U.S., Lengermann and Vilhuber (2002) report that accession, separation and churning rates decline monotonically with the skill category of the job. Abowd et al (1999) also show that in French firms there is much more entry and separation at lower skill when compared to higher levels. Bauer and Bender's study of German firms (2004) finds that job turnover rates are higher for lower skilled jobs in firms with stable or decreasing employment levels. They however report that churning rates are similar for high skilled and low skilled workers, although churning rates are much lower for engineers and professionals. They hypothesize that this is due to higher costs of separations and hirings for such a group, which makes a firm place extra effort in ensuring that the match is suitable. This is a popular explanation for why jobs requiring higher skills have lower churning rates than their lower skilled counterparts. Cahuc et al (2006), on the other hand, find that in French firms, higher skilled categories tend to be more mobile than lower skilled ones, since they receive more outside offers, while the rate of job termination is higher for low skilled categories.

One can instead look at labour market flows in terms of educational levels of a worker rather than the skill levels of a job. There have been very few studies that have examined job flow differences across educational levels, but two exceptions are Salvanes and Forre (2003), who study Norwegian data, and Gartell et al (2007), who look at evidence from Swedish firms.. Both studies show that, after abstracting from net overall increases and decreases in employment, equilibrium  $jcr$  and  $jdr$  levels should be similar for the high and low educated. Churning rates, however, are much higher for those with higher levels of education, thus showing that they change jobs more often.

In terms of flow dynamics over the business cycle, results from Sweden show that  $jdr$  is much more volatile for the lower educated, with firms adjusting mainly by increasing the  $jdr$  for low skilled workers rather than reducing  $jcr$ . In line with this, they find that job turnover is much more countercyclical for the low skilled than the high skilled. This result however may be country specific, as results for Norway seem to

point in the opposite direction. The main difference between the education levels was higher hiring and job creation rates for higher skilled workers when compared to low skilled workers, and thus  $jcr$  is the main driver of change.

Turning to the overeducated, most studies show that they generally have a higher worker flow rate than their lower educated counterparts in similar job types (Alba-Ramirez (1993), Sicherman (91)). The overeducated are more mobile between jobs and have a higher incidence of quitting due to outside offers and opportunities. Unfortunately there is insufficient data to indicate whether this also implies higher  $jdr/jcr$  rates for the overeducated.

An important issue to consider is the effects of overeducated workers on their lower educated counterparts in similar jobs over the business cycle. Some theories suggest that firms would take the opportunity of a recession to replace the lower educated workers by hiring more of the overeducated (Oi, 1962; Hamermesh, 1993; Gautier et al, 1999). The empirical evidence on this is mixed. Some authors, such as Teulings and Koopmanschap (1989), find that such a situation holds true in the Netherlands. Gautier et al (2002), on the other hand, show that in a recession firms adjust by increasing the separation rate of the lower educated. They find no evidence, however, that firms adjust by hiring more overeducated workers to replace the lower educated in a recession.

As is evident, the literature on job flows across different job complexities or worker educational levels is scant and the results are non-conclusive. All of the studies however show that there are important differences along different categories of jobs and workers. Thus it would be worthwhile to investigate what theory would predict for the business cycle properties across different employment categories, particularly those of the overeducated.

This chapter investigates the business cycle properties of the labour market across different educational and job skill levels, with a special emphasis on overeducated workers. A model that distinguishes along different job complexity levels and overeducation is constructed and its business cycle properties are investigated. As in the

previous chapter, we look at the effects of wage rigidities and varying the unemployment income and firing costs on the business cycle.

Although the general results of the previous chapters are reproduced, with firing costs and deviations from the Hosios condition playing an important role in explaining the cyclical dynamic of  $jcr$  and the persistence of vacancies, the performance of the model when compared to empirical data is considerably improved. The most important insight, however, is the behaviour of overeducated workers over the business cycle. Overeducated workers have the most volatile  $jcr$  rates by far, and they also experience dynamics unlike the other worker groups. Net employment change (net) is countercyclical, with the number of overeducated workers increasing in a recession, thus crowding out and replacing low skilled workers. These results show that endogenous job destruction integrated with differences along worker types and job complexities can be an important addition for analyzing cyclical properties of the labour market over the business cycle.

## III.2A Model with Overcrowding and Endogenous Job Destruction

We developed two models in the first chapter, one including and the other excluding overcrowding. For brevity's sake, the model with overcrowding will be the sole focus of our discussion below. Furthermore, any analysis of the model's features that are a repetition of what has been expounded previously will be discounted.

### III.2.1 The Labour Market

The labour market has the same basic characteristics as the overcrowding model developed in the first chapter:

$$n_t^l = n_t^{ll} + n_t^{lh} \quad (128)$$

$$n_t^h + u_t^h + n_t^{lh} = \gamma \quad (129)$$

$$n_t^{ll} + u_t^l = 1 - \gamma \quad (130)$$

$n_t^l$  stands for total workers employed in the simple sector, whether they are high-skilled or low skilled.  $n_t^{ll}$  stands for low skilled workers in simple jobs, while  $n_t^{lh}$  represents high skilled workers working in simple jobs.  $n_t^h$  continues to stand for workers in the complex sector (who are all high-skilled).  $\gamma$  is the proportion of high skilled workers in the economy, and correspondingly  $1 - \gamma$  is the proportion of low skilled workers in the economy.

Matching functions are unchanged from the overcrowding model in the first chapter:

$$m_t^l = M^l(u_t^l + u_t^h, v_t^l) \quad (131)$$

$$m_t^h = M^h(u_t^h + n_t^{lh}, v_t^h) \quad (132)$$

Similarly for market tightness  $\theta^i$  and the different probabilities of successfully filling a vacancy,  $q^i$ :

$$\theta_t^l = v_t^l / (u_t^l + u_t^h) \quad (133)$$

$$\theta_t^h = v_t^h / (u_t^h + n_t^{lh}) \quad (134)$$

$$\theta_t^{ll} = v_t^l / u_t^l \quad (135)$$

$$\theta_t^{lh} = v_t^l / u_t^h \quad (136)$$

$$q_t^l = m_t^l / v_t^l \quad (137)$$

$$q_t^h = m_t^h / v_t^h \quad (138)$$

$$q_t^{ll} = \frac{u_t^l}{u_t^l + u_t^h} q_t^l \quad (139)$$

$$q_t^{lh} = \frac{u_t^h}{u_t^l + u_t^h} q_t^l \quad (140)$$

The employment dynamics are however new. For each of the employed groups we have:

$$n_{t+1}^{ll} = (1 - \tau_{t+1}^{ll})(n_t^{ll} + q_t^{ll} v_t^l) \quad (141)$$

$$n_{t+1}^{lh} = (1 - \tau_{t+1}^{lh})(n_t^{lh} + q_t^{lh} v_t^l) \quad (142)$$

$$n_{t+1}^h = (1 - \tau_{t+1}^h)(n_t^h + q_t^h v_t^h) \quad (143)$$

Where:

$$\tau_{t+1}^{lh} = \tau^{lhex} + \theta_t^h q_t^h + (1 - \tau^{lhex} - \theta_t^h q_t^h) \tau_{t+1}^{lhen} \quad (144)$$

$$\tau_{t+1}^{ll} = \tau^{llex} + (1 - \tau^{llex}) \tau_{t+1}^{llen} \quad (145)$$

$$\tau_{t+1}^h = \tau^{hex} + (1 - \tau^{hex}) \tau_{t+1}^{hen} \quad (146)$$

$$\tau_{t+1}^{ien} = \tau^{ien}(\zeta_{t+1}^i) = F(\zeta_{t+1}^i) \quad (147)$$

The overall separation rate for high skilled workers in complex jobs and low skilled workers in simple jobs are similar to those developed in the second chapter; the overall separation rate is a function of the exogenous separation rate  $\tau^{iex}$  ( $i = ll, lh, h$ ) and the endogenous separation rate  $\tau^{ien}(\zeta^i)$ , where, as in the second chapter,  $\tau^{ien} = F(\zeta^i)$ . Equation (144) here is the most interesting and the one that needs the most explanation. It shows that there is an extra source of job termination  $\theta_t^h q_t^h$  for high skilled workers in simple jobs above and beyond the usual exogenous rate of  $\tau_t^{lh}$ . This extra source reflects the fact that some high skilled workers employed in the simple job sector leave to the complex job sector. Thus, this extra source of termination is incorporated in the definition of the overall separation here.

The job destruction rate for each type of worker is given by:

$$j_{t+1}^{des h} = \tau_{t+1}^h - \tau^{hex} \quad (148)$$

$$j_{t+1}^{des ll} = \tau_{t+1}^{ll} - \tau^{llex} \quad (149)$$

$$j_{t+1}^{deslh} = \tau_{t+1}^{lh} - \tau^{lhex} - \theta_t^h q_t^h \quad (150)$$

For high skilled workers employed in the simple sector, we subtract  $\theta_t^h q_t^h$  since this does not measure conscious job destruction by the firm, but instead it shows the rate of workers who leave the simple firm to the complex sector.

The job creation rate is defined as:

$$j_{t+1}^{creh} = (1 - \tau_{t+1}^h) \frac{q_t^h v_t^h}{n_t^h} - \tau^{hex} \quad (151)$$

$$j_{t+1}^{crell} = (1 - \tau_{t+1}^{ll}) \frac{q_t^{ll} v_t^l}{n_t^{ll}} - \tau^{llex} \quad (152)$$

$$j_{t+1}^{crelh} = (1 - \tau_{t+1}^{lh}) \frac{q_t^{lh} v_t^l}{n_t^{lh}} - \tau^{lhex} - \theta_t^h q_t^h \quad (153)$$

Once again we have to take account of jobs that act as a replacement for high skilled workers leaving the simple sector to the complex sector in our measurement of  $jcr^{lh}$ . Net employment change (*net*) and job turnover (*jt*) for each worker type *i* over the whole economy is consequently defined as:

$$net_{t+1}^i = j_{t+1}^{crei} - j_{t+1}^{desi} \quad (154)$$

$$jt_{t+1}^i = j_{t+1}^{crei} - j_{t+1}^{desi} \quad (155)$$

## III.2.2 The Intermediate Goods Firms

### III.2.2.1 The Complex Intermediate Goods Firm

The complex firm's output is given by:

$$Q_t^h = y^h n_t^h \int_{\zeta_t^h}^{\infty} z^h \frac{f(z^h)}{1-F(\zeta_t^h)} dz^h = y^h n_t^h G(\zeta_t^h) \quad (156)$$

The firm's maximizes:

$$\pi_1^h = E_1 \left\{ \sum_{t=1}^{\infty} B^{t-1} [c_t^h y^h n_t^h G(\zeta_t^h) - W_t^h - a^h v_t^h - \Omega^h \tau_{t+1}^h (n_t^h + q_t^h v_t^h)] \right\} \quad (157)$$

Where:

$$W_t^h = n_t^h w_t^{hav} = n_t^h \int_{\zeta_t^h}^{\infty} w_t^h(z^h) \frac{f(z^h)}{1-F(\zeta_t^h)} dz^h \quad (158)$$

Subject to the evolution of employment constraint:

$$n_{t+1}^h = (1 - \tau_{t+1}^h)(n_t^h + q_t^h v_t^h) \quad (159)$$

The first order conditions for the firm are as follows:

$$n_{t+1}^h : \lambda_t^h = BE_t [c_{t+1}^h y^h G(\zeta_{t+1}^h) + (1 - \tau_{t+2}^h) \lambda_{t+1}^h - w_{t+1}^{avh} - \Omega \tau_{t+2}^h] \quad (160)$$

$$v_t^h : \frac{a^h}{q_t^h} + \Omega^h \tau_{t+1}^h = (1 - \tau_{t+1}^h) \lambda_t^h \quad (161)$$

$$\lambda_t^h : n_{t+1}^h = (1 - \tau_{t+1}^h)(n_t^h + q_t^h v_t^h) \quad (162)$$

$$\zeta_t^h : (\lambda_t^h + \Omega^h) \frac{\partial \tau_{t+1}^h}{\partial \zeta_{t+1}^h} [v_t^h q_t^h + n_t^h] = BE_t \left[ n_{t+1}^h c_{t+1}^h y^l \frac{\partial G(\zeta_{t+1}^h)}{\partial \zeta_{t+1}^h} - \frac{\partial W_{t+1}^h}{\partial \zeta_{t+1}^h} \right] \quad (163)$$

These results replicate those in the previous chapter that incorporated endogenous job destruction, with the only difference being that the results now apply to the complex sector.

### III.2.2.2 The Simple Goods Intermediate Firm

To recap, simple intermediate firms can hire both low skilled and high skilled workers. The output of the simple firm becomes:

$$Q_t^l = y^l \left[ n_t^{lh} G(\zeta_t^{lh}) + \Xi n_t^{ll} G(\zeta_t^{ll}) \right] \quad (164)$$

$y^l$  stands for the exogenous productivity level on simple jobs, while  $\Xi$  represents the relative productivity of low skilled to high skilled workers on simple jobs.

The firm maximizes the present discounted value of profits:

$$\pi_t^l = E_1 \left[ \sum_{t=1}^{\infty} B^{t-1} \left\{ c_t^l y^l (\Xi n_t^{ll} G(\zeta_t^{lh}) + n_t^{lh} G(\zeta_t^{lh})) - W_t^{lh} - W_t^{ll} - a^l v_t^l \right\} \right] \quad (165)$$

Where:

$$W_t^{lh} = n_t^{lh} w_t^{avlh} = n_t^{lh} \int_{\zeta_t}^{\infty} w_t^{lh}(z^{lh}) \frac{f(z^{lh})}{1-F(\zeta_t^{lh})} dz^{lh} \quad (166)$$

$$W_t^{ll} = n_t^{ll} w_t^{avll} = n_t^{ll} \int_{\zeta_t}^{\infty} w_t^{ll}(z^{ll}) \frac{f(z^{ll})}{1-F(\zeta_t^{ll})} dz^{ll} \quad (167)$$

Subject to the evolution of employment constraints:

$$n_{t+1}^{ll} = (1 - \tau_{t+1}^{ll})(n_t^{ll} + q_t^{ll} v_t^l) \quad (168)$$

$$n_{t+1}^{lh} = (1 - \tau_{t+1}^{lh})(n_t^{lh} + q_t^{lh} v_t^l) \quad (169)$$

Maximizing subject to the constraint yields the following First Order Conditions:

$$n_{t+1}^{lh} : \lambda_t^{lh} = BE_t [c_{t+1}^l y^l G(\zeta_{t+1}^{lh}) + (1 - \tau_{t+2}^{lh}) \lambda_{t+1}^{lh} - w_{t+1}^{avlh} - \Omega^{lh} \tau_{t+2}^{lh}] \quad (170)$$

$$n_{t+1}^{ll} : \lambda_t^{ll} = BE_t [\Xi c_{t+1}^l y^l G(\zeta_{t+1}^{ll}) + (1 - \tau_{t+2}^{ll}) \lambda_{t+1}^{ll} - w_{t+1}^{avll} - \Omega^{ll} \tau_{t+2}^{ll}] \quad (171)$$

$$v_t^l : \lambda_t^{lh} = \frac{1}{q_t^{lh} (1 - \tau_{t+1}^{lh})} \left[ a^l - \lambda_t^{ll} q_t^{ll} (1 - \tau_{t+1}^{ll}) \right] + \left[ \Omega^{lh} \tau_{t+1}^{lh} q_t^{lh} + \Omega^{ll} \tau_{t+1}^{ll} q_t^{ll} \right] \quad (172)$$

$$\lambda_t^{ll} : n_{t+1}^{ll} = (1 - \tau_{t+1}^{ll})(n_t^{ll} + q_t^{ll} v_t^l) \quad (173)$$

$$\lambda_t^{lh} : n_{t+1}^{lh} = (1 - \tau_{t+1}^{lh})(n_t^{lh} + q_t^{lh} v_t^l) \quad (174)$$

$$\zeta_{t+1}^{lh} : (\lambda_t^{lh} + \Omega^{lh}) \frac{\partial \tau_{t+1}^{lh}}{\partial \zeta_{t+1}^{lh}} \left[ v_t^l q_t^{lh} + n_t^{lh} \right] = BE_t \left[ n_{t+1}^{lh} c_{t+1}^l y^l \frac{\partial G_{t+1}}{\partial \zeta_{t+1}^{lh}} - \frac{\partial W_{t+1}^{lh}}{\partial \zeta_{t+1}^{lh}} \right] \quad (175)$$

$$\zeta_{t+1}^H : (\lambda_t^H + \Omega^H) \frac{\partial \tau_{t+1}^H}{\partial \zeta_{t+1}^H} [v_t^l q_t^H + n_t^H] = BE_t \left[ \Xi n_{t+1}^H c_{t+1}^l y^l \frac{\partial G_{t+1}^H}{\partial \zeta_{t+1}^H} - \frac{\partial W_t^H}{\partial \zeta_{t+1}^H} \right] \quad (176)$$

As usual,  $\lambda_t^i$  represents the Lagrangian multiplier on the equation for the evolution of employment, which signifies the expected value of a future employee of each type to the firm. This can be seen in equations (170) and (171), where the value of an employee equals the output he will produce minus the costs foregone, in addition to the value he will bring in the subsequent period. Equation (172) outlines the relationship between the current values of hiring the two different types of employees, whether high or low skilled. Equations (173) and (174), as explained earlier, give the evolution of employment of each type of worker from one period to another. Equations (175) and (176) give the expression for the idiosyncratic productivity threshold for each type of worker in the simple sector. Once again the setup closely follows that expounded in the previous chapter. One notable addition however occurs in (172), which shows the new situation introduced by the presence of two types of workers for the simple firm to choose from when evaluating optimal vacancy postings.

### III.2.3 Wage Setting

#### III.2.3.1 The Complex Intermediate Goods Firm

Once again a Nash Bargaining problem with Bellman equations is used to derive the wages. Thus, for the complex job firm, the Nash Bargaining solution is of the following form:

$$\kappa^h [V_t^h] = (1 - \kappa^h) [J_t^h - U_t^h] \quad (177)$$

As in the previous models,  $V_t^h$  stands for the value of a filled job to the firm.  $J_t^h$  represents the value the worker receives from being employed, while  $U_t^h$  stands for the value of being unemployed. Finally,  $\kappa$  represents the worker's bargaining power in the solution, where a higher value implies a higher share of the production surplus accruing to the worker.

For the complex firm, the value of a job filled is:

$$V_t^h = c_t^h y^h G(\zeta_t^h) - w_t^h - \Omega^h \tau_{t+1}^h + BE_t \left[ (1 - \tau_{t+1}^h) \int V_{t+1}^h \frac{f(z^h)}{1 - F(\zeta_{t+1}^h)} dz^h \right] \quad (178)$$

The equation is similar to that developed in chapter 2.

The value of employment for a worker in a complex job,  $J_t^h$ , is also similar to the one developed in the previous chapters:

$$J_t^h = w_t^h + BE_t [(1 - \tau_{t+1}^h) \int J_{t+1}^h \frac{f(z^h)}{1 - F(\zeta_{t+1}^h)} dz^h + \tau_{t+1}^h U_{t+1}^h] \quad (179)$$

$U_t^h$ , the present value of unemployment to an unemployed high skilled worker, is:

$$U_t^h = w^u + BE_t \left[ \begin{aligned} &(1 - \tau_{t+1}^h) \theta_t^h q_t^h \int J_{t+1}^h \frac{f(z^h)}{1 - F(\zeta_{t+1}^h)} dz^h + (1 - \tau_{t+1}^h) \theta_t^h q_t^h \int J_{t+1}^h \frac{f(z^h)}{1 - F(\zeta_{t+1}^h)} dz^h \\ &+ (1 - (1 - \tau_{t+1}^h) \theta_t^h q_t^h - (1 - \tau_{t+1}^h) \theta_t^h q_t^h) U_{t+1}^h \end{aligned} \right] \quad (180)$$

Similar to the overcrowding model developed in the first chapter, an unemployed high skilled has a chance of being employed in both the complex sector ( $\theta_t^h q_t^h J_{t+1}^h$ ) and the simple sector ( $\theta_t^h q_t^h J_{t+1}^h$ ).

If the value functions are replaced in the Nash Bargaining solution, we arrive at the following expression for wages in the complex sector:

$$w_t^h = \kappa^h [a^h \theta_t^h + c_t^h y^h G(\zeta_t^h) - (1 - q_t^h \theta_t^h) \Omega^h \tau_{t+1}^h] + (1 - \kappa^h) [w_t^u] + \frac{(1 - \kappa^h) \kappa^{lh}}{(1 - \kappa^{lh})} [(1 - \tau_{t+1}^{lh}) \lambda_t^{lh} q_t^{lh} \theta_t^{lh}] \quad (181)$$

As in chapter 1, the complex sector wage depends positively on the unemployment income, hiring costs, market tightness, the productivity of the worker, and the price that the intermediate good is sold at. There is also an additional term reflecting the enticement that the complex firm has to pay in order to differentiate itself from the simple firm that the high skilled worker may also choose to work in. The only difference from chapter 1 is the presence of firing costs and the expected idiosyncratic productivity  $G(\zeta_t^h)$ , features similar to those in the previous chapter which emerge because of the introduction of endogenous job destruction .

### III.2.3.2 The Simple Goods Intermediate Firm

There are two wages that the simple intermediate firm has to offer, one for the low skilled workers and one for the high skilled workers.

#### The Low Skilled worker

The Nash Bargaining solution is:

$$\kappa^H [V_t^H] = (1 - \kappa^H) [J_t^H - U_t^H] \quad (182)$$

The value of a job filled is:

$$V_t^H = \Xi c_t^l y^l G(\zeta_t^H) - w_t^H - \Omega^H \tau_{t+1}^H + BE_t \left[ (1 - \tau_{t+1}^H) \int V_{t+1}^H \frac{f(z^H)}{1 - F(\zeta_{t+1}^H)} dz^H \right] \quad (183)$$

The value of employment for a low skilled worker,  $J_t^H$ , is:

$$J_t^H = w_t^H + BE_t [(1 - \tau_{t+1}^H) \int J_{t+1}^H \frac{f(z^H)}{1 - F(\zeta_{t+1}^H)} dz^H + \tau_{t+1}^H U_{t+1}^H] \quad (184)$$

Similarly for  $U_t^H$ :

$$U_t^H = w^H + BE_t \left[ (1 - \tau_{t+1}^H) \theta_t^H q_t^H \int J_{t+1}^H \frac{f(z^H)}{1 - F(\zeta_{t+1}^H)} dz^H + (1 - (1 - \tau_{t+1}^H) \theta_t^H q_t^H) U_{t+1}^H \right] \quad (185)$$

Replacing the value functions into the Nash Bargaining solution gives us:

$$w_t^H = \kappa^H [q_t^H \theta_t^H (1 - \tau_{t+1}^H) \lambda_t^H + \Xi c_t^l y^l G(\zeta_t^H) - \Omega^H \tau_{t+1}^H] + (1 - \kappa^H) [w_t^H] \quad (186)$$

Thus the equation for wages of low skilled workers in simple jobs replicates those presented in the previous chapters.

## The High Skilled Worker

The Nash Bargaining solution is:

$$\kappa^{lh} [V_t^{lh}] = (1 - \kappa^{lh}) [J_t^{lh} - U_t^h] \quad (187)$$

The value of a job filled for the firm is:

$$V_t^{lh} = c_t^l y^l G(\zeta_t^{lh}) - \Omega^{lh} \tau_{t+1}^{lh} - w_t^{lh} + BE_t \left[ (1 - \tau_{t+1}^{lh}) \int V_{t+1}^{lh} \frac{f(z^{lh})}{1 - F(\zeta_{t+1}^{lh})} dz^{lh} \right] \quad (188)$$

The value of employment for a high skilled worker in a simple job is:

$$J_t^{lh} = w_t^{lh} + BE_t \left[ (1 - \tau_{t+1}^{lh}) \int J_{t+1}^{lh} \frac{f(z^{lh})}{1 - F(\zeta_{t+1}^{lh})} dz^{lh} + (1 - \tau_{t+1}^{lh}) \theta_t^h q_t^h \int J_{t+1}^h \frac{f(z^h)}{1 - F(\zeta_{t+1}^h)} dz^h + (\tau_{t+1}^{lh} - (1 - \tau_{t+1}^h) \theta_t^h q_t^h) U_{t+1}^h \right] \quad (189)$$

The interesting term here is  $\theta_t^h q_t^h$ , which is inserted to reflect the fact a high skilled worker might leave a simple job for a complex job. Finally, the expression for the value of being unemployed for a high skilled worker was introduced previously:

$$U_t^h = w^u + BE_t \left[ (1 - \tau_{t+1}^h) \theta_t^h q_t^h \int J_{t+1}^h \frac{f(z^h)}{1 - F(\zeta_{t+1}^h)} dz^h + (1 - \tau_{t+1}^{lh}) \theta_t^{lh} q_t^{lh} \int J_{t+1}^{lh} \frac{f(z^{lh})}{1 - F(\zeta_{t+1}^{lh})} dz^{lh} + (1 - (1 - \tau_{t+1}^h) \theta_t^h q_t^h - (1 - \tau_{t+1}^{lh}) \theta_t^{lh} q_t^{lh}) U_{t+1}^h \right] \quad (190)$$

If the value functions are replaced in the Nash Bargaining solution, we arrive at the following expression for wages at the complex sector:

$$w_t^{lh} = \kappa^{lh} [c_t^l y^l G(\zeta_t^{lh}) - \Omega^{lh} \tau_{t+1}^{lh} + (1 - \tau_{t+1}^{lh}) \lambda_t^{lh} q_t^{lh} \theta_t^{lh}] + (1 - \kappa^{lh}) [w^u] \quad (191)$$

As in the first chapter, the fact that an overeducated worker may leave to the complex sector adversely affects his wages. This can be identified by recognizing that the overall separation rate for the overeducated  $\tau_{t+1}^{lh}$  includes the quit rate to the complex sector  $\theta_t^h q_t^h$  (equation 144).

Hence, the wages' derivations for all types of workers in all job levels combine the elements of those expounded in previous chapters. When compared to the first chapter, the difference here is the presence of endogenous job destruction and firing costs in the equations. When compared to the second chapter, the endogenous job destruction analysis is extended to incorporate the different types of workers and occupations, a feature present in the models of the first chapter.

### III.2.4 Closing the model, Specifying Functional Forms and Wage Rigidities

To complete the model, we need to introduce households and final firms. The specifications for both are unchanged from those expounded in the overcrowding model in the first chapter. The same applies for the functional forms of the two matching functions,  $M_t^l$  and  $M_t^h$ :

$$M^l(u_t^l, u_t^h, v_t^l) = g^l (u_t^l + u_t^h)^{1-\xi^l} (v_t^l)^{\xi^l} \quad (192)$$

$$M^h(u_t^h, n_t^h, v_t^h) = g^h (u_t^h + n_t^h)^{1-\xi^h} (v_t^h)^{\xi^h} \quad (193)$$

Finally, in order to model shocks within the economy, the (log of the) external productivity level is assumed to follow a first order autoregressive (AR (1)) process:

$$\log(Z_t) = \Psi \log(Z_{t-1}) + \varepsilon_t \quad (194)$$

Turning to wage rigidities, they take the exact same form of those described in the second chapter, except now there are three wages, one for each type of worker. We utilize both a Hall wage norm formulation as well as a formulation where only a certain fraction of wages are renegotiated in each period. The setups of wage rigidities for each worker type remain unchanged from the wage rigidities' constructions expounded in the previous chapter.<sup>37</sup>

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<sup>37</sup> With regards to the Hall formulation, the wage norm for each worker type is the average wage received by that worker type in the steady state of the base model.

### III.3 Calibration Parameters

Where relevant, we use the exact same parameters utilized in the first chapter in order to be consistent in our choice. One exception is that we set  $\Xi$ , the relative productivity of low skilled workers to high skilled workers in simple jobs, to 0.89. This is to ensure that the wages of high skilled workers in simple jobs are not lower than those of low skilled workers, in line with empirical findings. To account for the presence of endogenous job destruction, we also set the exogenous separation rate for all worker types at 0.03. The idiosyncratic productivities for each type of worker are assumed to be normally, independently and identically distributed (i.i.d) with mean  $\mu=1$  and standard deviation  $\sigma = 0.45$ . The aggregate productivity shock continues to have a standard deviation of  $\delta_e=0.04$ , in line with the previous chapter. The unemployment income is set at  $w^u=0.54$ , representing 0.52 of the steady state average wage for all workers. These values are subsequently varied in the robustness section to investigate how sensitive the results are to different specifications. Once again, the main conclusions derived do not change for a large set of different specifications, showing that the model is flexible in its calibration to other countries' data.

Since static steady state effects of varying the unemployment income and technological parameters (both biased and aggregate) have been dealt with in the first chapter and since the conclusions reached do not change, we do not reproduce the analysis here. Instead, we focus on cyclical properties, particularly those of job destruction and job creation rates.

### III.4 Results

#### III.4.1 Steady State Results

**Table 10**  
**Steady State Results**

$jdr^n, jcr^n$	$jdr^h, jcr^h$	$jdr^l, jcr^l$	$n^n$	$n^h$	$n^l$	$n^h/n^l$	$Q^l$
0.012	0.037	0.034	0.660	0.013	0.262	0.050	1.582
$urate^n$	$urate^l$	$q^n$	$q^l$	$w^h/w^l$	$w^l/w^n$	$c$	$k$
0.052	0.096	0.633	0.797	1.002	0.804	1.185	14.872

We begin first by giving a short description of the steady state. As in the overcrowding model in first chapter, low skilled workers have a higher rate of unemployment than their high skilled counter parts. They also receive a lower wage level. By construction, the overeducated, high skilled workers in low skilled jobs, have a similar wage to low skilled workers.

It is worth mentioning that the values of the variables obtained here are different from those in the first chapter, particularly the unemployment rates. The unemployment rates for both types of workers are higher in this model. This is because endogenous job destruction, and consequently job destruction ( $jdr$ ) and job creation rates ( $jcr$ ) are introduced here, unlike in the previous model. This causes the unemployment rates, among other values, to change when the exact same parameters are used in both models. We could obtain similar results in both models but that would require us to utilize different parameter values in each chapter. We choose, however, to keep the same parameters for consistency's sake. This does not affect the main conclusions reached.

By construction, job creation and destruction rates are similar for the overeducated and low skilled workers, while for both they are considerably higher than the values for high skilled workers in complex jobs. This seems in line with the empirical results that show higher  $jcr/jdr$  values for simple jobs when compared to

complex jobs and for lower paid jobs when compared to those with higher wages. Although the differences may be somewhat too high, this can be easily adjusted by varying the standard deviation of the idiosyncratic productivity distributions.<sup>38</sup> For example, utilizing a lower standard deviation for workers in the simple sector than that of workers in complex jobs reduces the differences in  $jcr/jdr$  equilibrium levels. This would assume that there is a lower variance of productivities on simple jobs than complex jobs. This assumption seems reasonable since performance on complex jobs, due to the complexity of the work, is probably more varied than that on simple jobs. For the reported results, however, we choose to utilize the same distributions for all the worker types. This does not affect the main thrust of our results.

The model is also flexible in terms of varying relative equilibrium  $jcr/jdr$  levels of overeducated versus low skilled workers. This can be achieved by changing their relative productivities in the simple sector  $\Xi$ , or their relative wage bargaining strengths on simple jobs. This is a welcomed feature given the lack of data on the relative levels of  $jcr/jdr$  of overeducated workers when compared to low skilled workers on simple jobs. Although job turnover rates are similar for both types of workers in the simple sector, the model produces separation and hiring rates that are much higher for overeducated workers, in line with empirical results. There are considerable numbers of overeducated workers leaving to the complex sector, thus resulting in a higher churning rate. This tallies well with the evidence that overeducated workers are more mobile and receive a higher rate of outside offers.

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<sup>38</sup> Variations are discussed in more detail in the robustness section.

### III.4.2 Base model Cyclical Properties

In this section, we subject the model to a unit negative aggregate productivity shock. We focus on certain results that are generally considered to be the most important when dealing with job flow dynamics, particularly the job destruction, job creation, job turnover and net employment change rates.

**Table 11**  
**Properties of Base Model,  $\sigma^e=0.04$  (Quarterly Data)**

#### High Skilled Workers in Complex Jobs

<b>Variables</b>	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) $u^h$	AR(1) $v^h$	
	0.20	0.16	0.55	0.72	0.78	0.32	
<b>Variables</b>	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr( $u^h, v^h$ )
	0.13	0.76	-0.08	-0.55	-1.00	-0.63	-0.63

#### Low Skilled Workers

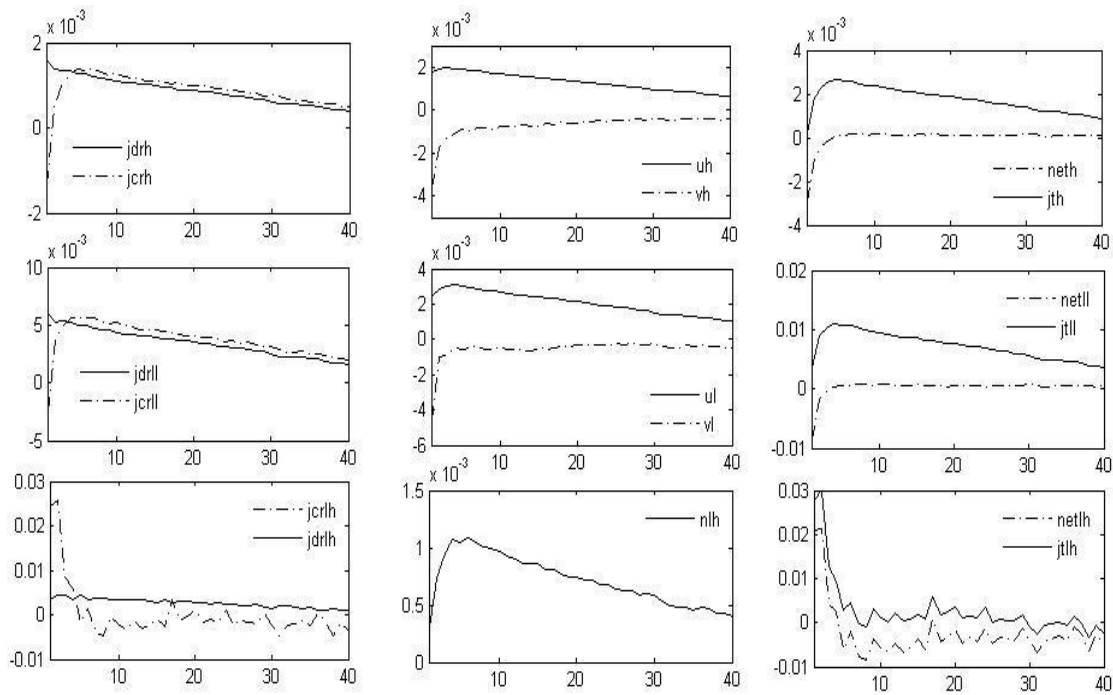
<b>Variables</b>	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) $u^l$	AR(1) $v^l$	
	0.23	0.22	0.67	0.73	0.83	0.21	
<b>Variables</b>	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr( $u^l, v^l$ )
	0.45	0.57	-0.38	-0.48	-0.99	-0.80	-0.11

#### High Skilled Workers in Simple Jobs

<b>Variables</b>	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr			
	1.20	0.15	0.65	0.73			
<b>Variables</b>	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(net, Z)
	0.69	1.00	-0.73	0.61	-0.99	-0.80	-0.66

H-P Filtered quarterly results for variables of interest in the base model for each type of worker. jcr and jdr in  $\sigma^{jcr}/jcr$  and  $\sigma^{jdr}/jdr$  are the steady state values.

**Figure 5**  
**Impulse Response to a Negative Productivity Shock**



On the y axis, the figures report absolute deviations from steady state values. The x axis indicates number of periods (quarters) after the shock.

The results for low skilled workers and (high skilled) workers in complex jobs are similar to those reported in the previous chapter for the single job type model.<sup>39</sup> The persistence of  $jdr$  is higher than that of  $jcr$ .  $Jcr$  is relatively more volatile than  $jdr$ . We also obtain the anomalous result of  $jcr$  being positively correlated with  $jdr$  and countercyclical ( $\text{corr}(jcr^{lh}, Z)$ ). In line with this, vacancies are not very persistent, indicating that the echo effect is too strong. Job turnovers for both are also very countercyclical

It should be noted, however, that the results are relatively better than those in the previous chapter.  $Jcr$  for low skilled workers and complex jobs are less countercyclical and positively correlated with  $jdr$ , while vacancies (for both job types) are more persistent. This indicates that disaggregating the model along job complexity and education levels can play an important role in increasing the accuracy of Mortensen Pissarides DSGE models with endogenous job destruction, and it can also help in explaining the cyclical data, which shows the importance of adopting such an approach.

<sup>39</sup> Please refer to the previous chapter for a more thorough discussion.

The case for high skilled workers in simple jobs (the overeducated) is unique and provides the most important insight of the model. Here, the relative volatility of  $jcr$  is very high, much higher than the other worker types. This is because conditions in both complex and simple jobs exert an influence on the overeducated. Changes in vacancies and market tightness in both types of firms have an effect on the overeducated. Thus the volatilities of  $jcr$  are magnified.

The most interesting result, however, is that net for the overeducated is countercyclical:  $n^{lh}$  increases in a recession (Figure 5). This is driven by the fact that both  $jcr^{lh}$  and  $jdr^{lh}$  are extremely countercyclical, with the effect of  $jcr^{lh}$  dominating that of  $jdr^{lh}$ . The increase in the job creation rate for the overeducated in a recession leads to a significant rise in  $n^{lh}$ . Thus our model seems to concur with the finding that the overeducated are increasingly hired by simple firms in a recession and that they crowd out lower skilled workers. Given the relative slack in the complex sector market and the increasing number of high skilled unemployed workers, simple sector firms increasingly choose to hire overeducated workers. These results, as we shall see, hold true across any specification or alteration we might introduce into the model.

### III.4.3 Varying Wage rigidities, Unemployment Income and Firing Costs

In this section, a taxonomy of the effects of changing wage rigidities, firing costs and unemployment income is outlined. Introducing wage rigidities or increasing the unemployment income has exactly the same effects as those expounded in the previous chapter.<sup>40</sup> Although increasing the unemployment income increases steady state  $jcr$  and  $jdr$  levels, and while wage rigidities make  $jcr$  and  $jdr$  relatively more volatile, the anomalies of the model remain.  $jcr$  for low skilled workers and workers in complex jobs remain countercyclical and positively correlated with  $jdr$ , while vacancies are impersistent, indicating an excessively strong echo effect. Furthermore,  $net^{lh}$  remains countercyclical, and overcrowding of low skilled workers by the overeducated in a recession occurs. The overeducated workers'  $jcr$  remains the most volatile of all the worker groups.

Introducing firing costs also has the same effects on low skilled workers and those in complex jobs as those expounded in the previous chapter. The correlation between  $jcr$  and  $jdr$  for complex job workers and low skilled workers becomes less positive, while  $jcr$  becomes less countercyclical. Vacancies become more persistent and the echo effect is reduced. Thus once again it seems that firing costs have an important role to play in explaining cyclical dynamics. It should be noted that the results are much more pronounced here than the model in the previous chapter, with only modest increases in firing costs required for the above results to hold. This once again indicates that a model disaggregated along job complexity and education can assist in matching empirical results.

However,  $net$  and  $jcr$  remain countercyclical for overeducated workers, with their  $jcr$  remaining the most volatile of all the groups.  $n^{lh}$  increases in a recession, thus overcrowding low skilled workers in simple jobs. Thus it seems no matter what specification the model is put under, it predicts overcrowding of low skilled workers by increasing hiring of high skilled workers in a recession.

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<sup>40</sup>To avoid cluttering, results for varying unemployment benefit, wage rigidities, and firing costs are given in the Appendix in III.7.3.1, III.7.3.2, and III.7.3.3 respectively.

Introducing firing costs, as witnessed in the previous chapter, also decreases equilibrium  $jcr$ ,  $jdr$  and unemployment levels. The only case where  $jcr$  and  $jdr$  remain high is once again for the overeducated, whose equilibrium  $jcr/jdr$  remain significantly above those of the other worker types. Overcrowding decreases as well.

Another modification of interest is the effects of introducing asymmetric firing costs. Several studies have pointed out there are higher firing costs associated with high skilled workers than low skilled workers, whether the high skilled workers are employed in complex or simple jobs (Pfann and Palm, 93). We investigate such a possibility by increasing the relative firing costs associated with high skilled workers when compared to their low skilled counterparts. Once again the results outlined above are reproduced under such a scenario. Even if there are higher firing costs associated with the overeducated, they end up with higher equilibrium  $jdr/jcr$  when compared to other worker types as long as there are firing costs present on the lower educated as well.

In both scenarios, the reason for such results is that firms prefer adjusting through the overeducated. This might seem counterintuitive given that there are higher firing costs on the overeducated, and hence it seems that it would make more sense to adjust through varying the  $jcr/jdr$  of the low skilled workers. However, firing costs reduce the wages that are earned by the overeducated when compared to their low skilled counterparts (equations 184 and 189), which makes them relatively cheaper for the firm as an instrument of adjustment. This is because firing costs have to be paid on workers leaving the firm whether through conscious job destruction or exogenous separation. Since the overeducated have a much higher churning rate, higher firing costs impact upon them considerably more than they influence other types of workers.

### III.5 Robustness and the Hosios Condition

Once again we vary parameter values in order to investigate whether this has any effects on the results. In line with the previous chapter, we vary the distribution of the idiosyncratic productivity  $z$ , matching function elasticity with respect to unemployment ( $1-\xi$ ), the workers bargaining strength in the Nash solution  $\kappa$ , while we also introduce the possibility of different exogenous separation rates for the different categories of workers.

As in the previous chapter, increasing the standard deviation of the distribution of the idiosyncratic productivities causes  $jcr$  and  $jdr$  equilibrium levels to increase and equilibrium unemployment to consequently rise. As expounded previously, utilizing different values for the standard deviation on simple jobs relative to those for the complex sector allows us to vary the equilibrium  $jcr$  and  $jdr$  values for each type of worker, a welcomed flexibility of the model.

Increasing ( $1-\xi$ ) and  $\kappa$  simultaneously to the same levels (to preserve the Hosios condition) causes  $jcr/jdr$  and consequently unemployment levels to increase. Decreasing the relative wage bargaining strength of low skilled workers compared to their overeducated counterparts allows for the equilibrium  $jcr/jdr$  levels for workers in the simple sector (both high and low skilled) to adjust downwards, with a more pronounced effect on the low skilled workers. This is a reasonable assumption since it could be argued that low skilled workers have lower outside employment options, thus weakening their bargaining position when compared to the overeducated.

Increasing vacancy costs leads to a reduction in equilibrium  $jcr/jdr$  levels, while unemployment increases. Increasing the exogenous separation rate for all workers by the same amount has no significant effects on the conclusions of the model, and the same applies to varying the exogenous separation rate of one worker type when compared to the others.

The above discussion shows that our model is flexible in accommodating different assumptions regarding the equilibrium values of labour market flows (whether churning or  $jcr/jdr$ ) for different worker and job categories, a welcomed feature. The most important result, however, is that the main insights of the model do not change for

a wide range of values for these parameters. Job creation for low skilled workers and high skilled workers in complex jobs remain countercyclical and positively correlated with output, while vacancies remain impersistent. NET remains countercyclical for the overeducated and their jcr remains the most volatile.

Once again there is the interesting case of when the values for the matching elasticity with respect to unemployment ( $1-\xi$ ) and the workers wage bargaining strength  $\kappa$  deviate from one another.<sup>41</sup> Jcr becomes procyclical and vacancies are more persistent for low skilled workers and those in complex jobs. However, once again the overeducated here have a countercyclical net and a very volatile jcr.<sup>42</sup>

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<sup>41</sup> As mentioned previously, however, the Hosios condition does not guarantee a social optimum in this model because of the presence of overcrowding.

<sup>42</sup> Sample results for deviations from the Hosios condition are given in the appendix.

### III.6 Conclusion

The main purpose of this chapter is to investigate the cyclical features of the labour market for different categories of job levels and education. We construct a DSGE model based on the Mortensen-Pissarides matching function that incorporates both differences in skills as measured by productivity levels and differences in skill as measured by educational attainment. The main contribution of such an analysis is that it allows for a richer investigation of the business cycle properties of different skill categories, particularly for high skilled workers in simple jobs (the overeducated). Such an analysis has been lacking in previous studies. We also provide a taxonomy that investigates the steady-state and cyclical effects of wage rigidities, firing costs and unemployment income, with the goal of analyzing whether any of these factors can contribute to explaining business cycle properties.

When assessing the cyclical properties of complex jobs and low skilled workers in simple jobs, the model in general reproduces the results expounded upon in the previous chapter.  $Jcr$  was found to be countercyclical and positively correlated with  $jdr$ , while vacancies lacked persistence. However, the perverse results were less marked than those in the model with only one type of worker.  $Jcr$  for the above mentioned workers was less countercyclical and vacancies were more persistent. This indicates that constructing Mortensen Pissarides models disaggregated along educational and job complexity levels can help in explaining some of the anomalies of such models and can provide a better fit of the data.

As in the previous chapter, varying the unemployment income and wage rigidities did not help in remedying the above mentioned problems. Increasing firing costs and the relative difference between the elasticity of substitution in the matching function and the wage bargaining strength of workers helped considerably in addressing these issues.

The most important new insight from the results relate to the overeducated, who experience unique dynamics over the business cycle. Their job creation rates were by far the most volatile, and their net employment change was found to be countercyclical.

Thus overeducated workers take over the jobs of low skilled workers in a recession. These results were robust to different specifications and calibrations of the model.

One of the most important insights that emerge from the study is that although different educational and job complexity levels experience diverging business cycle dynamics, there is a glaring lack of empirical studies on these issues. In particular, data on the cyclical properties of overeducated workers is missing. A richer investigation of empirical trends along these lines would be immensely helpful in furthering knowledge of the labour market experiences during business cycles, as our model predicts that such factors play an extremely important role in cyclical dynamics. We leave this possibility to future research.

### III.7 Appendix for Chapters 2, 3 and 4

#### III.7.1 Deriving the Idiosyncratic Productivity Threshold in Chapter 2

The derivations of the results for the third chapter only are outlined here, since similar techniques for all the chapters are employed.

Rearrange and iterate one period forward equation (106) (the vacancy first order condition) and substitute for  $\lambda_{t+1}$  in equation (104) (the employment first order condition):

$$\lambda_t = BE_t \left[ c_{t+1} G(\zeta_{t+1}) - \frac{\partial W_{t+1}}{\partial n_{t+1}} + \frac{a}{q_{t+1}} \right] \quad (195)$$

Substitute equation (195) into equation (105) (the idiosyncratic productivity threshold first order condition) and iterate one period backwards:

$$\left\{ c_t G(\zeta_t) - \frac{\partial W_t}{\partial n_t} + \frac{a}{q_t} + \Omega \right\} \frac{\partial \tau_t(\zeta_t)}{\partial \zeta_t} n_{t-1} + q_{t-1} v_{t-1} = n_t c_t \frac{\partial G(\zeta_t)}{\partial \zeta_t} - \frac{\partial W_t}{\partial \zeta_t} \quad (196)$$

Iterate the equation for the evolution of employment (92) one period backwards and substitute into (196):

$$\left\{ c_t G(\zeta_t) - \frac{\partial W_t}{\partial n_t} + \frac{a}{q_t} + \Omega \right\} \frac{\partial \tau_t(\zeta_t)}{\partial \zeta_t} \frac{n_t}{(1-\tau_t)} = n_t c_t \frac{\partial G(\zeta_t)}{\partial \zeta_t} - \frac{\partial W_t}{\partial \zeta_t} \quad (197)$$

Now use the following derivatives:

$$\frac{\partial \tau_t(\zeta_t)}{\partial \zeta_t} = (1-\tau^{ex}) f(\zeta_t) \quad (198)$$

$$\frac{\partial G(\zeta_t)}{\partial \zeta_t} = \frac{f(\zeta_t)}{G(\zeta_t)} \frac{(G(\zeta_t) - \zeta_t)}{(1-F(\zeta_t))} \quad (199)$$

$$\frac{\partial W_t}{\partial \zeta_t} = n_t \frac{f(\zeta_t)}{1-F(\zeta_t)} \left[ \int_{\zeta_{it}}^{\infty} w_t(z) \frac{f(z)}{1-F(\zeta_{it})} dz - w_t(\zeta_t) \right] \quad (200)$$

$$\frac{\partial W_t}{\partial n_t} = \int_{\zeta_{it}}^{\infty} w_t(z) \frac{f(z)}{1-F(\zeta_t)} dz \quad (201)$$

And the expression for the endogenous separation rate (100):

$$\tau_t^{en} = F(\zeta_t)$$

To arrive at equation (108):

$$\zeta_t = \left\{ w_t(\zeta_t) - \frac{a}{q_t} - \Omega \right\} c_t^{-1}$$

### III.7.2 Deriving the wage expression in Chapter 2

Once again the derivation of the results for the third chapter only is outlined here, since similar techniques for all the chapters are employed.

Insert the equations for the values of unemployment(112) and employment(111) to the worker and the value of a productive job to the firm (110) into the Nash Bargaining Solution (109):

$$\begin{aligned}
 & w_t + BE_t[(1-\tau_{t+1}) \int J_{t+1} \frac{f(z)}{1-F(\zeta_{t+1})} dz + \tau_{t+1} U_{t+1}] \\
 & - w^\mu - BE_t \left[ \theta_t q_t (1-\tau_{t+1}) \int J_{t+1} \frac{f(z)}{1-F(\zeta_{t+1})} dz + (1-\theta_t q_t (1-\tau_{t+1})) U_{t+1} \right] \\
 & = \frac{\kappa}{1-\kappa} \left\{ c_t G(\zeta_t) - w_t - \Omega \tau_{t+1} + BE_t \left[ (1-\tau_{t+1}) \int V_{t+1} \frac{f(z)}{1-F(\zeta_{t+1})} dz \right] \right\}
 \end{aligned} \tag{202}$$

Use the Nash Bargaining Solution to eliminate  $U_{t+1}$  and  $J_{t+1}$  :

$$\begin{aligned}
 & w_t - w^\mu + (1-\theta_t q_t) \frac{\kappa}{1-\kappa} BE_t \left[ (1-\tau_{t+1}) \int V_{t+1} \frac{f(z)}{1-F(\zeta_{t+1})} dz \right] \\
 & = \frac{\kappa}{1-\kappa} \left\{ c_t G(\zeta_t) - w_t - \Omega \tau_{t+1} + BE_t \left[ (1-\tau_{t+1}) \int V_{t+1} \frac{f(z)}{1-F(\zeta_{t+1})} dz \right] \right\}
 \end{aligned} \tag{203}$$

Now we need an explicit equation for the value of a future job to the firm,  $BE_t \left[ \int V_{t+1} \frac{f(z)}{1-F(\zeta_{t+1})} dz \right]$ . This is simply  $\lambda_t$ , the expected value of a future employee to the firm. This can be verified by comparing equation (104) (the employment first order condition) to equation (110) (the value of a match to a firm in the Nash Bargain). If we rearrange the vacancies first order condition (106) for  $\lambda_t$  and substitute into (203) we arrive at the expression for the average real wage:

$$w_t^{av} = (1-\kappa)w^\mu + \kappa \left[ c_t \int_{\zeta_{it}}^{\infty} z \frac{f(z)}{1-F(\zeta_{it})} dz + \theta_t a - (1-q_t \theta_t) \Omega \tau_{t+1} \right] \tag{204}$$

Consequently, the individual wage (equation (113)) is:

$$w_t^{ind} = (1-\kappa)w^\mu + \kappa c_t z_t + \theta_t a - (1-q_t \theta_t) \Omega \tau_{t+1} \tag{205}$$

### III.7.3 Chapter 4 model Cyclical Results

#### III.7.3.1 Varying Wage Rigidities

**Table 12**

#### Wage Rigidities Properties

**Hall Formulation,  $\chi=0.5$  for all worker types.**

##### High Skilled Workers in Complex Jobs

Hall Formulation, $\chi=0.5$							
Variables	$\sigma^{cr}/jcr$	$\sigma^{dr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) $u^h$	AR(1) $v^h$	
Value	0.34	0.31	0.62	0.69	0.79	0.25	
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr( $u^h, v^h$ )
Value	0.30	0.63	-0.28	-0.55	-0.99	-0.77	-0.20

##### Low Skilled Workers

Hall Formulation, $\chi=0.5$							
Variables	$\sigma^{cr}/jcr$	$\sigma^{dr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) $u^l$	AR(1) $v^l$	
Value	0.47	0.45	0.73	0.75	0.85	0.38	
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr( $u^l, v^l$ )
Value	0.49	0.53	-0.37	-0.48	-0.99	-0.77	0.24

##### High Skilled Workers in Simple Jobs

Hall Setting, $\chi=0.5$							
Variables	$\sigma^{cr}/jcr$	$\sigma^{dr}/jdr$	AR(1) jcr	AR(1) jdr			
Value	1.48	0.21	0.62	0.73			
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(net, Z)
Value	0.67	0.99	-0.73	0.58	-0.99	-0.79	-0.65

H-P Filtered correlation quarterly results for variables of interest. base model  $\chi$  value = 1 (no wage rigidities) for all worker types. All other parameters are unchanged from the base model.

## Hall Formulation, $\chi=0.1$ for all worker types.

### High Skilled Workers in Complex Jobs

Hall Formulation, $\chi=0.1$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) $u^h$	AR(1) $v^h$	
Value	0.41	0.36	0.56	0.68	0.77	0.18	
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr( $u^h, v^h$ )
Value	0.28	0.67	-0.26	-0.53	-0.99	-0.75	-0.22

### Low Skilled Workers

Hall Formulation, $\chi=0.1$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) $u^l$	AR(1) $v^l$	
Value	0.59	0.55	0.68	0.74	0.84	0.35	
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr( $u^l, v^l$ )
Value	0.45	0.58	-0.33	-0.47	-0.98	-0.76	0.20

### High Skilled Workers in Simple Jobs

Hall Setting, $\chi=0.1$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr			
Value	1.71	0.25	0.60	0.70			
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(net, Z)
Value	0.68	0.99	-0.74	0.59	-0.99	-0.80	-0.66

H-P Filtered correlation quarterly results for variables of interest. base model  $\chi$  value = 1 (no wage rigidities) for all worker types. All other parameters are unchanged from the base model.

## Alternative Wage Formulation, $\chi=0.5$ for all worker types.

### High Skilled Workers in Complex Jobs

Alternative Setting, $\chi=0.5$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) $u^h$	AR(1) $v^h$	
Value	0.24	0.16	0.39	0.65	0.72	0.20	
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr( $u^h, v^h$ )
Value	0.00	0.83	-0.07	-0.56	-1.00	-0.61	-0.63

### Low Skilled Workers

Alternative Setting, $\chi=0.5$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) $u^l$	AR(1) $v^l$	
Value	0.25	0.22	0.59	0.69	0.80	0.15	
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr( $u^l, v^l$ )
Value	0.36	0.64	-0.37	-0.49	-1.00	-0.80	-0.20

### High Skilled Workers in Simple Jobs

Alternative Setting, $\chi=0.5$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr			
	1.35	0.16	0.59	0.66			
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(net, Z)
	0.70	1.00	-0.69	0.64	-1.00	-0.75	-0.62

H-P Filtered correlation quarterly results for variables of interest. base model  $\chi$  value = 1 (no wage rigidities) for all worker types. All other parameters are unchanged from the base model.

**Alternative Wage Formulation,  $\chi=0.1$  for all worker types.**

High Skilled Workers in Complex Jobs

Alternative Setting, $\chi=0.1$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) $u^h$	AR(1) $v^h$	
Value	0.69	0.47	0.40	0.63	0.74	0.25	
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr( $u^h, v^h$ )
Value	-0.08	0.84	-0.15	-0.60	-0.94	-0.67	-0.67

Low Skilled Workers

Alternative Setting, $\chi=0.1$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) $u^l$	AR(1) $v^l$	
Value	0.60	0.54	0.58	0.66	0.79	0.14	
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr( $u^l, v^l$ )
Value	0.28	0.65	-0.43	-0.54	-0.95	-0.85	-0.29

High Skilled Workers in Simple Jobs

Alternative Setting, $\chi=0.1$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr			
Value	4.35	0.29	0.58	0.67			
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(net, Z)
Value	0.63	1.00	-0.52	0.58	-0.99	-0.57	-0.48

H-P Filtered correlation quarterly results for variables of interest. base model  $\chi$  value = 1 (no wage rigidities) for all worker types. All other parameters are unchanged from the base model.

### III.7.3.2 Varying the Unemployment Income

**Table 13**

#### Varying the Unemployment Income

$w^u = 0.64$

#### High Skilled Workers in Complex Jobs

w <sup>u</sup> = 0.64 equilibrium values: urate <sup>h</sup> = 0.072 jcr,jdr <sup>h</sup> : 0.025							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) u <sup>h</sup>	AR(1) v <sup>h</sup>	
Value	0.20	0.18	0.64	0.71	0.80	0.31	
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(u <sup>h</sup> ,v <sup>h</sup> )
Value	0.24	0.66	-0.19	-0.57	-1.00	-0.73	-0.40

#### Low Skilled Workers

w <sup>u</sup> = 0.64 equilibrium values: urate <sup>h</sup> = 0.167 jcr,jdr <sup>l</sup> : 0.077							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) u <sup>l</sup>	AR(1) v <sup>l</sup>	
Value	0.21	0.20	0.69	0.73	0.85	0.26	
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(u <sup>l</sup> ,v <sup>l</sup> )
Value	0.24	0.58	-0.34	-0.50	-0.99	-0.78	-0.01

#### High Skilled Workers in Simple Jobs

w <sup>u</sup> = 0.64 equilibrium values: jcr,jdr <sup>h</sup> = 0.060 n <sup>h</sup> /n <sup>l</sup> = 0.076							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr			
Value	0.93	0.15	0.63	0.72			
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(net, Z)
Value	0.67	0.99	-0.72	0.57	-0.99	-0.79	-0.62

H-P Filtered correlation quarterly results for variables of interest. base model w<sup>u</sup> value = 0.54. All other parameters are unchanged from the base model.

$w^u = 0.84$

### High Skilled Workers in Complex Jobs

w <sup>u</sup> = 0.84 equilibrium values: urate <sup>h</sup> = 0.185 jcr,jdr <sup>h</sup> : 0.092							
<b>Variables</b>	$\sigma^{cr}/jcr$	$\sigma^{dr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) u <sup>h</sup>	AR(1) v <sup>h</sup>	
Value	0.19	0.17	0.62	0.72	0.82	0.30	
<b>Variables</b>	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(u <sup>h</sup> ,v <sup>h</sup> )
Value	0.14	0.69	-0.15	-0.62	-0.99	-0.74	-0.34

### Low Skilled Workers

w <sup>u</sup> = 0.84 equilibrium values: urate <sup>l</sup> = 0.451 jcr,jdr <sup>l</sup> : 0.246							
<b>Variables</b>	$\sigma^{cr}/jcr$	$\sigma^{dr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) u <sup>l</sup>	AR(1) v <sup>l</sup>	
Value	0.16	0.13	0.61	0.72	0.87	0.27	
<b>Variables</b>	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(u <sup>l</sup> ,v <sup>l</sup> )
Value	0.21	0.72	-0.07	-0.53	-0.99	-0.62	-0.41

### High Skilled Workers in Simple Jobs

w <sup>u</sup> = 0.84 equilibrium values: jcr,jdr <sup>h</sup> = 0.135 n <sup>h</sup> /n <sup>l</sup> = 0.259							
<b>Variables</b>	$\sigma^{cr}/jcr$	$\sigma^{dr}/jdr$	AR(1) jcr	AR(1) jdr			
Value	0.43	0.12	0.60	0.72			
<b>Variables</b>	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(net, Z)
Value	0.69	0.97	-0.73	0.48	-0.99	-0.83	-0.53

H-P Filtered correlation quarterly results for variables of interest. base model w<sup>u</sup> value = 0.54. All other parameters are unchanged from the base model.

### III.7.3.3 Varying Firing Costs

**Table 14**

#### Varying Firing Costs

$\Omega = 0.2$  for all worker types

High Skilled Workers in Complex Jobs

$\Omega^h = 0.2$ equilibrium values: $urate^h = 0.044$ $jcr, jdr^h: 0.004$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) $u^h$	AR(1) $v^h$	
	0.30	0.13	0.35	0.72	0.80	0.46	
Variables	Corr(jdr, jcr)	Corr(jcr, net)	Corr(jcr, Z)	Corr(jdr, net)	Corr(jdr, Z)	Corr(jt, Z)	Corr( $u^h, v^h$ )
	-0.24	0.95	0.29	-0.54	-1.00	-0.09	-0.83

Low Skilled Workers

$\Omega^l = 0.2$ equilibrium values: $urate^l = 0.069$ $jcr, jdr^l: 0.006$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) $u^l$	AR(1) $v^l$	
	0.37	0.20	0.47	0.73	0.86	0.43	
Variables	Corr(jdr, jcr)	Corr(jcr, net)	Corr(jcr, Z)	Corr(jdr, net)	Corr(jdr, Z)	Corr(jt, Z)	Corr( $u^l, v^l$ )
	-0.06	0.88	0.14	-0.53	-0.99	-0.37	-0.66

High Skilled Workers in Simple Jobs

$\Omega^h = 0.2$ equilibrium values: $jcr, jdr^h = 0.029$ $n^h/n^l = 0.032$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr			
	1.04	0.13	0.70	0.73			
Variables	Corr(jdr, jcr)	Corr(jcr, net)	Corr(jcr, Z)	Corr(jdr, net)	Corr(jdr, Z)	Corr(jt, Z)	Corr(net, Z)
	0.73	1.00	-0.77	0.66	-0.99	-0.82	-0.71

H-P Filtered correlation quarterly results for variables of interest. base model  $\Omega$  value = 0 for all worker types. All other parameters are unchanged from the base model.

$\Omega = 0.4$  for high skilled workers (in complex and simple jobs),  $\Omega = 0.2$  for low skilled workers

#### High Skilled Workers in Complex Jobs

$\Omega^h = 0.4$ equilibrium values: $urate^h = 0.042$ $jcr, jdr^h: 0.001$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) $u^h$	AR(1) $v^h$	
Value	0.86	0.09	0.29	0.73	0.79	0.52	
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr( $u^h, v^h$ )
Value	-0.47	1.00	0.53	-0.54	1.00	0.46	-0.90

#### Low Skilled Workers

$\Omega^l = 0.2$ equilibrium values: $urate^l = 0.074$ $jcr, jdr^l: 0.003$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) $u^l$	AR(1) $v^l$	
Value	0.66	0.21	0.41	0.74	0.86	0.47	
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr( $u^l, v^l$ )
Value	-0.27	0.96	0.35	-0.51	-0.99	0.04	-0.68

#### High Skilled Workers in Simple Jobs

$\Omega^h = 0.4$ equilibrium values: $jcr, jdr^h = 0.023$ $n^h/n^l = 0.026$							
Variables	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr			
Value	1.11	0.11	0.74	0.72			
Variables	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(net, Z)
Value	0.71	1.00	-0.76	0.66	-0.99	-0.80	-0.71

H-P Filtered correlation quarterly results for variables of interest. base model  $\Omega$  value = 0 for all worker types. All other parameters are unchanged from the base model.

### III.7.3.4 Deviation from the Hosios Condition

**Table 15 Deviating from the Hosios Condition**

**(1-ξ) = 0.2, κ = 0.7 for all worker types**

High Skilled Workers in Complex Jobs

(1-ξ) = 0.2    κ = 0.7    equilibrium values:    u = 0.074    jcr,jdr: 0.014							
<b>Variables</b>	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) $u^h$	AR(1) $v^h$	
Value	0.24	0.06	0.56	0.70	0.88	0.53	
<b>Variables</b>	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr( $u^h, v^h$ )
Value	-0.51	0.95	0.54	-0.75	-1.00	0.08	-0.47

Low Skilled Workers

(1-ξ) = 0.2    κ = 0.7    equilibrium values:    u = 0.166    jcr,jdr: 0.049							
<b>Variables</b>	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr	AR(1) $u^l$	AR(1) $v^l$	
Value	0.20	0.13	0.62	0.68	0.91	0.45	
<b>Variables</b>	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr( $u^l, v^l$ )
Value	-0.23	0.84	0.27	-0.72	-1.00	-0.45	-0.25

High Skilled Workers in Simple Jobs

(1-ξ) = 0.2    κ = 0.7    equilibrium values: $n^h/n^l = 0.119$ jcr,jdr:0.053							
<b>Variables</b>	$\sigma^{jcr}/jcr$	$\sigma^{jdr}/jdr$	AR(1) jcr	AR(1) jdr			
Value	0.58	0.12	0.37	0.30			
<b>Variables</b>	Corr(jdr, jcr)	Corr(jcr,net)	Corr(jcr, Z)	Corr(jdr,net)	Corr(jdr,Z)	Corr(jt, Z)	Corr(net, Z)
Value	0.95	0.96	-0.33	0.81	-0.19	-0.29	-0.43

H-P Filtered correlation quarterly results for variables of interest. base model κ, (1-ξ) values = 0.6 for all worker types. All other parameters are unchanged from the base model.

## **IV. A CGE Model: Analyzing Fuel Subsidies and Unemployment in Iran**

In the next chapter the analysis switches from DSGE models to Computable General Equilibrium (CGE) models. Although both approaches are based on Neo-classical Walrasian equilibrium, the setup and purposes of each differ in direction. DSGE models tend to focus on business cycle dynamics of a specific field of interest (in our case the labour market), and in terms of the overall model are much less detailed than CGE models. Because the general setup is quite simplified, this permits for more attention to the modeling of the sector of interest. As we witnessed, the DSGE models allowed us to incorporate vacancies, job destruction, and job creation rates that address both high skilled and low skilled labour and the interaction between them.

CGE models, as we shall illustrate below, employ a much more detailed analysis of the general formulation of the economy. There is considerable disaggregation across economic sectors, and this disaggregation is fitted to correspondingly disaggregated economic data. The analysis is usually geared more towards the effects of specific policy proposals in an economy and to long run changes rather than short run fluctuations. As a consequence, however, this means that CGE models frequently do not go into the same modeling depth in regards to the sector of interest (the labour market) as DSGE models. Modelling concepts such as market tightness, job destruction and job creation rates are not included within a CGE model. This is because such data is typically not available at the disaggregated levels required for CGE models, and since the analysis usually focuses on long run effects rather than short term business cycle dynamics. Indeed, as will be evident, although the labour market is considerably more disaggregated data-wise, we will employ a simpler modeling framework for the labour market in this chapter.

This chapter constructs a specific CGE model that addresses the relationship between fuel subsidies and the labour market in the Islamic Republic of Iran. Iran has one of the highest fuel subsidies in the world coupled with a significant unemployment problem. Removing these subsidies can be one potential reform that could help alleviate the high unemployment rates prevalent in the labour market. The complexity and policy

relevance of the issue creates an ideal scenario in which to apply a CGE modeling approach. We develop a CGE model with particular foci on the factors of production, fuels and the oil industry. This is coupled with a unique data set of the Iranian economy, allowing us to investigate the effects of removing these subsidies on employment within a static and dynamic setting.

## IV.1 Introduction

One of the major challenges facing the Islamic Republic of Iran's economy is the enduring problem of high unemployment. Indeed the leadership of the republic has identified unemployment as its greatest worry.<sup>43</sup> Jobless rates reached an official figure of 12% in 2006 (International Monetary Fund, 2007a), with unofficial estimates indicating much higher values. This problem can potentially grow in severity given the huge anticipated increase in the labour supply. Spurred by the significant population growth experienced in the 1980s, annual growth in the labour force reached a high of 5% in 2003, with the increase estimated to continue at an annual rate of 2.5-3.0% over the next ten years (World Bank, 2003). The post-revolution "baby-boomers" are reaching working age and are entering the labour force in growing numbers. According to United Nations estimates (2007), 64.8% of the population in 2005 was of working age (15-64 years old) and 28.8% fell into the 0-14 age category.

Furthermore, even though the population growth rate has dramatically decreased over the past ten years (falling from a high of 4.2% in 1985 to 1.0% in 2005)<sup>44</sup>, entry levels into the labour force are forecast to continue to rise due to the increasing participation of women in the job market. Given these factors, the World Bank (2003) forecasts Iran to require an annual real GDP growth of 6.5% simply to maintain unemployment at the 2003 levels of 16%, while GDP growths of 10% and a rise in Savings and Investment to the magnitude of 10% of GDP are needed to bring unemployment levels down to a more acceptable level of 10%. Such high jobless and labour force entry rates could be harbingers of serious economic and social instability. The obvious internal social problems that accompany unemployment are magnified by the large numbers of high skilled workers leaving the country in search of employment that match their pay and job expectations, a leakage of resources aptly dubbed 'the brain drain'.

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<sup>43</sup> Speech by President Khatami quoted in Iranmania.com citing AFP, September 23, 2002. Quoted in The World Bank (2003).

<sup>44</sup> United Nations (2007).

The World Bank's (2003) comprehensive report on the Iranian economy has identified targeting the high subsidy rates on crude oil and petroleum commodities as one of the most important potential reforms that could help alleviate the problem of unemployment. Crude oil is sold in the domestic market at artificially low prices to produce refined fuels. Indeed, while 42% of crude oil output is consumed locally (with the rest being exported), only 10% of total crude oil revenue comes from local sales.<sup>45</sup> Since crude oil is primarily used locally as an intermediate input in the production of fuel goods, this in turn leads to fuel goods being sold at extremely low prices domestically when compared to international prices (the border price of gasoline, for example, was 2.8 higher in 2001/2002 than local prices). The demand for cheap fuel is so high that Iran needs to import and subsidize a considerable amount of its gasoline (around 45% of the total) because its refining capacities are inadequate to meet total demand. Crude oil and energy subsidies were estimated to be 10% of total GDP (70 trillion Rials) in 2001/2002, the highest in the world in absolute and relative terms.

In general, there are four objectives that this study aims to investigate in relation to the removal of crude oil and fuel subsidies in Iran. First and foremost is to examine the impact on the labour market, where it is hoped that new opportunities for job seekers will be created. Closely linked are the effects on GDP and consumer welfare, where the aim is to generate a substantial increase in total output growth and the welfare of households. Finally, it is hoped that local consumption of crude oil and fuels could be reduced substantially. The aim of this study is to shed light on all of these angles. Being one of the main highlights of this study, there will be particular focus on the effects on the labour market.

There are several ways in which the removal of crude oil and fuel subsidies could potentially impact the economy generally and the labour market specifically:

1. Local prices of fuel would increase dramatically with the removal of crude oil (a major ingredient in the production of fuels) and fuel imports' subsidies. The ramifications of this are complex: On the consumption side, the amount of income spent by households per unit of fuel would rise, potentially causing a decrease in the purchasing power of

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<sup>45</sup> All data in this section, unless otherwise specified, are taken from World Bank (2003).

households and putting a damp on total domestic consumption (an income effect), which in turn could feed to a reduction in employment. However, the amount of fuel consumed by households- which is arguably highly distorted given the current very low prices- could decrease substantially (substitution effect). Indeed, there could be a substitution effect away from fuel towards other goods, thus alleviating pressures on fuel production and boosting demand for the alternative commodities and workers employed in their production.

2. Fuels are an important intermediate input in several industries' production structure. Possible effects include:
  - a. The increasing cost of fuel inputs could make production in fuel-intensive industries (e.g. transportation or the chemical industries) increasingly prohibitive cost-wise (income effect).
  - b. The increase in fuel costs, however, could cause these industries to innovate and become more fuel efficient. Indeed, current production is probably extremely skewed towards fuel inputs, and the higher fuel costs could force these industries to employ to a greater extent new fuel-saving technologies.
  - c. Higher fuel costs could lead to a shift away from fuel use towards other factors of production. This could switch demand away from fuels towards increased utilization of labour, thus boosting employment (substitution effect).
3. The removal of the subsidies would free up a substantial amount of government revenue. Firstly, crude oil would be sold at its border price locally, hence alleviating domestic subsidies. In addition, the increase in local crude oil prices could also potentially decrease the demand for crude oil locally, thus freeing up more crude for exports at border prices, further filling up the government coffers (Iran's total production of crude oil is constrained by OPEC requirements and production capabilities, but although total production is relatively fixed the overall amount could be relocated between domestic use and exports). This increase in government revenue could potentially be used to generate extra savings

and investment in the economy, a proposal championed by the World Bank (2003). Alternatively it could be returned to households in the form of rebates or tax cuts.

- a. If the extra revenue is to be channeled into increased savings and investment, this could provide a boost to the local economy and increase GDP. Indeed the subsidies' total of 10% of GDP would conveniently provide the extra amount of savings and investment the World Bank forecasts to be needed to bring unemployment down to a 10% level. The World Bank (2003) recommends that this extra investment be channeled towards the private sector to achieve the double goal of diversifying the economy from the crude oil and the public sectors. The boost in Investment, GDP and the diversification away from the public and fuel intensive sectors could potentially create an increasing number of jobs, particularly in the private sector, thus going a long way towards solving the unemployment problem.
  - b. Alternatively, returning the extra revenue to households through tax cuts and rebates could substantially increase domestic consumption in the economy. This in turn could provide a boost to GDP and the increase in demand could create extra nationwide jobs. However, the supply response would be critical, as this has to be balanced against the possibility that most of this increased consumption is concentrated on imports, thus failing to create growth in local industries.
4. The potential increase in crude oil exports could create a significant appreciation of the exchange rate, causing a classic Dutch Disease case, where local industries end up being less competitive with those abroad. Thus there could be an expenditure switching effect towards foreign goods. Coupled with the price increase in intermediate fuel inputs, this could lead to a double blow to local industries and their labour force, causing them to contract.

5. Finally, the potential increase in GDP growth, *ceteris paribus*, would imply a rise in total demand for fuel in the economy.

Although interrelated, the effects of these factors could evidently move in different directions, with the effect on labour markets, GDP, consumer welfare and the level of fuel consumption being *a priori* ambiguous. Furthermore, an improvement in one of these objectives does not necessarily mean progress in the others. For example, rebating the increased government revenue to consumers could potentially increase their welfare and GDP, but it could potentially hurt local industries and employment through higher fuel input prices and the Dutch Disease effect. On the other hand, channeling the revenue into extra investment could boost GDP and employment while leaving consumers less well off due to the rise in fuel prices. Even if an overall increase in employment is witnessed, this improvement could be unevenly spread, with unskilled workers possibly gaining while higher skilled workers lose out (or vice versa).

Indeed, the distortions present in the economy due to the crude oil and fuel subsidies are vast and multifaceted, with the current conditions prevalent in the economy being potentially far away from the equilibrium that would attain if the subsidies were removed. This study attempts to analyze each of the above effects and objectives, breaking down and highlighting specific issues wherever possible.

The most viable option for analyzing such a complex problem is a computable general equilibrium (CGE) modelling approach. A small open economy model will be constructed to meet the requirements of the analysis both in a static and a recursive dynamic setting. A Social Accounting Matrix (SAM) detailing economic activity within the Iranian economy is constructed and fitted to the model. Within this framework the effects of removing the crude oil and fuel subsidies are highlighted. The two alternative scenarios for potential policy measures are for subsidies to be channeled towards increased savings and investment, or alternatively the subsidies can be given back to households as rebates and tax cuts.

This chapter advances previous studies of fuel commodities and the labour market in Iran in several respects. It is to our knowledge the first CGE study that explicitly focuses on the effects of fuel and crude oil subsidies on the labour market in Iran. A unique SAM of the Iranian economy for the year 2001 is constructed. The SAM

includes data on several types of labour and fuel commodities, features which allow for a more detailed assessment of the conditions and interactions between the labour market and fuel goods in the economy. The model developed is specifically catered to take account of these features. Factors of production and fuel inputs in production receive particular attention in the analysis. Due to their importance, the energy and crude oil industries have their own unique production structure. An oil fund is also included in both the SAM and the model for the redistribution of extra oil revenues. We also employ a dynamic CGE setting in order to gauge the intertemporal and transitional effects of the policy simulations, a feature which could be important in assessing the Investment effects of the removal of the subsidies.

The only previously existing CGE study on the effects of crude oil and fuel subsidies removal in Iran that we are aware of is Jensen and Tarr (2003), who examine the welfare effects of removing fuel subsidies in Iran within a static CGE model. The authors investigate the effects of redistributing the extra revenues from the removal of the subsidies back to households, reaching the conclusion that there are significant welfare gains for households from such a scheme. Their analysis however lacks several of the main features presented in this chapter. Their study does not look at the effects of such subsidies on the labour market, with the SAM having only one labour type used in production as well as a less detailed fuel commodities disaggregation. The SAM also employs less updated data, with the Input-Output table based on 1995 figures. The possibility of directing the subsidies windfall to Investment as a policy option is not considered, and no distinction between commodities and activities that produce these commodities is made, unlike in the present chapter. Finally, the study is set within a static model only, neglecting possible dynamic issues from the removal of such subsidies.

## IV.2 The Social Accounting Matrix

Social Accounting Matrices (SAMs) have been at the heart of any CGE analysis since the groundbreaking work of Sir Richard Stone in the 1960s. At the general level, a SAM is an economic accounting system that records all transactions and transfers between agents in an economy within a specified time period, usually of a particular year. It takes the shape of a square balanced matrix, where all agents receive income and pay expenses and where all payments exhaust receipts. In essence, it provides a very detailed account of the circular flow of income. The interactions between different institutions (including households, enterprises, government institutions, production agents and the foreign account) are explicitly spelled out within a framework that incorporates factor markets, production, consumption, saving, investment and transfers between the different institutions.<sup>46</sup>

SAMs are typically constructed as an amalgamation of Input-Output (IO) tables and data on the households and other institutions. Pioneered by the work of Nobel laureate Wassily Leontief, Input-Output analysis focuses on the production side of the economy. They typically show the inputs used by specific industries to produce their output, the commodities produced by these industries, as well as the allocation of the final goods produced by these industries to different economic agents.<sup>47</sup> What distinguishes SAMs from IO tables is the former's additional focus on household data and transfers between different economic institutions, hence explaining the 'social' component in Social Accounting Matrices. Households' receipts and expenditures are combined with data on intra- and inter- institutional transfers (e.g. between different household groups or between households and other institutions such as the government) to give a clearer picture of economic activity on the institutional front.

A sufficiently detailed and representative SAM is crucial to any CGE analysis of the economy. Hence, this study develops a unique Social Accounting Matrix based on 2001 data that has been specifically constructed for its purposes.<sup>48</sup> Iranian Input-Output tables for the year 2001 combined with a previously existing SAM by Banouei (2007)

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<sup>46</sup> For a detailed discussion of SAMs, see Round (2003).

<sup>47</sup> For more on Input-Output tables, see Horowitz and Planting (2006).

<sup>48</sup> More detailed specifics on the construction and data sources of the SAM are given in the appendix, where the SAM in its entirety can also be found.

are used to generate a SAM that specifically caters to the focus of this study. The diagram below depicts a general outline of the SAM employed, with each shaded cell entry depicting payments from the column entities to the row entities. Alternatively, one can view the cell entries as income received by the row entities from the column entities, with the receipts for each entity exhausting payments. Thus row totals equal column totals. In what follows we give a detailed account of the different transactions occurring within the SAM.

	Production	Commodities	Transaction Costs	Factors of Production	Taxes and Subsidies	Institutions	Savings/ Investment	Rest of the World	Total
Production									
Commodities									
Transaction Costs									
Factors of Production									
Taxes and Subsidies									
Institutions									
Savings/ Investment									
Rest of the World									
Total									

## Commodities and Activities Sectors

Production activities receive their income (activities' rows) from the commodities they produce, while they allocate their purchases (columns) between intermediate commodity inputs, factors of production (value-added) and taxes due on activities. Commodities, on the other hand, receive income from institutions consuming commodities (particularly households and the government) as well as Investment payments to Investment commodities. Two specific commodities, transportation and retail services, also receive income from the transactions accounts (margins). The commodities in turn allocate their expenditure to the activities that produce them, transaction costs, the rest of the world as payment for imports, as well as commodity taxes paid to the government.<sup>49</sup>

<sup>49</sup> For a more extensive elucidation for the different payments and income transactions in a SAM, see Lofgren et al (2002).

The SAM we develop has 29 commodities' sectors (2 agricultural, 6 manufacturing, 1 crude oil, 9 energy and 11 services) and 22 activities sectors (2 agricultural, 8 manufacturing, 1 crude oil, 2 energy and 9 services). Given the important role energy plays in the study, the energy commodities sector has been disaggregated quite significantly and is composed of the 'fuels' sectors, the electricity sector, and the utility gas sector. The 'fuels' sectors have been further decomposed into seven sectors: Motor Spirit (gasoline), burning oil (kerosene), fuel oil, gas oil, liquefied gas, other fuel and finally 'lubricants, coke and petroleum oil'. The activities sector is not as detailed due to data limitations, with only two energy production sectors present (the fuel production sector and the electricity, utility gas and water production sector).

## **Factors of Production**

We distinguish 7 primary factor input categories, with labour disaggregated along 4 sectors according to occupation. Labour sub-groups are composed of unskilled labour, skilled labour, agricultural mixed income labour and non-agricultural mixed income labour. Unskilled labour corresponds to major group 9 (Elementary occupations) in the International Standard Classification of Occupations (ISCO-88), with skilled labour comprising the other groups (0, 1-8).<sup>50</sup> Mixed-income refers to individuals in self-employment, or more specifically employment in enterprises owned by households that are not corporations.<sup>51</sup> Given that the labour market is one of the main foci of the study, this disaggregation allows us to assess unemployment and wages implications for several different categories of labour. The remaining primary factors are agricultural land, capital and the natural resource factor of crude oil and natural gas (which for brevity's sake will be referred to as crude oil).

All factors of production receive their income from the activities sectors they are utilized in. This income is then allocated to payment to taxes, households, enterprises, the foreign account and the government sectors that own the factors of production.

One particular factor, crude oil, deserves a more detailed analysis. Since the behavior of the crude oil sector plays a crucial role in the analysis of the economy, it

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<sup>50</sup> For more information on (ISCO-88), see International Labour Office (1994).

<sup>51</sup> For more information on mixed income see Commission for European Communities et al (1993), Paragraph VII.E.7.81.

was important to treat this natural resource separately and not lump it with capital as one primary factor. Any rent payment (profit) from the oil sector beyond the payment to fixed capital and labour can be identified as rent accruing to this natural resource, with the income of this rent going directly to the government or the oil fund set up by the government (which will be discussed in detail below). This seems like a natural formulation given that the crude oil sector is nationally owned and the revenues of the Iranian National Oil company are the only ones reported in the state budget, unlike other state owned enterprises (which have their own distinct SAM entry, expanded on below). Hence the government is the residual claimant to all rent accrued to the sector after the other factors of production have been paid off.

## **Institutions and Other Accounts**

The institution account includes households, enterprises, the government and the oil fund. Households are comprised of two blocks, the rural and the urban households. Households receive their income from the primary factors of production and transfers from other institutions (including the government). They allocate their expenditure to government income taxes, consumption of commodities (calculated at purchaser prices), transfers to other institutions and savings.

The enterprises account is subdivided into government and privately owned enterprises. They receive their income from factors of production and government transfers, and their payments go to household transfers as well as savings. The government account has a similar setup except that it also allocates expenditure to commodities consumed, while it also receives income from the tax accounts. Tax accounts are subdivided into income tax, import tariffs and subsidies, production tariffs and subsidies, as well commodities taxes and subsidies.

An important institution in the model is the Oil Fund. This institution has been set up by the Iranian government to receive parts of the extra income that might accrue due to changes in the crude oil market (due to e.g. increased world prices). This study tries to mimic this setup as closely as possible. In our SAM, the oil fund receives its income from the crude oil factor of production and allocates its payment between savings and transfers to households. This fund will play an important role in the simulations as any

extra revenue from changes in the crude oil sector could potentially be poured in this fund and then redistributed back to the households.<sup>52</sup>

Finally, the SAM includes a Savings-Investment account and the rest of the world (foreign) account. The Rest of the World account receives income from its exports to the domestic economy (domestic imports), factors of production payments heading abroad and transfers from institutions. Its expenditure goes on imports (local exports), factors of production payment from abroad to domestic owners, transfers to other institutions, as well as its savings in the local economy. The Savings-Investment account's receipts arise from the savings of household, government, enterprises, the oil fund and the foreign account. Its expenditure is allocated to Investment goods in the economy.

## **Crude Oil and Fuel Subsidies**

The most important entry in the tax accounts, and indeed the whole SAM, is the subsidy on the crude oil commodity sold locally within the Iranian economy. This subsidy is implicitly present in the original sources and nowhere calculated explicitly. The reason for this is that crude oil commodities accounts are calculated using different prices locally and when sold abroad. The original sources simply input the payments to the crude oil commodities sector using domestic (subsidized) prices when sold locally and international prices when sold abroad, and the amount of the local crude oil subsidy is overlooked. Indeed Iranian National Statistics generally employ a similar procedure in their accounts, where the subsidy is not accounted for and its exact amount is not calculated. Hence this subsidy had to be made explicit in order to carry out the analysis.<sup>53</sup> Once this is done the enormity of the subsidy becomes apparent, with the crude oil subsidy making up roughly 9% of GDP, and the local price being one sixth of that at the border. Another important subsidy is that placed on imported petroleum goods. As mentioned previously, Iran imports a substantial amount of its petroleum consumption (around 45%), and so these imports have to be subsidized to be sold at local prices (where border prices are 2.8 times those at home).

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<sup>52</sup> Further analysis of the oil fund will be given in the simulation section.

<sup>53</sup> Details of how the subsidy was calculated are given in the appendix.

### IV.3 The Static model

Taken alone, the SAM is simply a system of accounting identities presenting flows of accounts between the different agents in the economy. It stands silent on the nature of the economic relationships that tie the different data inputs together to form an equilibrium. Indeed a SAM on its own is unable to forecast how changes in economic policies or conditions would shift the interactions between the different agents and the equilibrium attained. To achieve this objective a computable general equilibrium (CGE) model detailing relationships that define the economic equilibrium has to be constructed and fitted to the data.

In essence, CGE models present a system of equations that define an economic-theoretic equilibrium, typically of the Arrow-Debreu Walrasian type. The models are then combined with real world data (SAMs) in order to simulate the possible effects of different economic and policy scenarios on the economy. The models themselves can be extremely diverse in nature, with some models opting to remain purely Walrasian in nature (the so called ‘fundamentalist school’), while others incorporate Keynesian short run and monetary effects within the framework.<sup>54</sup> The models’ level of details also vary in form depending on the scenarios analyzed, with CGE models being applied to issues as diverse as global and regional trade (e.g. Francois et al’s analysis of the Uruguay Round Agreements, 1996) to environmental regulation (e.g. Weyant’s analysis of the Kyoto protocol, 1999).

The model employed in this chapter is neo-classical in nature and is based on the theory of a Walrasian general equilibrium within a small open economy. In this section the model is static: there is only one equilibrium showing the final effects of policy implementations on the economy with no inter-temporal dynamics. Particular features include an explicit treatment of transaction costs for imports, exports and domestically produced commodities that enter the market sphere. There is also separation between production activities and commodities produced, with each activity able to produce multiple commodities and the possibility that a particular commodity can be produced by several activities. Hence the act of producing the goods (activities) and the goods

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<sup>54</sup> See Robinson (2005) for an overview of the different types and forms of CGE models.

themselves (commodities) are separated. The model takes its starting point from the Standard CGE model developed at the International Food Policy Research Institute (IFPRI) by Lofgren et al (2002)<sup>55</sup>, considered the benchmark model in the current literature. The model is then extensively modified to take account of the specific features of this study. Of particular importance are the oil industry structure, the energy industries structure and the role that energy and factor inputs play in production.<sup>56</sup> .

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<sup>55</sup> This section only mentions in passing the standard features that are already present in the IFPRI standard CGE model. For a more detailed analysis of those features please see Lofgren et al (2002).

<sup>56</sup> The full static model equations are presented in GAMS code in the appendix.

## **IV.3.1 Production (Activities)**

### **IV.3.1.1 Non-Oil, Non-Energy Production Sectors**

The analysis given takes a bottom-up approach, where we begin describing the structure at the bottom of the production nest and subsequently move up. The inputs in production are broadly divided into three categories: factors of production (value-added), intermediate commodity inputs and energy inputs. Each category is further subdivided into its own unique setup and interacts with the other categories in a specialized manner. In what follows we give a detailed account.

#### **Intermediate Inputs**

The aggregate intermediate input is composed of the individual intermediate goods via a Leontief production structure, where the ratios of intermediate inputs per unit of output are fixed (section A in figure 1). This is a widely employed formulation based on the available empirical evidence<sup>57</sup>, which indicates that there is very low substitutability between the different inputs in production. Either domestic or imported goods could be used in each of the individual intermediate commodities. We model this through a CES aggregation function (usually referred to as an Armington function when applied specifically to the imperfect substitution between imports and domestic goods).

#### **Value Added (Primary Factors of Production)**

The aggregate value added input is made up of the individual factors of production, which in the current model are divided into capital, skilled labour, unskilled labour, agricultural (mixed-income) land, agricultural labour mixed-income, and non-agricultural labour mixed income (section B in figure 1). We assume that there is imperfect substitutability between the factors of production modeled through a Constant Elasticity of Substitution (CES) function. This is intended to capture the substitution effect between the different factors (e.g. between unskilled labour and capital) when policy changes are introduced in the model.

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<sup>57</sup> See, for example, de Melo and Tarr (1992).

## **Energy Inputs**

The aggregate energy input is composed of nine individual energy goods: electricity, utility gas and the seven ‘fuel’ commodities of Motor Spirit (gasoline), burning oil (kerosene), Fuel oil, gas oil, liquefied gas, other fuels and finally ‘lubricants, coke and petroleum oil’. As in the value added sector, there is constant elasticity of substitution between the different energy inputs to capture the potential substitution between them when there is an increase in fuel prices (section C in figure 1). Each individual energy commodity could either be bought locally or abroad, with domestic goods and imports being imperfectly substitutable through an Armington function similar to that employed in the intermediate inputs section.

## **Composite Production Function (Top of Production Nest)**

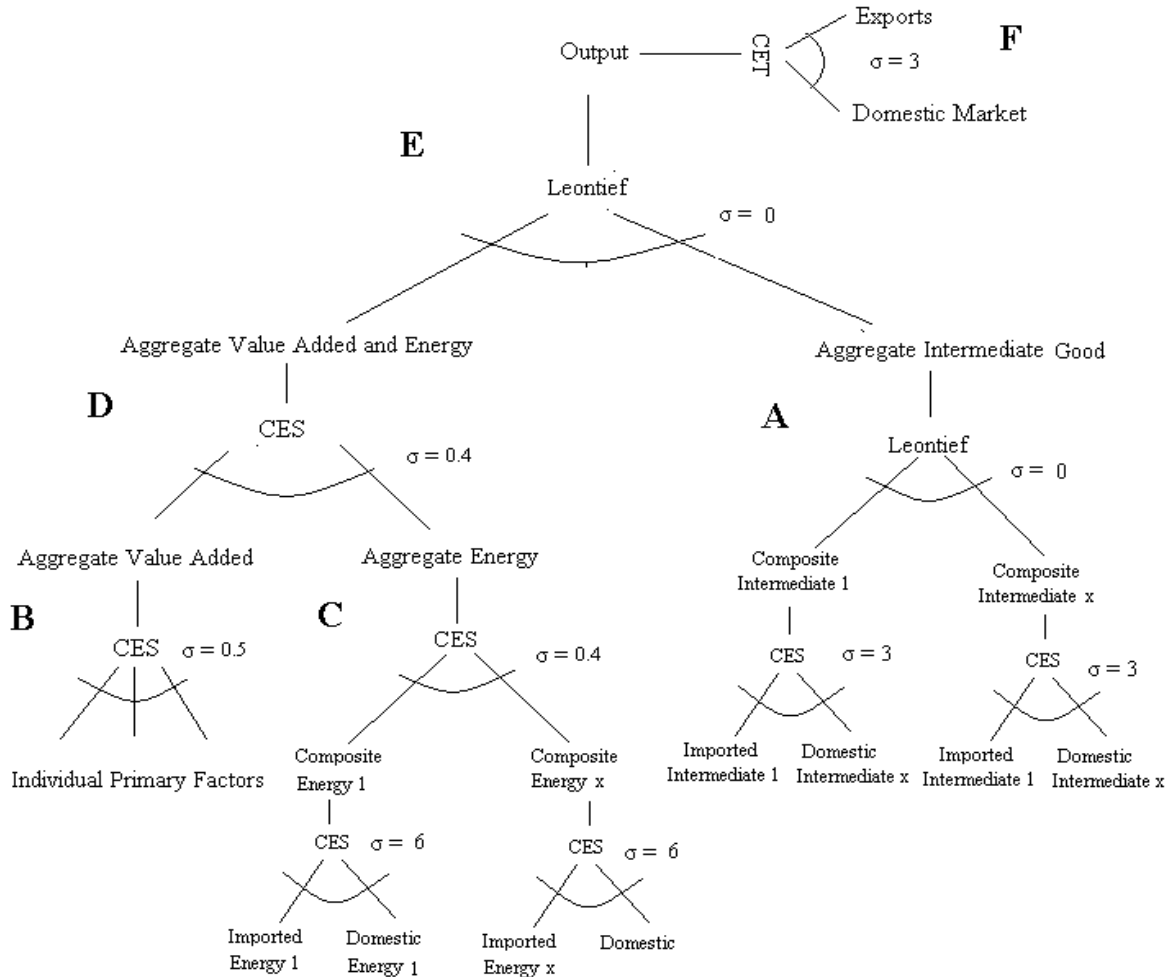
We now turn to the interaction between the three broad input categories of aggregate value added, aggregate energy inputs and other intermediate inputs. There are two aggregation levels: Firstly, at the lower level, there is imperfect substitution between aggregate value added and the aggregate energy input, modeled through constant elasticity of substitution (section D in figure 1). This feature is important to capture the long term substitution effects between factors of production and energy inputs. One possible critical consequence of the increase in crude oil and fuel prices is a shift away from the reliance on energy towards increased utilization of primary factors of production. Production would become more ‘energy-efficient’. If there is a strong enough shift from the reliance on energy to value added factors then there could be a potential increase in the employment of labour. The current setup is the most appropriate to account for this effect.<sup>58</sup>

At the top of the production nest, the above resulting aggregate amount of fuel and value added have a Leontief fixed coefficient function with respect to the aggregate intermediate input (section E in figure 1). Hence the aggregate amount of fuel and value added enter in fixed proportions when compared with the aggregate intermediate

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<sup>58</sup> For a paper that utilizes a similar construction for the substitution between energy goods and value-added, see Faehn et al (2004).

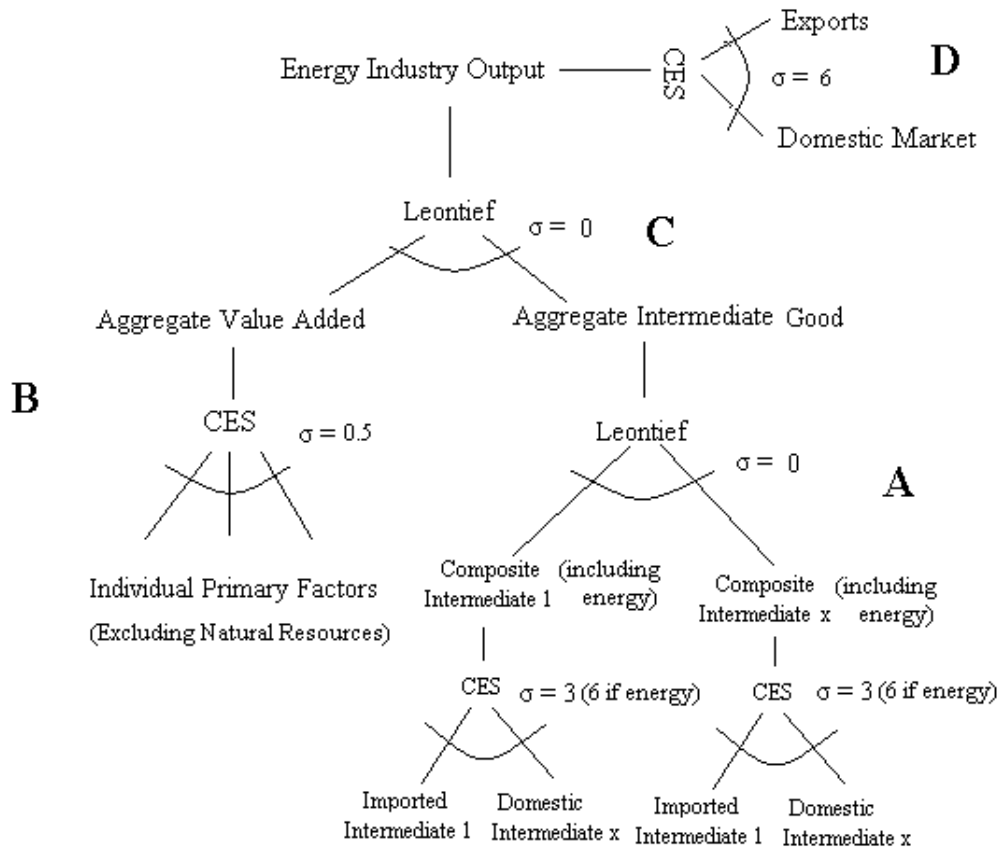
input. Finally, the resulting output could be potentially sold in domestic or foreign markets (section F in figure 1). The standard methodology for representing the choice between domestic and foreign markets for local producers is through a Constant Elasticity of Transformation function, where there is imperfect substitutability between sales in the two markets. Figure 1 gives a detailed diagrammatic explanation of the production structure.



### **IV.3.1.2 The Fuels Sector**

The main difference between the fuel sector and the structure described above is the lack of substitutability of energy goods in production. Neither are individual energy goods substitutable between each other, nor is the aggregate energy input substitutable with aggregate value added. In fact, individual energy goods are treated just like any other individual intermediate input. They enter into the Leontief structure defining the aggregate intermediate good just like any other individual intermediate commodity (section A in figure 2). This is intended to capture that there is roughly a fixed physical relationship between the commodity inputs into production. For example, a certain amount of crude oil is required to produce a certain amount of gasoline. A Leontief setup also shapes the way that the aggregate intermediate good (which includes energy goods) interacts with the aggregate Value added good at the top of the production function nest, implying no substitutability between the two (section C in figure 2).

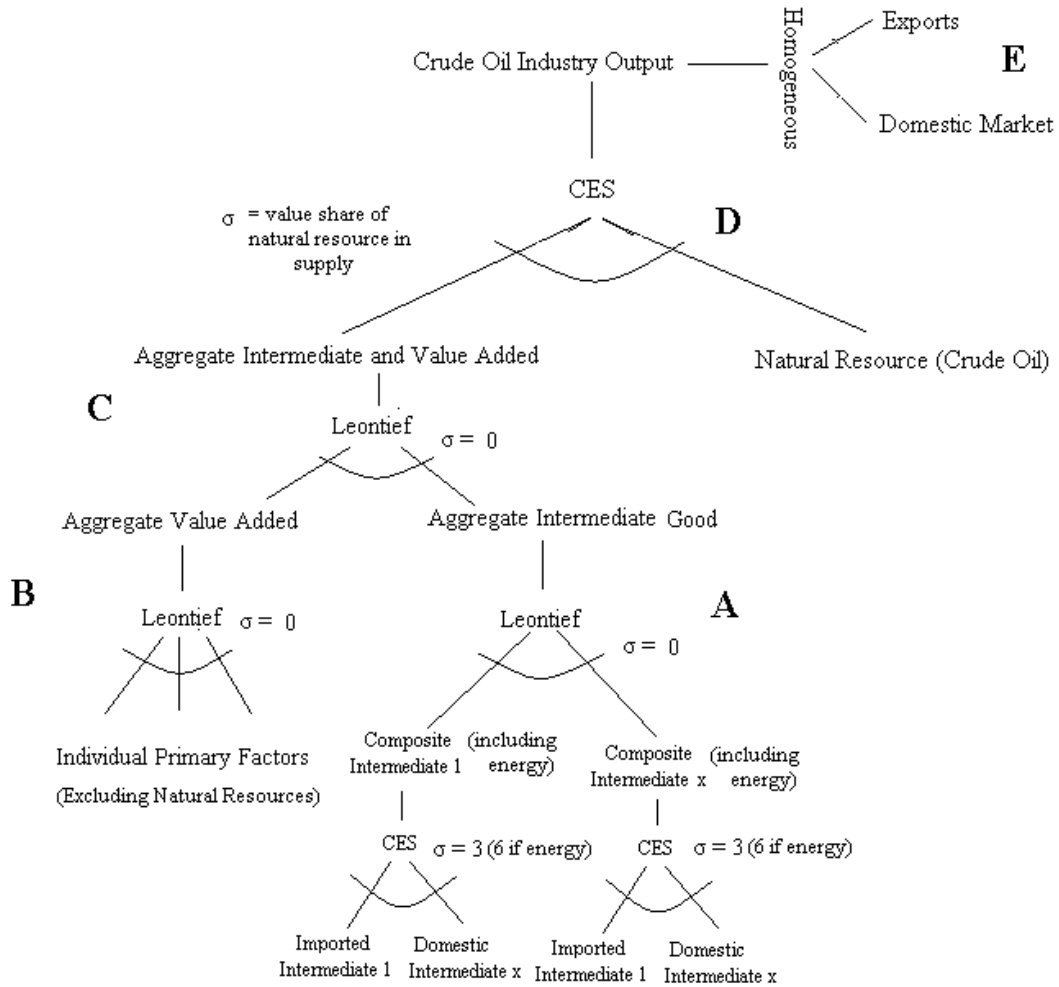
There is imperfect substitution between the individual factors of production at the bottom of the aggregate value-added technology nest (section B in figure 2), just like in the previous non-fuel production section. Also similar to the previous formulation is the presence of imperfect substitutability between local and imported goods in each of the individual intermediate inputs through Armington Elasticities. For the producers, a constant elasticity of transformation characterizes the choice of selling to exports versus to the local markets (section D in figure 2). The production structure, similar to that employed in Jensen and Tarr (2003), is given in Figure 2.



### IV.3.1.3 The Crude Oil Production Sector

The third of the major production sectors, the crude oil sector, has its own unique production structure, mainly due to the presence of the primary factor of natural resources (crude oil). Like in the energy production sectors, energy goods are treated like any other intermediate good and have a Leontief formulation within the aggregate intermediate good (section A in figure 3). Primary factors with the exclusion of the crude oil natural resource make up aggregate (non-crude) value-added, with the difference from the previous setups being that there is no substitution between the individual primary factors (Leontief structure; section B in figure 3). This non-crude aggregate value-added then combines with the aggregate intermediate good via a Leontief setup to create a new aggregate nest which amalgamates both intermediate goods and value added (section C in figure 3). Finally, there is imperfect substitutability between the natural resource (crude oil) and the aggregate nest which combines both intermediate goods and value added, with the elasticity of substitution depending on the

value share of the natural resource in the crude oil supply (section D). Figure 3 gives a diagrammatic depiction of the oil sector, which is similar to that used in Rutherford and Paltsev (2000). One further crucial difference between the crude oil sector and other sectors is that the good produced is homogenous, with exports or domestic sales being perfectly substitutable from the viewpoint of the crude oil producer (Section E). Imports and local commodities continue to be imperfectly substitutable in the individual intermediate inputs through Armington functions.



### **IV.3.2 Other Economic Agents**

Household consumption is allocated to commodities according to a Linear Expenditure Demand System (LES), which is derived from the maximization of a Stone-Geary utility function. This utility function is a generalization of the Cobb-Douglas form, and thus is additive but not homothetic. Minimum consumption is allowed for, and although it yields linear Engel curves they do not have to go through the origin. As in the case of intermediate inputs in the production section, there is also imperfect substitutability between imports and domestic goods consumed through an Armington function.

Government consumption on the other hand is assumed to be constant in quantities and composition, while levies imposed by the government take the form of ad valorem tax rates. The country is assumed to be a small open economy, and hence it is a price taker on the world market with no terms of trade influences. Investment takes the form of expenditure on Investment commodities, with total savings of institutions equaling total expenditure on Investment goods.

## IV.4 Elasticities

Given the functional forms we have assumed, we require data on the elasticities in the model to proceed with the analysis. The elasticities used have been collected from several sources in order to reflect the best available empirical evidence on the Iranian economy. The main studies employed are: 1. Ahangarani (1999) who estimated a system of demand functions for Iran; 2. Hope and Singh (1995), who estimated a set of energy elasticities for several developing countries; 3. Jensen and Tarr (2003), who conducted a previous study on the modelling of the fuel sector in Iran in a CGE model setting; and 4. The World Bank (2003), a comprehensive study on the effects of fuel subsidies on the Iranian economy.

These studies suggest central estimates of 1 for expenditure elasticities of most goods. Some essential household goods, (mainly energy commodities, food, water, and housing) are reported to have an expenditure elasticity of less than 1. We choose 0.5 for these goods, in line with The World Bank (2003). The Frisch parameter, which measures the elasticity of the marginal utility of income with respect to income, is set at -1.

Most studies estimate energy demand elasticities in production between -0.2 and -0.7 (e.g. Hope and Singh, 1995). We choose an intermediate value of -0.4 for the elasticity of substitution between the different energy intermediate inputs and for the elasticity of substitution between the aggregate intermediate energy good and aggregate value added. Data on the elasticity of substitution between the different factors of production is unavailable. We set the elasticity of the substitution at a default rate of 0.5, based on data from Bautista et al (1999).

For the remaining elasticities, we use estimates employed in similar analyses, such as de Melo and Tarr (1992) Rutherford, Rutström, and Tarr (1997), and Jensen and Tarr (2003). The output aggregation elasticity (which governs the rate of substitution between different activities that produce the same commodity) is set at six. A value of three is employed for the Armington elasticity of substitution between domestic and foreign varieties in demand for both final and intermediate goods. For energy products,

which are relatively homogeneous, a value of six is chosen. Crude oil is considered to be a completely homogenous commodity with perfect substitutability between exports and domestic sales.

The elasticities, particularly the elasticity of substitution between the different factors of production and between the aggregate value added and the aggregate energy input could potentially play a very crucial role in determining the results of the simulation. Hence we run the simulations for different possible values of the elasticities under consideration, where we highlight significant differences in the qualitative results.

## **IV.5 Closures and Different Alternatives**

Just as the SAM imposes accounting balance on the data, CGE models require certain assumptions regarding the closure rules for the model to balance as well. In what follows we discuss the closure rules employed in the labour market and the macroeconomic balances: the government account, the rest of the world, and the Savings-Investment Account.

### **IV.5.1 Factor Markets**

Two ways are used to close the labour market and to assess the effects of the removal of the fuel subsidies. In the first option, the quantity supplied of each labour type is fixed while the wage paid to each labour sector is allowed to freely move. There is full employment of each factor and fully flexible wages. In this scenario, the change in wages serve as an indication of changes in the demand for labour and hence unemployment. If the wage for labour increases, this indicates that there is a higher demand for labour and hence that unemployment is reduced.

In the alternative scenario, wage levels are fixed and the quantity employed of each labour factor is allowed to vary to equilibrate the labour markets. Hence the labour supply curves are infinitely elastic (horizontal line). Unemployed labour is explicitly allowed for here. An argument can be made for the use of either labour market closures. It could be argued, for example, that there is a large amount of slack in the Iranian economy (with unemployment exceeding 16% in 2003). This could favour keeping wages constant and letting the quantities employed of each factor vary, since such a high rate of unemployment implies that high pressures on wages do not exist. As Devarajan and de Melo (1987) point out, however, assessing changes in factor wages (i.e. keeping supplies fixed) could provide a more reliable indicator of changes in labour demand, since the results are not as sensitive to the numeraire used in the model. Hence in what follows the main results will be reported using both closures.

Indeed, if both scenarios point towards the same direction (e.g. decreased wages and decreased quantities employed) then a definite conclusion can be reached on the situation in the labour market in our model (in our example a deterioration). This is because these two closures act as boundaries, with a fixed wage implying an infinite wage elasticity of labour supply, while a fixed quantity of labour implies zero wage elasticity of labour supply. Any other modeling form of an upward sloping labour supply curve will have to assume an intermediate form between the two closures employed here. Hence if the two closures point towards the same direction, then a definite deduction regarding the effects on the labour market in our model can be reached.

Turning to other factors, capital is assumed to be fully employed and mobile between sectors, with the rental rate (wage) on capital varying in order to equilibrate the market. Land used in agriculture is assumed to be fully employed and activity specific (fixed). Crude oil is confined to one sector (the crude oil industry), with the amount of the factor used being fixed (which seems reasonable given that the output of crude oil is fixed). Looking at each factor individually, the return to each unit of the factor, regardless of the industry of employment, receives the economy wide average return. Although it would have been ideal to detail specific returns to factors in each industry, such information is unavailable for the Iranian economy.

#### **IV.5.2 The Government Account**

The government account can be closed by assuming that either government savings or tax rates are flexible with the other being fixed. If government savings are fixed, the difference between current government revenues and expenditure stays constant while institutional tax rates adjust accordingly. If the tax rates are fixed, government savings are allowed to change while tax rates remain constant.

### IV.5.3 External Balance and Savings-Investment

There are two alternative closures for the external balance. One possibility is to keep the current account balance fixed while the real exchange rate moves in order to equilibrate the current account at its previous level. The other option is to fix the real exchange rate while allowing the current account to fluctuate

Generally it is preferable to use the first option, since fixing the real exchange rate and allowing foreign savings to fluctuate can give misleading welfare results. An increase in foreign savings in the model, with all else being equal, translates into either increased investment or reduced taxes on households (depending on which scenario we are simulating). This is misleading because it neglects the costs of an increase in foreign debt in the economy. Conversely, a decrease in foreign savings, *ceteris paribus*, translates to either decreased investment or increased taxes on households, which gives the misleading implication that overall welfare has been reduced. Hence our simulations focus on results with a flexible real exchange rate and fixed foreign savings.<sup>59</sup>

Turning to the Savings-Investment closure, the model allows for savings to be investment driven, where the base-year savings rates of selected non-government institutions are adjusted to keep investment fixed. Alternatively, investment can be allowed to vary while savings are held constant, with the base-year amount of investment commodities changed by equal percentage points. An important issue should be mentioned here. The modeling of Investment changes in a static model is by nature incomplete. There is no intertemporal aspect to Investment, and the effects of Investment on future accumulation of capital are neglected. Hence the effects of the change in the stock of capital are completely absent in a static model. This severely limits the usefulness of modeling investment in a static setting and provides a big incentive for adopting a dynamic modeling framework. Although the variable Investment closure in a static model is of limited use, results will still be presented to provide a useful comparison to the dynamic model.

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<sup>59</sup> The numeraire used in our simulations is the consumer price index (cpi). If the real exchange rate was to be fixed, the alternative numeraire of the producer price index for domestically marketed output (dpi) would have to be used.

Finally a convention has to be chosen for the assignment of prices versus quantities in the model, as the SAM entries represent expenditures/receipts values and does not distinguish explicitly between quantities versus prices. The model adopts the usual methodology of assigning base prices at unity with the corresponding SAM entries reflecting quantity amounts (e.g. Lofgren et al, 2002). Export commodities' prices, domestic supply of commodities' prices, activities' prices, the wages of the factors of production and the exchange rate are set at unity, with the remaining prices and the quantities set relative to the base prices chosen.

## IV.6 Static Simulations

The main thrust of the simulation is to analyze the effects on the economy of removing the huge crude oil and fuel subsidies.<sup>60</sup> Tackling this problem requires two steps. Firstly, the rate of the subsidy on crude oil is assumed to drop down to zero. Furthermore, the subsidy rates on imports of fuels are also driven down to zero, with fuels having to sell at their border prices (after factoring in transportation costs). This is important since one of the main implications of the removal of the crude oil subsidies is that prices of locally produced fuels will rise, and hence a similar adjustment is needed in the imports market. One important point that should be mentioned is that in all simulations the level of overall crude oil production in the economy is held fixed. Iran is constrained by OPEC requirements (which apply to overall production levels and not export levels) and by limited oil production capabilities, with current crude oil production levels at their maximum potential. While overall crude oil output is fixed, the proportion of crude that can be exported versus consumed locally can vary depending on changes from the simulation.

Since the government no longer has to pay the massive crude oil and fuel subsidies under the simulations (which total approximately 68 trillion Rials in our SAM, or roughly 10% of GDP), the important question then centers around the manner in which this extra government revenue is to be utilized in the economy. We consider two alternative policy scenarios. The first option is for all revenue collected by the government to be redistributed back to households in the form of income tax reductions and/or institutional transfers. The tax rates on both rural and urban households are reduced by similar percentage points and transfers to each household from the oil fund also increase in similar proportions.<sup>61</sup> Hence the increased revenue from the removal of the subsidy is first channeled towards households through a tax rate reduction. If tax rates reach zero and the revenue of the subsidy is still not fully exhausted, then the leftover revenue is channeled to the oil fund, which then redistributes it as handouts to

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<sup>60</sup> The model is simulated using the General Algebraic Modeling System (GAMS) software. For further information see Brooke et al (1988).

<sup>61</sup> The model has to use both institutional transfers and reductions in tax rates. This setup is necessary because the subsidy amounts are so huge that tax rates could potentially drop all the way down to zero and still a considerable amount of the subsidy revenues will be left over. Institutional transfers from the oil fund to households are used to account for the rest of the subsidy.

urban and rural households, with the size of the handout being proportional to the (income) size of the household in question. In terms of the previously discussed closures, this amounts to fixed government savings and variable tax rates in the government closure and fixed investments and variable savings in the Savings – Investment Closure. These closures can be interpreted as the increased government revenue from the removal of the oil subsidy being channeled to consumers (households) as a rebate.

The alternative policy measure is for the generated revenue to be spent on Investment. In this case, the base amount of Investment commodities (which in the Iranian economy are overwhelmingly composed of construction and industry commodities) are increased by equal percentage points. In terms of the previously discussed closures, this translates to fixed tax rates and variable government savings in the government account closure, while there is variable overall Investment coupled with fixed overall savings in the Savings-Investment closure. In this manner all the increase in government savings are translated into extra investment. The reasoning for employing such a closure is outlined in the World Bank (2003), whose central recommendation is that Iran increase its Investment by about 10% of GDP, particularly specifying that this extra savings and Investment should come from the removal of its crude oil and fuel sectors subsidies (which roughly amount to the same value of 10% of GDP). As mentioned previously, however, a variable Investment closure is of limited use in a static model.<sup>62</sup> Results will still be presented to provide a useful contrast to the dynamic model.

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<sup>62</sup> See section IV.5.3.

## IV.7 Static Results

### IV.7.1 Base Simulation

The analysis begins by outlining a brief description of the data from the base (default) simulation, where all subsidies are kept unchanged.<sup>63</sup> According to our SAM and model, Iran's GDP at market prices stood at 741 trillion Rials in 2001, with exports and imports registering at 21% and 17% of GDP respectively (measured at spending). Private Consumption, Government Consumption, and Investment registered at 54%, 14%, and 21% of GDP respectively. The crude oil and natural gas sector makes up 15% of GDP and 66% of exports. Other notable industries contributing to GDP include farming (8% of Value Added), Construction (5%), Real Estate (12%), Communication and Transportation (7%), and wholesale and retail trade (14%). In terms of exports, the main contributing commodities other than crude oil are textiles, food, and tobacco (10% of exports), Industry excluding metal and equipment (8%), and agriculture, farming and forestry (4%).

The most labour-intensive industries are construction (expenditure on labour makes up 74% of value added), education (87%), public services and social security (62%), healthcare (52%), and financial intermediaries (51%). Most of unskilled labour's receipts come from the construction sector (52% of total unskilled labour receipts), followed by the public services sector (16%). Skilled labour receives most of its total income from the public services sector (19%), the education sector (17%), healthcare (7%), and industries (8%). Total income for non-agricultural mixed labour comes mostly from wholesale and retail trade (31%), communication and transportation (18%) and construction (12%).

Household income stands at 66% of GDP, with 72% of the income accruing to urban households and the rest going to rural households. The marginal propensity to save is 13% for urban households and 8% for the rural. Households expend 1.5% of their income on fuels, and this expenditure makes up 2% of total household expenditure on consumption goods. Industries spend 2% of their gross revenue (which totals 160%

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<sup>63</sup> The results are reported in the section below.

of GDP) on fuel, and their total expenditure on fuel makes up 3% of industries' total expenditure on intermediate inputs. The least fuel efficient industries are communications and transportation (in our model setup, 1 unit of output requires 0.06 units of fuel commodities as intermediate input in this sector), chemicals and plastics (6%), minerals (3%), fuels (1%) and mining (1%).<sup>64</sup> It should be kept in mind that fuel expenditures by households and industries are calculated at the extremely subsidized fuel prices, and so expenditure on fuel should increase considerably if the true costs of fuel are paid.

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<sup>64</sup> The percentages for fuel intensity are not reflective of actual conditions prevailing in the industries, due to the convention adopted of base prices being set to unity and the corresponding SAM entries reflecting quantities (see the closures section). However, they are very important in reflecting changes in intensity of fuel use in industries after the removal of subsidies in the simulations, as this reflects how industries adapt to the higher fuel prices by increasing their fuel efficiency in production.

## IV.7.2 Varying Tax Rates

The results of the policy changes are evaluated using the aforementioned criteria of GDP, consumer welfare, fuel consumption, and -above all- the effects on the labour market, where most of the discussion will be focused. On the first three criteria, redistributing the extra government revenue as tax cuts and household rebates scores quite well. Real GDP experiences an increase, household welfare as measured by Equivalent variation (EV) rises, while the total consumption of fuel commodities in the economy decreases significantly. Industries become more fuel efficient in their production while consumers also reduce their fuel consumption.

**Table 16**  
**Base Model and Policy Simulation Aggregate Results**

	Change from Base				
	base	tax flexq	tax flexw	SI flexq	SI flexw
Real exchange Rate	1.0	-12.6	-12.4	-10.0	-9.5
Private Consumption	3973.7	2.9	6.9	-6.1	-5.1
Investment	2062.1			20.4	23.6
EXPORTS	1577.3	12.1	13.1	13.9	14.8
IMPORTS -	1249.8	15.3	16.5	17.6	18.7
Real GDP	7410.7	1.6	3.7	2.4	3.8
Income Tax rates on urban households	7.8	-100.0	-100.0	0.0	0.0
Income Tax rates on rural households	7.1	-100.0	-100.0	0.0	0.0
transfer to urban household	0.0	7.2*	19.4*	0.0	0.0
transfer to rural household	0.0	2.8*	7.6*	0.0	0.0
Skilled Labour wage			-9.9		-7.2
Unskilled Labour wage			-8.9		19.0
Agricultural Mixed Income Labour wage			-5.4		-14.9
Non-agricultural Mixed Income Labour Wage			-8.5		-3.3
Skilled Labour Quantity Employed		-6.9		-5.3	
Unskilled Labour Quantity Employed		-3.5		6.6	
Agricultural Mixed Income Labour Quantity Employed		-5.7		-8.9	
Non-agricultural Mixed Income Labour Quantity employed		-6.5		-3.7	
Total Fuel Use		-30.7	-29.5	-31.1	-30.5
Household Fuel Consumption		-33.4	-32.5	-35.9	-35.8
Equivalent Variation		88.9	246.9	-265.4	-228.2

Results for policy simulations are shown as percentage deviation from the base model. Items marked with a star \* show absolute values. 'taxflexq' refers to the closure with flexible taxes and flexible quantities of labour supplied. 'taxflexw' refers to the closure with flexible taxes and flexible wages for labour. 'SIflexq' refers to the closure with flexible Investment and flexible quantities of labour supplied. 'SIflexw' refers to the closure with flexible Investment and flexible wages for labour.

On the most important criterion, reducing taxes does quite poorly. The labour market, whether measured by flexible wages or quantities employed, is affected adversely. When quantities supplied of labour are held fixed, the wages received by all labour types decrease substantially (Table 16). When labour wages are held fixed, the quantities supplied of all labour factors experience a noticeable decline as well. To understand the dynamics behind this one needs to take a closer look at the different effects within the economy.

Firstly, it is important to notice the effects of removing the subsidies on the prices of crude oil and fuel commodities ( $P$  in Table 17 Base Model and Flexible Taxes Policy Simulations (Commodities Results)). Crude oil prices increase by around 500%, reflecting that crude oil was being sold at one sixth of its international price. All of the fuel products which are dependent on crude oil for their production experience a significant price increase as well, with their producers passing on the costs of the higher crude oil.

The income tax rates on rural and urban households drop sharply due to the redistribution of the windfall from the subsidies removal. In fact, income tax rates on both households drop to zero (they are completely abolished), and there is still some extra government income left over that is redistributed to households as rebates. Consequently, total household consumption in the economy increases due to the rise in households' purchasing power. Household consumption of all goods increase with the exception of fuel products ( $C_{households}$  in Table 17 Base Model and Flexible Taxes Policy Simulations (Commodities Results)), with the drop in their consumption explained by their higher prices. This overall increase in consumption explains the increase in the EV welfare of the households.

**Table 17 Base Model and Flexible Taxes Policy Simulations (Commodities Results)**

	Base economy						tax flex q						tax flex w					
	P	Q <sub>localind</sub>	X	M	S <sub>localecon</sub>	C <sub>households</sub>	P	Q <sub>localind</sub>	X	M	S <sub>localecon</sub>	C <sub>households</sub>	P	Q <sub>localind</sub>	X	M	S <sub>localecon</sub>	C <sub>households</sub>
agriculture, farming, and forestry	1.3	762.4	50.8	83.7	795.2	293.5	-8.7	0.2	-16.8	10.9	2.3	6.4	-7.6	1.6	-19.0	17.6	4.5	9.5
husbandry, poultry and fishery	1.2	473.7	5.8	0.9	468.9	99.4	-7.2	-2.5	-21.5	13.9	-2.2	1.4	-5.9	-0.2	-22.5	21.0	0.1	3.5
crude oil and natural gas	0.2	1797.9	1032.8		765.0		479.2	0.0	35.8		-48.3		480.9	0.0	35.4			-47.8
mining	1.9	48.2	6.1	7.6	49.7	0.2	-4.8	-14.6	-50.8	12.5	-6.6	0.1	-5.3	-10.8	-45.5	15.5	-3.0	4.6
electricity	1.0	177.2	0.8	0.6	176.9	54.2	12.3	-11.0	-80.4	306.0	-9.9	-8.1	12.8	-8.7	-80.0	319.9	-7.6	-6.4
utility gas	1.0	65.2	8.0	0.6	57.8	30.4	-2.0	-11.2	-53.1	89.9	-4.8	-0.2	-2.1	-8.9	-50.7	89.3	-2.5	2.4
water	1.0	43.0		84.5	43.0	25.7	35.2	-11.2		18.4	-11.2	-16.3	31.8	-8.9		23.3	-8.9	-13.7
food, tobacco and textiles	1.4	1265.1	106.1		1243.5	896.0	-6.7	-1.2	-25.3		2.1	3.8	-6.7	3.2	-20.9		6.5	8.4
industry excluding metal and equipment	1.4	879.0	92.9	340.8	1126.9	250.2	-6.7	-12.0	-36.4	14.8	-2.2	4.4	-6.9	-9.2	-33.1	17.0	0.4	9.3
lubricant and coke	1.1	42.8	12.1	5.2	35.9	5.2	11.6	-54.7	-93.3	185.9	-12.4	-7.5	11.4	-54.2	-93.0	198.8	-10.4	-5.4
motor spirit	1.1	65.9		16.8	82.7	45.9	158.2	-51.9		29.7	-36.5	-36.0	159.3	-51.6		34.0	-35.5	-35.2
burning oil	1.7	7.7			7.7	6.0	1240.0	-54.7			-54.7	-51.1	1175.7	-54.2			-54.2	-50.8
gas oil	1.7	18.4			18.4	1.1	584.9	-54.7			-54.7	-48.5	610.2	-54.2			-54.2	-48.5
fuel oil	1.2	39.8	21.7		18.1	0.1	20.7	-54.7	-92.2		-16.5	-12.0	24.8	-54.2	-93.5		-14.6	-12.1
liquid gas	1.1	36.4	27.0		9.4	3.0	-8.6	-25.9	-32.7		-7.1	2.6	-7.8	-27.1	-34.4		-6.6	4.2
other fuels	1.9	1.3			1.3	0.0	526.1	-54.7			-54.7	-49.5	533.8	-54.2			-54.2	-49.2
metal products and equipment	1.2	765.9	21.6	581.0	1325.3	190.9	-8.9	-7.6	-28.3	8.7	-0.2	7.3	-9.6	-4.3	-20.9	7.7	1.2	13.1
construction	1.0	824.6			824.6	11.2	-4.6	-0.1			-0.1	0.8	-7.3	0.1			0.1	8.5
wholesale and retail trade	1.0	1236.7		2.2	1238.9	1.0	-8.0	-3.1		13.1	-3.1	6.2	-8.7	-0.2		12.8	-0.2	12.1
repairs and household sales	1.0	126.0			126.0	52.3	-4.2	-3.7			-3.7	1.7	-2.2	-0.7			-0.7	4.0
hotels and restaurants	1.0	147.7	13.4	27.8	162.1	141.3	-9.1	2.0	-10.7	19.3	5.9	7.7	-8.6	5.6	-8.4	24.9	10.0	11.9
transportation and storage	1.0	709.0	6.5	84.9	787.5	140.5	0.2	-9.4	-43.2	45.3	-3.7	-4.2	-1.3	-5.5	-36.9	42.4	-0.4	1.9
communication	1.0	91.1			91.1	66.4	8.0	-9.2			-9.2	-11.6	7.7	-5.2			-5.2	-7.1
financial intermediaries	1.0	178.4	34.5		143.9	6.3	-4.5	-9.5	-27.7		-5.4	1.7	-8.5	-4.1	-13.8		-1.8	11.7
insurance	1.0	21.8	15.3	10.6	17.1	7.4	-11.6	-9.5	-12.2	6.1	2.4	11.3	-11.5	-4.1	-6.4	9.4	6.2	16.3
real estate	1.0	855.9			855.9	790.9	-9.0	3.5			3.5	4.2	-7.0	4.7			4.7	5.3
business services	1.0	198.7	0.0	0.4	199.1	24.8	-28.5	2.9	87.7	-43.6	2.8	40.1	-26.0	4.2	72.8	-37.2	4.1	40.7
public services and social security	1.0	582.8			582.8	14.0	-4.9	0.0			0.0	1.5	-8.7	0.2			0.2	10.9
other social services	1.0	701.6	8.8	3.4	696.3	187.3	-2.9	-0.9	-27.7	36.7	-0.4	-0.4	-8.0	2.5	-11.5	19.0	2.7	10.6

Results for policy simulations are shown as percentage deviation from the base model. *P* refers to prices, *X* refers to exports, and *M* refers to imports. *Q<sub>localind</sub>* refers to national output of the sector (including exports), *S<sub>localecon</sub>* refers to local sales (including imports but excluding exports), while *C<sub>households</sub>* refers to total consumption of households of the particular commodity (both locally produced and imports).

Another intriguing result is the marked rise in both aggregate real imports and exports. This is coupled with the real exchange rate experiencing a significant appreciation, giving a preliminary clue to the reason for the adverse effect on the labour market.

Although overall exports increase, the exports of all goods (*X* in Table 17 Base Model and Flexible Taxes Policy Simulations (Commodities Results)), experience a decline with the exception of crude oil, which increase substantially. Indeed the crude oil makes up all the increase in exports, with all the others contracting. A classic Dutch Disease Case is witnessed. In the imports sector (*M* in Table 17 Base Model and Flexible Taxes Policy Simulations (Commodities Results)), all commodities witness a substantial rise in imports.

Production wise (Table 18 Base Model and Flexible Taxes Policy Simulations (Activities Results), all industries where substitution of fuel inputs is allowed for in the production structure become more fuel efficient, with the amount of fuel input required in production (fuel intensity) decreasing by 15-30%. Indeed this increased fuel efficiency coupled with households' reduction in fuel consumption leads to overall petroleum and fuel use in the economy to drop significantly, a welcomed effect.

As alluded to previously, an increase in fuel costs causes firms to substitute expensive fuel with other factors of production. As the prices of fuel rise, firms should employ less energy-intensive capital and rely more on less energy-consuming factors of production such as labour and low energy-utilizing capital. Overall, this substitution away from fuel inputs to other factors of production tends to increase the wages/quantities employed of workers.

Unfortunately for employment, the adverse shocks experienced by the industries dominate this positive effect on labour employed. Industries experience the double shock of the Dutch disease effect and the increase in the cost of fuel inputs. The rise in the exports of crude oil makes the exchange rate appreciate, leading to a loss of competitiveness by local producers. This loss of competitiveness is further exasperated by the increased cost of fuel inputs. All non-oil exports experience a decline. Moreover, the increased consumption of local households does not translate to increased sales for local producers, as consumers focus most of their purchases on the relatively cheaper imports (expenditure switching effect). Indeed, disregarding crude oil, the only commodities that benefit from increased local consumption and do not experience a decline in National production ( $Q_{localind}$  in Table 17 Base Model and Flexible Taxes Policy Simulations (Commodities Results), are agriculture, food, real estate, business services and hotels and restaurants, all non-fuel intensive industries. All the other commodities experience a decline in their total national output.

**Table 18 Base Model and Flexible Taxes Policy Simulations (Activities Results)**

	Base						tax FLEX Q						TAX FLEXW					
	q <sub>a</sub>	d <sub>sk</sub>	d <sub>un</sub>	D <sub>miagl</sub>	D <sub>minagl</sub>	Fuel Efficiency	q <sub>a</sub>	d <sub>sk</sub>	d <sub>un</sub>	D <sub>miagl</sub>	D <sub>minagl</sub>	Fuel Efficiency	q <sub>a</sub>	d <sub>sk</sub>	d <sub>un</sub>	D <sub>miagl</sub>	D <sub>minagl</sub>	Fuel Efficiency
farming, forestry and horticulture	764.7	15.9	1.1	50.1		0.6	0.2	-5.3	-5.3	-5.3		-36.4	1.6	2.6	2.0	0.11		-35.9
husbandry poultry and fishery	544.8	25.0	1.7	31.4		0.5	-2.5	-6.4	-6.4	-6.4		-27.5	-0.2	2.3	1.7	-0.18		-26.9
crude oil and natural gas	1797.9	18.7	2.0		0.8	0.0	-1.2	-5.7	-5.7	-5.7		-4.5	-1.6	-7.4	-7.4		-7.4	-5.9
Mining	50.0	8.0	1.1		0.8	1.3	-14.6	-16.7	-16.7	-16.7		-36.0	-10.8	-8.3	-8.8		-9.0	-36.3
food, beverages, tobacco	768.6	32.1	1.1		13.3	0.3	1.1	-2.9	-2.9	-2.9		-27.0	2.5	4.0	3.5		3.3	-27.3
textile, clothing and leather	420.5	30.0	1.1		43.1	0.1	-5.0	-8.3	-8.3	-8.3		-24.9	5.1	6.0	5.4		5.2	-25.7
wooden products and paper	90.4	8.4	0.3		6.6	0.3	1.6	-1.9	-1.9	-1.9		-24.3	8.7	9.6	9.0		8.8	-25.2
chemicals and plastic	343.1	32.4	1.1		3.4	5.8	-17.7	-18.6	-18.6	-18.6		-15.6	-19.4	-15.5	-16.0		-16.2	-15.5
Fuel	190.2	8.0	0.3			1.1	-54.7	-57.7	-57.7		0.0	-54.2	-54.5	-54.8				0.0
non-metal minerals	195.6	28.7	1.0		5.8	3.4	-12.7	-14.4	-14.4	-14.4		-11.2	-5.0	-2.6	-3.1		-3.4	-12.3
other industries	1054.0	104.8	3.7		43.0	0.5	-7.6	-10.1	-10.1	-10.1		-19.9	-4.3	-3.1	-3.6		-3.8	-21.0
water, electricity and gas	290.1	41.4	3.6		1.9	0.8	-11.2	-15.7	-15.7	-15.7		-8.9	-9.3	-9.8			-10.0	
construction	815.2	88.6	74.4		88.2	0.3	0.0	-1.2	-1.2	-1.2		-30.2	0.2	1.2	0.7		0.5	-32.1
wholesale and retail trade	1344.4	89.5	5.1		227.9	0.6	-3.3	-7.6	-7.6	-7.6		-29.8	-0.3	0.2	-0.3		-0.5	-30.1
hotels and restaurants	128.4	9.1	0.5		9.6	0.4	2.3	-2.9	-2.9	-2.9		-13.2	6.8	6.8	6.3		6.1	-13.5
communication and transportation	787.5	104.1	2.2		133.8	5.6	-9.5	-8.2	-8.2	-8.2		-22.3	-5.5	-0.1	-0.6		-0.8	-23.3
financial intermediaries	200.2	79.4	2.5		1.4	0.3	-9.5	-12.6	-12.6	-12.6		-32.8	-4.1	-4.1	-4.6		-4.8	-33.8
real estate and business services	1033.9	38.1	1.7		27.3	0.2	3.6	-3.6	-3.6	-3.6		-12.2	4.9	4.3	3.7		3.5	-11.1
public services and social security	596.6	261.2	23.3			0.3	0.0	-2.5	-2.5			-31.0	0.2	0.5	0.0			-32.5
education	327.2	236.9	8.2		3.6	0.5	-12.6	-12.8	-12.8	-12.8		-32.2	2.9	3.6	3.1		2.9	-34.6
healthcare	286.5	100.0	5.6		7.8	0.5	14.8	11.5	11.5	11.5		-29.8	4.1	4.6	4.0		3.8	-30.9
others	134.6	29.6	3.0		27.4	1.1	-5.2	-5.6	-5.6	-5.6		-29.0	-3.2	-1.1	-1.6		-1.8	-30.7

Results for policy simulations are shown as percentage deviation from the base model. q<sub>a</sub> refers to total activity quantities. d<sub>x</sub> refers to quantity demanded of factor x by a sector. Subscripts *sk*, *un*, *miagl*, *minagl* refer to skilled labour, unskilled labour, agricultural labour mixed income and non-agricultural labour mixed income respectively. Fuel efficiency refers to the percentage of fuel inputs used per unit of activity output.

The data from the activities sector supports this, with the majority of activities experiencing a decline in their levels (q<sub>a</sub> in Table 18 Base Model and Flexible Taxes Policy Simulations (Activities Results)). Particularly hard hit are mining, chemicals, fuels, minerals, industries, and communication and transports, all fuel-intensive or export oriented industries. This decline in industry depresses the demand and wages of

labour for two reasons. Overall production decreases since extra production becomes increasingly unprofitable. Furthermore, to compensate for the increasing fuel costs firms transfer some of these costs to their workers in terms of lower wages or reduced hiring. These two effects outweigh the positive fuel efficiency effect of substitution away from fuel and towards other factors of production. Indeed the demand for all types of labour ( $d_i$  in Table 18 Base Model and Flexible Taxes Policy Simulations (Activities Results)), drops significantly in the industries outlined above, with the overall effect being a reduction in the wages/quantity employed of labour regardless of type. The qualitative results of all the simulations are not affected by the use of different elasticities of substitution between the factors of production and between aggregate value added and the composite fuel intermediate input.<sup>65</sup>

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<sup>65</sup> Sensitivity analysis results are given in the appendix.

## IV.7.3 Varying Investment

As mentioned previously, static models are not well-g geared towards assessing the effects of changes in Investment since capital accumulation effects are absent. However for comparison purposes, it is illustrative to present the results of varying Investment.

**Table 19**  
**Base Model and Variable Investment Policy Simulation Results (Commodities)**

	Base economy						si flexq						si flexw					
	P	Q <sub>localind</sub>	X	M	S <sub>locatecon</sub>	C <sub>households</sub>	P	Q <sub>localind</sub>	X	M	S <sub>locatecon</sub>	C <sub>households</sub>	P	Q <sub>localind</sub>	X	M	S <sub>locatecon</sub>	C <sub>households</sub>
agriculture, farming, and forestry	1.3	762.4	50.8	83.7	795.2	293.5	-7.7	-2.9	-12.6	1.5	-1.8	-5.0	-7.2	-1.9	-11.8	3.0	-0.8	-4.5
husbandry, poultry and fishery	1.2	473.7	5.8	0.9	468.9	99.4	-8.2	-4.4	-11.5	-0.7	-4.3	-6.5	-8.6	-2.9	-6.8	-2.1	-2.9	-4.9
crude oil and natural gas	0.2	1797.9	1032.8		765.0		496.5	0.0	35.6		-48.1		500.1	0.0	35.4			-47.8
mining	1.9	48.2	6.1	7.6	49.7	0.2	-3.5	-3.0	-37.9	21.9	4.6	-10.6	-3.1	0.3	-34.6	25.6	8.0	-9.9
electricity	1.0	177.2	0.8	0.6	176.9	54.2	13.6	-13.1	-78.7	257.2	-12.1	-12.7	14.4	-12.2	-78.6	262.2	-11.2	-12.6
utility gas	1.0	65.2	8.0	0.6	57.8	30.4	-0.7	-13.2	-49.6	66.6	-7.7	-5.9	-0.7	-12.2	-47.4	62.6	-6.9	-5.4
water	1.0	43.0		84.5	43.0	25.7	33.2	-13.2		3.3	-13.2	-19.2	31.4	-12.2		3.6	-12.2	-18.3
food, tobacco and textiles	1.4	1265.1	106.1		1243.5	896.0	-6.0	-7.8	-23.4		-5.8	-7.0	-5.9	-6.3	-20.6			-4.5
Industry excluding metal and equipment	1.4	879.0	92.9	340.8	1126.9	250.2	-5.4	-5.2	-25.7	15.8	2.7	-7.4	-5.2	-2.8	-22.5	17.3	4.8	-6.5
lubricant and coke	1.1	42.8	12.1	5.2	35.9	5.2	14.2	-54.9	-93.0	191.7	-12.0	-12.9	14.7	-54.6	-92.9	199.2	-10.8	-12.6
motor spirit	1.1	65.9		16.8	82.7	45.9	163.7	-51.7		22.5	-37.6	-38.2	165.2	-51.4		23.8		-38.2
burning oil	1.7	7.7			7.7	6.0	1240.1	-54.9			-54.9	-51.5	1199.6	-54.6				-51.3
gas oil	1.7	18.4			18.4	1.1	616.5	-54.9			-54.9	-49.5	638.1	-54.6				-54.6
fuel oil	1.2	39.8	21.7		18.1	0.1	25.6	-54.9	-92.6		-16.4	-16.8	28.4	-54.6	-93.3			-15.4
liquid gas	1.1	36.4	27.0		9.4	3.0	-7.0	-21.3	-26.6		-6.7	-3.3	-6.4	-21.1	-26.4			-3.0
other fuels	1.9	1.3			1.3	0.0	619.6	-54.9			-54.9	-51.4	635.8	-54.6				-51.5
metal products and equipment	1.2	765.9	21.6	581.0	1325.3	190.9	-6.7	4.4	-16.2	20.7	11.8	-5.8	-6.6	7.9	-10.8	22.1	14.4	-4.8
construction	1.0	824.6			824.6	11.2	-3.6	19.1			19.1	-9.9	-2.7	22.1			22.1	-9.8
wholesale and retail trade	1.0	1236.7		2.2	1238.9	1.0	-6.6	-2.5		9.1	-2.4	-5.9	-6.4	-0.7		10.1	-0.6	-5.1
repairs and household sales	1.0	126.0			126.0	52.3	-13.7	-2.9			-2.9	3.3	-13.9	-1.1				4.8
hotels and restaurants	1.0	147.7	13.4	27.8	162.1	141.3	-8.9	-4.5	-8.5	0.4	-3.4	-3.2	-8.5	-3.5	-6.9	0.7	-2.5	-2.4
transportation and storage	1.0	709.0	6.5	84.9	787.5	140.5	1.7	-9.7	-40.5	37.8	-4.7	-15.1	1.3	-7.7	-37.0	36.2	-3.0	-13.6
communication	1.0	91.1			91.1	66.4	-0.7	-9.6			-9.6	-12.3	-1.7	-7.7				-10.1
financial intermediaries	1.0	178.4	34.5		143.9	6.3	-4.7	-7.8	-20.1		-5.0	-8.1	-7.3	-4.2	-9.8		-2.9	-4.0
insurance	1.0	21.8	15.3	10.6	17.1	7.4	-9.6	-7.8	-8.9	-1.6	-3.1	-2.2	-9.3	-4.2	-4.8	-0.9	-1.7	-1.4
real estate	1.0	855.9			855.9	790.9	-12.9	1.1			1.1	1.3	-12.4	1.5				1.5
business services	1.0	198.7	0.0	0.4	199.1	24.8	-7.7	0.6	-7.0	8.9	0.6	-4.9	-1.1	1.1	-22.5	31.8	1.1	-11.0
public services and social security	1.0	582.8			582.8	14.0	-4.6	0.0			0.0	-8.6	-6.4	0.1				-5.5
other social services	1.0	701.6	8.8	3.4	696.3	187.3	-2.5	-3.3	-24.0	23.5	-3.0	-10.7	-5.5	-1.9	-13.9	12.2	-1.7	-6.3

Results for the policy simulations are shown as percentage deviation from the base model.

Allowing Investment to vary produces similar results to those elucidated above but with two important differences. Firstly, households no longer experience a rise in welfare, with their EV decreasing significantly (Table 16). This is expected given that they no longer receive tax reductions and rebates, while they have to pay higher prices for petroleum goods. Hence their overall welfare declines.

**Table 20 Base Model and Flexible Investment Policy Simulations (Activities Results)**

	Base						SI FLEXQ						SI FLEX W						
	q <sub>a</sub>	d <sub>sk</sub>	d <sub>un</sub>	D <sub>miagl</sub>	D <sub>minagl</sub>	Fuel Efficiency	q <sub>a</sub>	d <sub>sk</sub>	d <sub>un</sub>	D <sub>miagl</sub>	D <sub>minagl</sub>	Fuel Efficiency	D <sub>k</sub>	q <sub>a</sub>	d <sub>sk</sub>	d <sub>un</sub>	D <sub>miagl</sub>	D <sub>minagl</sub>	Fuel Efficiency
farming, forestry and horticulture	764.7	15.9	1.1	50.1		0.6	-2.9	-8.2	-8.2	-8.2		-37.1	-0.9	-1.9	-3.4	-14.7	0.9		-37.2
husbandry poultry and fishery	544.8	25.0	1.7	31.4		0.5	-4.4	-10.0	-10.0	-10.0		-29.3	-2.8	-2.9	-5.6	-16.7	-1.4		-29.9
crude oil and natural gas	1797.9	18.7	2.0		0.8	0.0	-0.8	-4.0	-4.0		-4.0	-3.1	-4.0	-1.1	-4.9	-4.9			-4.9
Mining	50.0	8.0	1.1		0.8	1.3	-3.0	-5.1	-5.1		-5.1	-36.7	2.5	0.3	2.3	-9.7			0.2
food, beverages, tobacco	768.6	32.1	1.1		13.3	0.3	-6.3	-9.8	-9.8		-9.8	-27.8	-2.6	-5.9	-5.7	-16.7			-7.6
textile, clothing and leather	420.5	30.0	1.1		43.1	0.1	-11.3	-14.1	-14.1		-14.1	-25.7	-7.3	-7.9	-7.7	-18.5			-9.6
wooden products and paper	90.4	8.4	0.3		6.6	0.3	7.4	3.9	3.9		3.9	-25.1	12.2	12.0	12.1	-1.0			9.8
chemicals and plastic	343.1	32.4	1.1		3.4	5.8	-11.7	-12.4	-12.4		-12.4	-16.1	-5.4	-11.5	-8.4	-19.1			-10.2
Fuel	190.2	8.0	0.3			1.1	-54.9	-57.8	-57.8			0.0	-54.4	-54.6	-55.6	-60.8			0.0
non-metal minerals	195.6	28.7	1.0		5.8	3.4	-11.2	-12.7	-12.7		-12.7	-12.1	-5.7	-7.6	-6.0	-17.0			-7.9
other industries	1054.0	104.8	3.7		43.0	0.5	4.4	1.7	1.7		1.7	-20.7	9.9	8.0	8.5	-4.1			6.4
water, electricity and gas	290.1	41.4	3.6		1.9	0.8	-13.2	-17.5	-17.5		-17.5	0.0	-10.9	-12.2	-13.4	-23.6			-15.2
construction	815.2	88.6	74.4		88.2	0.3	19.5	18.2	18.2		18.2	-30.9	27.7	22.6	27.1	12.3			24.6
wholesale and retail trade	1344.4	89.5	5.1		227.9	0.6	-2.5	-6.7	-6.7		-6.7	-30.4	0.7	-0.7	-1.1	-12.7			-3.1
hotels and restaurants	128.4	9.1	0.5		9.6	0.4	-5.8	-10.4	-10.4		-10.4	-13.8	-3.3	-4.4	-5.4	-16.5			-7.3
communication and transportation	787.5	104.1	2.2		133.8	5.6	-9.8	-8.2	-8.2		-8.2	-23.0	-0.9	-7.7	-2.9	-14.2			-4.8
financial intermediaries	200.2	79.4	2.5		1.4	0.3	-7.8	-10.9	-10.9		-10.9	-33.4	-3.8	-4.2	-4.9	-16.0			-6.8
real estate and business services	1033.9	38.1	1.7		27.3	0.2	1.3	-5.6	-5.6		-5.6	-12.8	2.0	1.7	-0.6	-12.2			-2.6
public services and social security	596.6	261.2	23.3			0.3	0.0	-2.4	-2.4			-31.6	5.4	0.1	0.3	-11.4			-32.4
education	327.2	236.9	8.2		3.6	0.5	-13.5	-13.7	-13.7		-13.7	-32.8	-6.8	-3.3	-2.4	-13.8			-4.4
healthcare	286.5	100.0	5.6		7.8	0.5	12.0	8.8	8.8		8.8	-30.4	17.6	4.4	4.3	-7.9			2.2
others	134.6	29.6	3.0		27.4	1.1	-11.2	-11.5	-11.5		-11.5	-29.7	-4.4	-14.2	-12.1	-22.3			-13.8

Results for policy simulations are shown as percentage deviation from base model.

The second important difference is in the labour market. While all other types of labour experience a decline in their wages/quantities employed (albeit of a lesser magnitude than in the previous simulation), unskilled labour actually experiences a rise in these variables (Table 16). The reason for this can be deduced from the rise in the domestic output of two commodities sectors, the construction sector and the metal and equipment sectors (Table 19). This is because the overwhelming majority (over 80%) of investment expenditure in the Iranian economy is concentrated on these two investment goods, and hence any increase in investment will necessarily be mainly channeled into these two goods. Thus an increase in investment increases the output of these two sectors, which is reflected in an increase in the wages for unskilled labour and the lower decline in wages for other labour types when compared with the fixed investment scenario. A large proportion of unskilled workers are concentrated in the construction sector, and hence the increase in the output of that sector actually increases their wages.

However, given the factors outlined in the previous section, mainly the loss of competitiveness in industries due to the Dutch disease effect and the increasing costs of fuel inputs, the beneficial consequences of increased Investment goods are not enough to overcome the decline in wages/quantities employed of the other labour types. These results should be treated with extreme caution, however, until further investigation is carried out using a dynamic model, as intertemporal capital accumulation could have important effects unrecognized in our one-period static model.

## IV.8 Dynamic Simulations

This section takes the previous static model and extends it within a recursive dynamic framework. A dynamic framework offers several advantages over a static model:

- Most importantly, a dynamic setting allows for a more detailed modeling of Investment and capital accumulation effects. As mentioned previously, if the variable Investment closure was adopted in the static model, an increase in investment simply translates to a proportional increase in the amount of investment goods bought in the economy. The aggregate quantity of capital does not get updated. In a dynamic setting, we can model Investment in a more detailed fashion, where the amount of capital in the economy is endogenously changed.
- A static model neglects transitional effects and costs associated with removing the subsidies, while a dynamic framework allows us to investigate more closely the transition path of the economy over the specified period.
- Closely related is the fact that a dynamic model allows for policy simulations not possible in a static model. It is unlikely that the removal of the subsidies could be implemented in reality all at one time. A dynamic model allows for a gradual phasing in of the subsidy reduction and a study of the associated transitional path over a specified period.
- The dynamic model allows for exogenous growths in population, labour supply and total factor productivity to be incorporated in the setting, elements which were absent in the static model.

The extension is implemented as a recursive dynamic model<sup>66</sup> over a 20 year horizon, where a loop updates the evolution of the economy on a yearly basis. In

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<sup>66</sup> An alternative way of implementing dynamic features is by using a forward looking rational expectations model instead of a recursive dynamic setting, where expectations of agents about future paths and events are explicitly incorporated in the setup (e.g. Harrison and Rutherford (1999)). This alternative method has the advantage of fully incorporating rational expectations, a feature which our model lacks. On the other hand, it suffers from the drawback that the equilibrium in the economy is

essence, each year in the dynamic model resembles one equilibrium of the static model, with each subsequent year representing a new equilibrium incorporating the changes in variables from the previous year.

The modelling of Investment warrants some extra comments. Within each period, Investment takes a form similar to that in the static model, where total Investment is distributed proportionally to Investment goods. However, Investment now has a capital accumulation effect lacking in the static model. The total amount of capital in a specific period is determined by the total capital stock in addition to the Investment from the previous period after discounting for depreciation.<sup>67</sup> The employment of capital in the different sectors depends on the demand for capital in that sector, similar to the static model. Hence capital accumulation effects are explicitly and endogenously determined in the model, unlike in the static model. This will be vital for assessing the effects of increased investment in the economy, as the increased stock of capital could have potentially positive ramifications on the economy not accounted for in the static model.

Exogenous yearly growth rates in total factor productivity, the population, and the quantity of each of the individual labour categories are included in the model. Furthermore, government consumption spending is kept constant in real terms across periods via varying the quantity of commodities consumed by the government (since commodity prices are determined endogenously in the model). Subsistence spending of households is also increased to take account of the exogenous population growth. The model is based on Thurlow (2004), with extensions to take account of the specific features of the study.<sup>68</sup>

To implement the dynamic simulations extra information is needed regarding the evolution of the economy over time. Population growth is set at 1.3% annually, in accordance with UNDP statistics (UN, 2007). Total factor productivity growth is based

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uniquely and strongly determined by the expectations of agents (Yang 1999). This becomes particularly significant once one realizes the several complications and alternatives that this method opens up (such as whether the policies are announced or unannounced, or whether myopic expectations or perfect foresight are assumed, which imply significantly differing outcomes in a model involving forward looking expectations), and the fact that choices between these different alternatives are often based on ad hoc assumptions, which in turn uniquely drive the results. For these reasons a dynamic recursive model is adopted.

<sup>67</sup> The equation for the evolution of capital over time is similar to those presented in the previous three chapters.

<sup>68</sup> For a more detailed assessment of the features of the dynamic part of the model, see Thurlow (2004).

on World Bank staff estimates and set at 1% annually. Exact estimates on the rate of capital depreciation are unavailable, so we set the rate at a standard 10% annually. Although estimates for the annual overall labour supply growth is known (The World Bank (2003) estimates it at 2.5% annually over a 20 period horizon), the growth broken down along skills is not available, and so we set the growth for each labour group at 2.5%.<sup>69</sup>

An important question that arises is the implementation of the elasticities of substitution, particularly those for energy goods in production and consumption as well as elasticities of substitution between the different (non-crude) primary factors of production. It could be argued that in the first few years the elasticities of substitution should be quite low, since there is a lack of maneuvering space for those affected, increasing gradually over time to the long-run values used in the static model. On the other hand, it could be argued that very little is known about the evolution of elasticities over time, and that the ones employed previously should be used here throughout as well. This is especially the case since this a long-run simulation where actors will be able to adjust over time. For this reason we report results using the same elasticities as previously used.

We do however also implement an alternative scenario where the elasticity of substitutions between (non-crude) primary factors of production, between the different energy goods, and between the aggregate energy good and aggregate value added in the relevant sectors are gradually updated over time. We implement the case where all these elasticities start at the low value of 0.2 and gradually reach their long run levels over a five year period, with the magnitude of the change distributed evenly over the five years. It is conceivable that this debate turns out to be academic with little effect in practice. The results reported below are those using the original static model elasticities throughout, with any changes between the two scenarios highlighted if appropriate.

We continue to employ the same closure rules adopted in the static model for comparison purposes. This means that once again either the quantity of supply of each labour type or the wages will be held fixed with the other varying in order to assess the

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<sup>69</sup> We also employ several other values as a cross check, including using different growth for the different types of labour. Where appropriate, results that are markedly different from the benchmark results reported are highlighted.

effects of the policies on each labour type. In terms of policy options, we continue to implement both Investment (where extra government revenue is channeled into Investment) and Consumption (where the revenue is channeled to increased household income) closures as alternatives, but we introduce two further possibilities. As in the static model, one alternative gauges the effects of removing the subsidy completely in year one using the above two closures. The other scenario sees us reducing the subsidy gradually over a ten year period, with the amount of the subsidies reduced by 10% each year (i.e. the subsidies in the first year are 90% of the original amounts, etc). This allows us to assess the transitional and final impacts of removing the subsidies piecemeal or immediately.

## IV.9 Dynamic Results

The simulations of removing the crude oil and fuel subsidies are compared with the alternative defaults of keeping the subsidies intact over the twenty years. Since they are counterfactual simulations, what is most important in the analysis is the relative comparison of the base simulation results to those with the subsidies removed, with the differences in results being the focus of attention.

We begin our analysis by looking at the immediate removal of the subsidies in the first year with the extra revenue being redistributed back to households. As expected, the dynamic results confirm those of the static model. Although Real GDP and private consumption increase when compared with the default setting (Table 21 Average Yearly Growth for Base and Alternative Policy Simulations and Figure 6), industries overall experience a decline. The double blow of the Dutch Disease effect and the increasing cost of fuel inputs cause industries to contract, with the implication of wages/quantities employed of labour decreasing (Figure 7). The only difference is that in the dynamic simulation the percentage of the decrease by the 20<sup>th</sup> year of the simulation when compared to the same year in the default setting is less than that in the static simulation. This is expected given that the economy has a longer time period to adjust over in the dynamic simulation. Introducing the tax gradually over twenty years does not produce any important differences in the results.<sup>70</sup>

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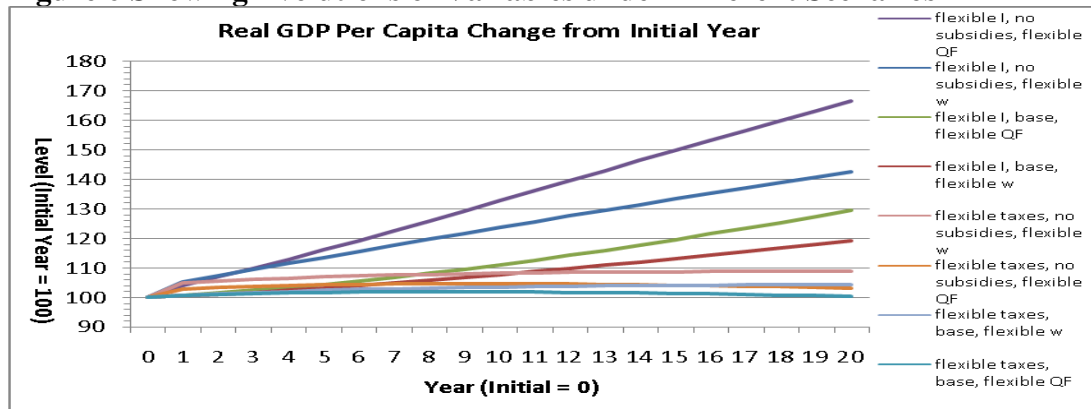
<sup>70</sup> The simulations with a gradual change in the elasticities of substitution between the primary factors of production and between total value added and the composite intermediate fuel input does not cause any distinguishable difference in the results in all of the dynamic simulations.

**Table 21 Average Yearly Growth for Base and Alternative Policy Simulations**

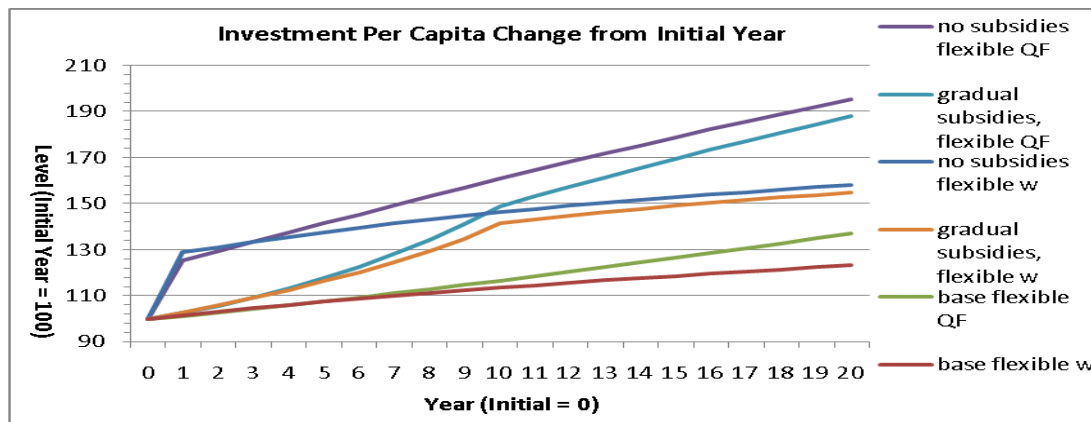
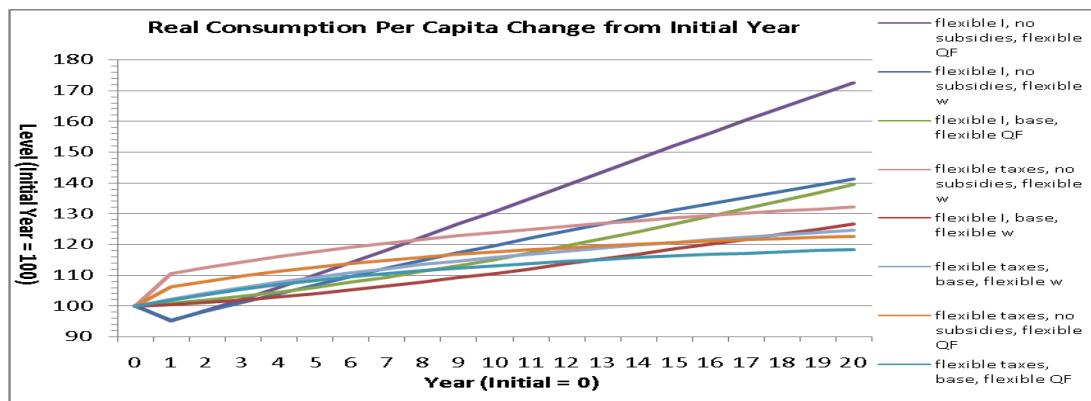
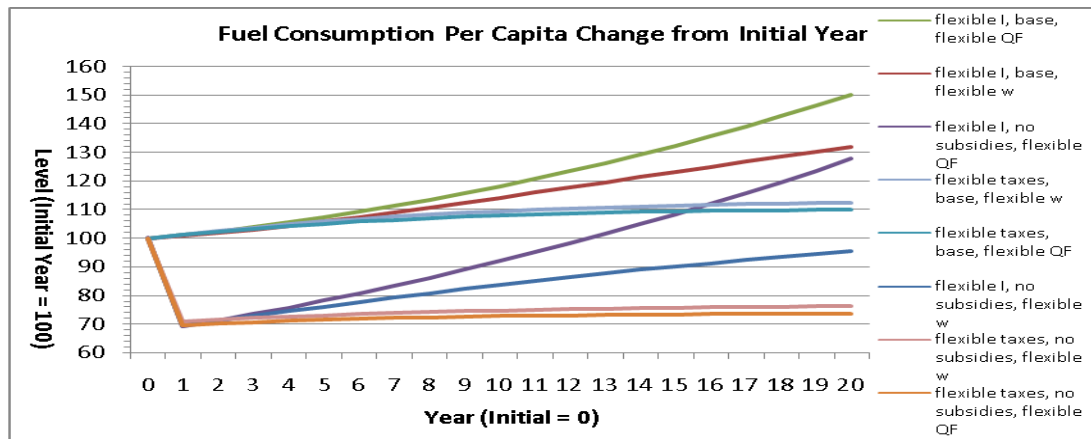
	Average Yearly Growth											
	Flexible W, taxes			Flexible Q, Taxes			Flexible W, SI			Flexible Q, SI		
	Base	No Subsidies	Gradual Subsidies	Base	No Subsidies	Gradual Subsidies	Base	No Subsidies	Gradual Subsidies	Base	No Subsidies	Gradual Subsidies
GDP per capita	0.2	0.4	0.4	0.0	0.2	0.2	0.9	1.8	1.7	1.5	3.3	3.0
Investment Per Capita							1.2	2.9	2.7	1.8	4.8	4.4
Consumption Per Capita	1.2	1.6	1.6	0.9	1.1	1.1	1.3	2.1	1.9	2.0	3.6	3.2
Fuel Consumption Per Capita	0.6	-1.2	-1.2	0.5	-1.3	-1.3	1.6	-0.2	-0.3	2.5	1.4	1.0
Skilled Labour W	-2.5	-3.1	-3.1				-0.9	-0.2	-0.3			
Unskilled Labour W	-5.3	-5.8	-5.8				-1.7	0.7	0.5			
Non-Agricultural Mixed Income W	2.0	1.6	1.6				4.1	5.4	5.3			
Agricultural Mixed Income W	3.3	3.2	3.2				5.5	7.4	7.1			
Skilled Labour QF				0.8	0.4	0.4				2.4	3.8	3.5
Unskilled Labour QF				-0.1	-0.3	-0.3				2.1	4.1	3.8
Non-Agricultural Mixed Income QF				1.1	0.8	0.8				3.0	4.5	4.2
Agricultural Mixed Income QF				1.7	1.5	1.5				3.7	5.5	5.2

The results do change dramatically however when the extra revenues are channeled into Investment. We start by looking at the effects of removing the subsidies immediately. By the end of the twenty year simulation, wages and quantities employed of labour have increased substantially when compared to the default simulation of keeping the subsidies intact (Figure 7). Particularly impressive is the increase in unskilled labour when compared with the base simulation, although all types of labour register noticeable rises as well.

**Figure 6 Showing Evolutions of Variables under Different Scenarios**



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<sup>71</sup> To avoid cluttering, the graphs for the gradual removal of the subsidies for real GDP per capita, private consumption per capita and fuel consumption per capita are presented in the appendix.

The transition of the economy over the simulation years is revealing. For the first four years, the results are similar to those in the static model. The only type of labour that registers an increase in its wages/employment levels is unskilled labour, just as witnessed in the static model. All the other types show a lower level when compared to the default simulation. By the fifth year however, all types of labour have outstripped their counterpart default simulation values. This reveals the new insight that a dynamic simulation brings in about capital accumulation. For the first five years industry and the labour employed within it (with the exception of low skilled labour) experience a contraction for the same reasons detailed in the static section. Unskilled labour experiences an increase from the start because of the goods that Investment is spent on (particularly construction).

Over each year, however, this increased Investment when compared to the default simulation translates into increased capital accumulation. The economy now is flooded with extra capital that gradually allows industry to grow. By the fifth year industry has grown enough that the return to labour under the subsidy removal simulation outstrips the default simulation.

Increased capital accumulation is not the only story, however. The composition of the economy also shifts due to this increased Investment. Most of the new Investment is concentrated in farming, retail and estate: all non-fuel or oil intensive industries (Table 22 Investment and Value Added Share). This allows the structure of the Iranian economy to shift away from its traditional reliance on fuel and oil intensive industries and expand into other sectors. Hence the increased Investment allows not only for increased capital accumulation but also for an adjustment in the structure of the economy, with significant repercussions on GDP and welfare (as measure by private consumption). Both of those variables register impressive increases when compared with the default simulation by the end of the 20 years (Figure 6).

Introducing the subsidy removal gradually over ten years does not change the overall results, but it does change the transition of the economy. The initial decline experienced in the labour market is less severe, but it is stretched out longer. Because the revenue from the subsidy removal is less, the yearly increase in Investment is also

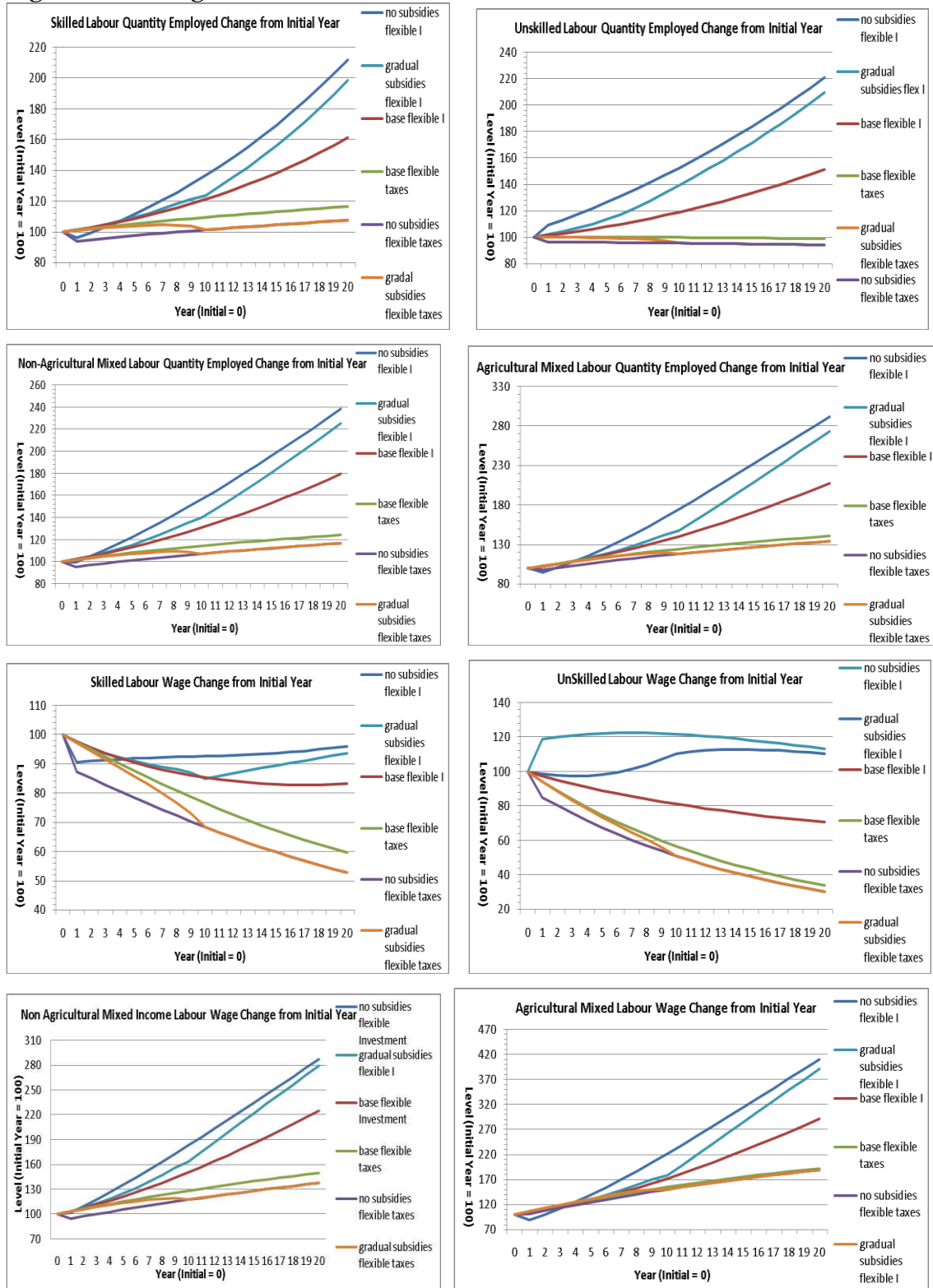
lower. Hence capital accumulation and the shift in the structure of the economy happen at a lower speed. Wages and quantities employed take longer in order to catch up with the values in the default simulation. Hence the overall increase in GDP, welfare, and wages/quantities employed in labour is reduced, but the initial transition costs are lower. Indeed they are lower in two forms. The increase in the costs of the fuel goods is less felt as it is introduced gradually over ten years, and the initial decline in industry is also less severe.

**Table 22 Investment and Value Added Share**

	Investment Share (%)				Total VA Quantity Share at start/end of simulation				
	Flexible I, W		Flexible I, Q		Initial Year	Flexible I, W		Flexible I, Q	
	base	no subsidies	base	no subsidies		base	no subsidies	base	no subsidies
farming, forestry and horticulture	12.5	12.9	12.6	13.1	7.5	8.1	8.9	8.6	9.0
husbandry poultry and fishery	1.7	1.9	1.7	2.0	3.2	3.0	2.9	3.0	2.4
crude oil and natural gas	4.2	3.3	4.0	3.1	21.5	13.8	11.7	12.2	8.5
Mining	0.9	0.9	1.0	1.2	0.5	0.9	0.9	1.3	1.9
food , beverages , tobacco	3.8	3.7	3.7	3.4	2.5	2.6	2.7	2.5	2.1
textile, clothing and leather	2.4	2.2	2.8	2.6	2.2	2.0	1.7	2.9	2.5
wooden products and paper	0.5	0.6	0.7	0.8	0.5	0.5	0.5	0.8	1.1
chemical s and plastic	4.2	3.8	3.9	3.2	2.6	2.6	2.3	2.1	1.0
Fuel	1.6	0.7	1.6	0.7	0.9	1.0	0.4	1.1	0.4
non-metal minerals	1.9	1.9	2.0	2.3	1.2	2.3	2.5	2.8	3.8
other industries	4.8	5.4	5.0	5.9	4.2	5.1	5.7	5.9	7.3
water, electricity and gas	2.4	2.0	2.4	2.1	1.8	2.1	1.8	2.0	1.7
construction	2.2	2.9	2.1	2.7	4.2	4.4	5.3	4.5	5.6
wholesale and retail trade	19.3	19.5	19.2	19.4	13.3	14.6	14.9	16.1	16.6
hotels and restaurants	1.3	1.3	1.3	1.2	0.9	0.9	0.9	0.9	0.7
communication and transportation	6.9	7.1	7.0	7.3	6.4	7.1	7.1	8.2	8.8
financial intermediaries	3.0	3.1	2.7	3.1	2.1	6.7	7.3	4.4	6.3
real estate and business services	19.7	19.6	19.4	19.3	11.0	11.3	12.6	11.0	11.8
public services and social security	3.4	3.3	3.3	3.0	5.9	3.9	3.5	3.4	2.6
education	0.9	0.8	0.8	0.7	3.4	4.6	3.0	3.4	2.3
healthcare	2.2	2.8	2.2	2.5	3.0	2.2	3.3	2.1	2.6
others	0.4	0.4	0.6	0.6	1.2	0.3	0.2	0.9	0.8

Values other than the initial year are for the final year of the simulation (year=20).

**Figure 7 Showing Evolutions of Variables under Different Scenarios**



## IV.10 Conclusion

This chapter's aim is to simulate the removal of the large crude oil and fuel subsidies in the Iranian economy, with the attention particularly focused on the labour market. The simulation was carried out within a static and a dynamic Computable General Equilibrium framework using a 2001 SAM of the Iranian economy. The additional revenue from the subsidy removal presented two alternative options to the government: Either to redistribute it back to households in the form of tax cuts and rebates, or to utilize the additional income to increase Investment.

A main theme that emerges is that the current structure of the Iranian economy is heavily biased towards industries that are crude oil and fuel intensive in production. This is a consequence of the extremely low prices of these inputs, which over the years have created severe distortions in the economy. Redistributing the extra revenue back to households would not be enough to overcome these distortions. Indeed the wages and quantities employed of labour suffer under such a scenario, even though Real GDP and household welfare rise. Iranian industries contract due to the Dutch Disease effect. Considerable quantities of crude oil are freed up for export as local demand for the more expensive crude oil drops, causing the exchange rate to appreciate. Industries face the further setback of the increased cost of fuel inputs. Their overall production declines, translating into a reduction in the wages and quantities of labour employed. Even though the economy experiences a decrease in fuel use and a substitution away from fuel towards other factors of production (increased fuel efficiency), these effects are not enough to outweigh the adverse shocks outlined above.

What the Iranian economy needs is for this extra revenue to be channeled into Investment. Such a simulation improves the labour market's fortune dramatically in the long run. In the short run, the above mentioned shocks cause a contraction in the labour market, but over time it expands for two reasons. Firstly, there is increased capital accumulation because of the extra investment. Secondly, the structure of the Iranian economy shifts. The extra capital is directed towards non-fuel or crude oil intensive industries, allowing the Iranian economy to adjust away from its current reliance on industries dependent on these inputs.

Our Investment simulation assumed that this extra Investment is channeled towards the private sector, with the profit motive allowed to play its allocative role, in line with what the World Bank (2003) recommends. One possible future investigation is for this extra revenue to be invested directly by the government itself (i.e. the public sector). The danger with such a scenario is that the government can end up investing in non-sustainable or white elephant industries, an occurrence all too common in developing countries.

Another possible extension is to introduce an explicit unemployment function through an upwards sloping labour supply curve. The benefits of this are minimal, however. Firstly, as previously elucidated, our setup of either a completely vertical or a completely horizontal labour supply curve construct two boundaries, with any other formulation producing results that fall within these two limits. Since the results of either flexible wages or flexible quantities employed point towards the same direction, it can be deduced that any other setup will produce results in the same direction as well. Secondly, it is not obvious what type of unemployment function would best suit the Iranian economy, and the choice would be in many ways arbitrary. Indeed, one could argue that the closure we employ of fixed wages and flexible quantities of labour supplied is probably the best function to describe the Iranian economy, given the high slack in the labour market which exhibits double digit unemployment rates.

In the same vein, one could also utilize different substitution constructions between labour and other primary factors of production. However, it is not obvious what would be the most appropriate assumption out of the several different combinations available. Should unskilled labour and skilled labour be imperfectly substitutable at the bottom of the value added nest, with the resulting composite then being imperfectly substitutable with capital? Or should capital be a complement that is imperfectly substitutable with skilled labour at the bottom of the technology nest, with the resulting composite then being substitutable with unskilled labour? And how would mixed income labour fit into the picture? In any case, it is extremely doubtful that the different combinations will affect the results greatly, since as we witnessed it was capital accumulation effects that were the main driver of the results, with the substitution effects between the different factors of production and fuel inputs not playing a significant role in explaining the dynamics of the simulations.

A more interesting possibility is to investigate the effects on households demarcated by income levels. Currently the SAM only includes urban and rural households. It is possible that the subsidy removal would have different effects on high income versus low income households. Hence introducing income differentiation across households and investigating the effects on different household income groups could prove a fruitful and important addition.

The global prices of oil in 2008 are much higher than those prevailing in 2001. This implies that the total subsidies for crude oil and fuel in Iran are much higher in 2008, with the IMF (2007a) estimating them at 17.5% of GDP in 2005/2006. The distortions in the economy in 2008 probably exceed those in 2001, with the potential benefits from removing the subsidies magnified. Ideally, more updated SAM data would be obtained to run the simulations for prevalent conditions in 2008. However, it could be argued that the simulation carried out in this study analyzes long term trends in the Iranian economy. Future oil prices over a 20 year horizon are uncertain, and hence 2001 data could act as one potential estimate of long run conditions in the oil market. We leave the possibility of further analysis to future research.

## **IV.11 Appendix**

### **IV.11.1 SAM Construction:**

The data sources for the construction of the SAM are use and supply (at both producer and purchaser prices) 2001 input-output tables provided by the Statistical Center of Iran (Statistical Center of Iran (2007)) and a pre-existing SAM for the year 2001 by Banouei (2007), which incorporates both Household data from a 2001 household survey as well as input-output values. This is necessary since each of the sources on its own does not provide sufficient material to construct the necessary SAM, but when the information of both is combined an adequate SAM construction is feasible.

The disaggregation of commodities and industries in the two sources are not similar, with the Input-Output tables (147 commodities x 99 industries) having a much more detailed composition than the Banouei SAM (22 commodities x 21 industries). Hence the first step was to aggregate the Input-Output tables to correspond with the Banouei SAM.

The format of the Banouei SAM is based on that of the United Nations 1993 System of National Accounts (SNA93). This format is not conducive to the simulation of CGE models and a format closer to the standard SAM representation of Pyatt (1991) is needed. Hence the SAM was modified and rearranged to correspond to the standard SAM representation of Pyatt (1991).

A more important limitation is the absence of a fuel energy sector in the Banouei SAM, where fuels are aggregated in the “chemicals and plastic” sector in the production account and in the “other industrial products” sector in the commodities account. The SCI IO table is used to disaggregate the necessary fuel sectors.

Disaggregating the fuel industries sector requires information on the composition of the type (skill) of workers in the sector. This is not available from the SCI IO table. The assumption made here is that the skill composition of workers in the fuel

production sector mirrors that in the chemicals and plastic sector, a reasonable assumption given the similar production nature of the two sectors.

A further problem arises from the fact that the different SAM entries for the sectors do not correspond exactly between the two sources. The method employed here is to take the exact values from IO tables for the disaggregated fuel sectors, with the residual values left after subtracting these values from the aggregated Banouei SAM's sectors being assigned to the "chemical and plastic" or the "other industrial products" sectors. Luckily the residual values did not differ greatly from those in the Input-Output tables. Some simple rounding of the cells was needed to ensure that the Matrix balances. Since only small adjustments were needed, this was done manually instead of having to resort to more computationally intensive methods, such as the cross entropy method of Robinson et al. (1998).

In the Banouei SAM, the mixed income sector was not disaggregated. For the agricultural sectors (farming and husbandry) it was decided to disaggregate the values based on simple assumptions derived from Dorosh et al's work on Pakistan (2006). 50% of the payments were assumed to accrue to land in the farming production sector (the value was 80% in the case of the husbandry sector), with the rest going to mixed income agricultural labour. This step is not necessary or of importance to the main objective of the model, but it was felt that it would give a more detailed description of the setup in agricultural activities, where land plays an important part in production.

The Banouei SAM lacks information on payments to the crude oil natural resource. This information was obtained from the IO tables, which reported both payments to fixed capital and operating surplus in the sector. The operating surplus (rent) accruing to the sector is designated as income accruing to the crude oil natural resource. In turn this natural resource pays all its revenue to the government account, consistent with the fact that oil is nationally owned in Iran.

Transaction (transportation) costs in the Banouei SAM are not disaggregated as to whether they are costs of imports, exports, or domestic transaction costs. Although this is not crucial, it would be more helpful to have information on the breakdown of these transaction costs. The disaggregation was done using a simple technique of assuming

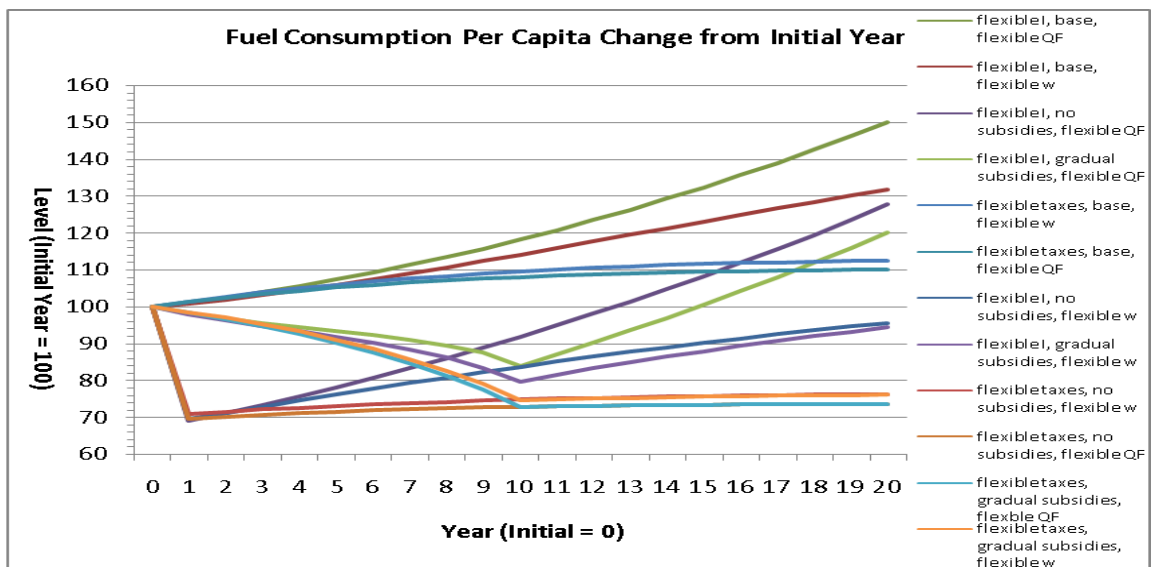
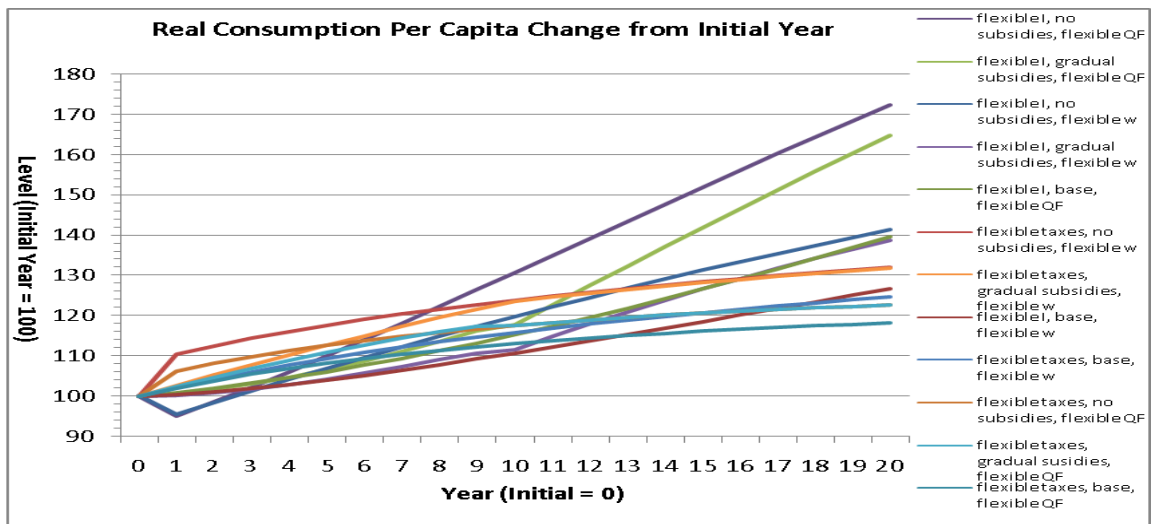
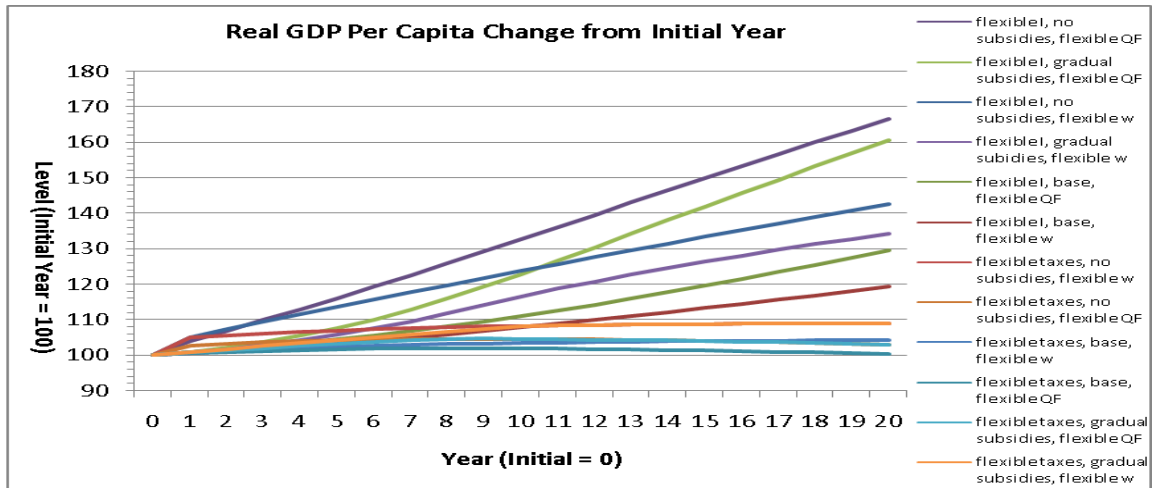
that transaction costs for imports, exports, or domestically used goods are proportional to the amounts of each of these different segments. For example, the proportion of imports' transaction costs as a ratio of total transportation costs is directly proportional to the ratio of imports' when compared to the overall amount of the goods (including domestic use, exports and imports).

The most glaring problem with both sources is the complete absence of the crude oil subsidies, arising from the fact that crude oil commodities accounts are calculated using different prices locally and when sold abroad. As mentioned previously, the source of the huge crude oil subsidies is the fact that the crude oil commodity is sold at a massively discounted price to fuel producers locally when compared with those sold abroad. Both sources simply input the payments to the crude oil commodities sector using domestic (subsidized) prices when sold locally and international prices when sold internationally. Indeed Iranian National Statistics generally do not compute the exact amount of the subsidy. This can be seen from the fact that international revenues from the crude oil commodities sector account for roughly 90% of total revenue in the SAM and IO tables, while World Bank and Iranian data shows that roughly 40% of crude oil output was consumed locally in 2001 (with the ratio roughly holding steady over the past 5 years). Hence the discrepancy in revenue arises from the different prices that crude oil is sold at locally and abroad. This subsidy to local prices is not made explicit anywhere in either source.

Making this subsidy explicit is the most crucial feature required in the SAM; otherwise modeling policy changes becomes impossible. Data was obtained from World Bank staff estimates regarding the allocation of crude oil output between domestic use and exports, which indicated that 42% of the crude oil output was used locally as intermediate inputs in domestic production (mainly in the fuel sector). The rest (58%) was exported abroad. Taking international oil prices as the reference, with the difference between local prices and those abroad (after accounting for transportation costs) constituting the local subsidy on the crude oil commodity, and given that the IO tables and the Banouei SAM show only 10% of crude oil revenues coming from the local market, the exact amount of the subsidy can be made explicit. The amount of the subsidy on local sales of the crude oil commodity then simply becomes the difference between the 10% and the 42% of local revenues if they were to be accounted at

international prices. The enormity of the subsidy becomes apparent once this is done, with the crude oil subsidy making up roughly 9% of GDP.

#### IV.11.2 Gradual Subsidies Removal Graphs



## IV.11.3 BASE STATIC MODEL IN GAMS FORMAT<sup>72</sup>

### \*\*\*MODEL SETS

AC global set for model accounts - aggregated microsam accounts  
A(AC) activities  
ALEO(A) activities with Leontief fn at top of technology nest

\*NEW=====

AFU(A) energy activities  
AOI(A) oil activities  
ANO(A) ALL OTHERS

\*=====

C(AC) commodities

\*NEW=====

CF(C) energy commodities  
CNF(C) non-energy commodities  
  
CO(C) CRUDE OIL COMMODITY  
CNO(C) NON CRUDE OIL COMMODITIES  
CPETROL(C) FUEL COMMODITIES

\*=====

CD(C) commodities with domestic sales of output  
CDN(C) commodities without domestic sales of output  
CE(C) exported commodities  
CEN(C) non-export commodities  
CM(C) imported commodities  
CMN(C) non-imported commodities  
CX(C) commodities with output

F(AC) factors  
INS(AC) institutions  
INSD(INS) domestic institutions  
INSDNG(INSD) domestic non-government institutions  
H(INSDNG) households

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<sup>72</sup> The model equations are presented in GAMS format for expositional purposes and are based on Lofgren et al(2002), to which the reader can refer to for a more detailed analysis. Sections with new additions or changes begin with “\*NEW==”, with the end of each of the new sections demarcated by “\*=====”.

CINV(C)	fixed investment goods
CT(C)	transaction service commodities
CTD(AC)	domestic transactions cost account
CTE(AC)	export transactions cost account
CTM(AC)	import transactions cost account

AAGR(A)	agricultural activities
ANAGR(A)	non-agricultural activities
CAGR(C)	agricultural commodities
CNAGR(C)	non-agricultural commodities
EN(INS DNG)	enterprises
FLAB(F)	laboUr
FLND(F)	land
FCAP(F)	capital

\*NEW=====

FNAT(F)	NATURAL RESOURCE (CRUDE OIL) FACTOR
FNOTNAT(F)	NON-NATURAL RESOURCE (CRUDE OIL) FACTORS

\*=====

;

### \*\*\*VARIABLES

CPI	consumer price index (PQ-based)
DPI	index for domestic producer prices (PDS-based)
DMPS	change in marginal propensity to save for selected inst
DTINS	change in domestic institution tax share
EG	total current government expenditure
EH(H)	household consumption expenditure
EXR	exchange rate
FSAV	foreign savings
GADJ	government demand scaling factor
GOVSHR	govt consumption share of absorption
GSAV	government savings
IADJ	investment scaling factor (for fixed capital formation)
INVSHR	investment share of absorption
MPS(INS)	marginal propensity to save for dom non-gov inst ins
MPSADJ	savings rate scaling factor
PA(A)	output price of activity a
PDD(C)	demand price for com'y c produced & sold domestically
PDS(C)	supply price for com'y c produced & sold domestically
PE(C)	price of exports
PINTA(A)	price of intermediate aggregate (non-energy intermediates if in non-oil and non-energy sectors)
PM(C)	price of imports
PQ(C)	price of composite good c
PVA(A)	value added price

PWE(C) world price of exports  
 PWM(C) world price of imports  
 PX(C) average output price  
 PXAC(A,C) price of commodity c from activity a

\*NEW=====

PFA(A) price of aggregate energy input and Aggregate VA Composite in non-oil and non-energy industry  
 PQFUEL(A) price of aggregate energy input in non-oil and non-energy industry  
 PVVA(A) price of aggregate non-crude VA in oil industry  
 PLUMPA(A) quantity of aggregate non-crude VA and aggregate intermediate input composite in oil industry

\*=====

QA(A) level of domestic activity  
 QD(C) quantity of domestic sales  
 QE(C) quantity of exports  
 QF(F,A) quantity demanded of factor f from activity a  
 QFS(F) quantity of factor supply  
 QG(C) quantity of government consumption  
 QH(C,H) quantity consumed of marketed commodity c by household h  
 QHA(A,C,H) quantity consumed of home commodity c fr act a by hhd h  
 QINT(C,A) quantity of intermediate demand for c from activity a  
 QINTA(A) quantity of aggregate intermediate input (excludes intermediate energy inputs in non-energy and non-crude activities)  
 QINV(C) quantity of fixed investment demand  
 QM(C) quantity of imports  
 QQ(C) quantity of composite goods supply  
 QT(C) quantity of trade and transport demand for commodity c  
 QVA(A) quantity of aggregate value added  
 QX(C) quantity of aggregate marketed commodity output  
 QXAC(A,C) quantity of output of commodity c from activity a

\*NEW=====

QQFUEL(A) quantity of aggregate energy input in non-crude and non-energy activity  
 QFA(A) quantity of aggregate energy input and aggregate VA Composite in non-crude and non-energy activity  
 QQCF(C,A) quantity of individual energy commodity input in non-crude and non-energy activity  
 QLUMPA(A) quantity of aggregate non-crude VA and aggregate intermediate input composite in oil industry  
 QVVA(A) quantity of aggregate non-crude VA in oil industry  
 PETROLEFF(A) percentage of fuel quantity units per unit of activity output (fuel efficiency)  
 FUELEFF(A) percentage of energy quantity units per unit of activity output (energy efficiency)

\*=====

TABS	total absorption
TINS(INS)	rate of direct tax on domestic institutions ins
TINSADJ	direct tax scaling factor
TRII(INS,INSP)	transfers to dom. inst. insdng from insdngp
WALRAS	savings-investment imbalance (should be zero)
WALRASSQR	Walras squared
WF(F)	economy-wide wage (rent) for factor f
WFDIST(F,A)	factor wage distortion variable
YF(F)	factor income
YG	total current government income
YIF(INS,F)	income of institution ins from factor f
YI(INS)	income of (domestic non-governmental) institution ins

;

### \*\*\*PARAMETERS APPEARING IN MODEL EQUATIONS

\*Parameters other than tax rates

alphaa(A)	shift parameter for top level CES function
alphaac(C)	shift parameter for domestic commodity aggregation fn
alphaq(C)	shift parameter for Armington function
alphat(C)	shift parameter for CET function
alphava(A)	shift parameter for CES activity production function

\*NEW=====

alphafa(A)	shift parameter for CES QFA function
alphafuel(A)	shift parameter for CES energy intermediates function

alphavva(AOI)	shift parameter for crude oil function
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\*=====

betah(A,C,H)	marg shr of hhd cons on home com c from act a
betam(C,H)	marg share of hhd cons on marketed commodity c
cwts(C)	consumer price index weights
deltaa(A)	share parameter for top level CES function
deltaac(A,C)	share parameter for domestic commodity aggregation fn
deltaq(C)	share parameter for Armington function
deltat(C)	share parameter for CET function
deltava(F,A)	share parameter for CES activity production function

\*NEW=====

deltafa(A)	share parameter for CES QFA function
deltafuel(C,F,A)	share parameter for energy intermediates function

deltavva(AOI) share parameter for crude oil function  
\*=====

dwts(C) domestic sales price weights  
gammah(A,C,H) per-cap subsist cons for hhd h on home com c fr act a  
gammam(C,H) per-cap subsist cons of marketed com c for hhd h

\*NEW=====

ica(CNF,A) non-energy intermediate input CNF per unit of aggregate non-energy  
intermediate input in non-oil and non-energy sectors  
icaa(C,A) share of intermediate input C per unit of aggregate intermediate in oil  
and energy industries

\*=====

inta(A) aggregate intermediate input coefficient  
iva(A) aggregate value added coefficient

\*NEW=====

ifa(A) aggregate QFA coefficient  
ivfa(F,A) non-oil factor ratio in oil industry total Value added  
ivvfa(FNOTNAT,AOI) crude oil factor ratio in total value added  
ivvva(AOI) ratio of QVVA in QLUMPA in oil industry  
ivvint(AOI) ratio of aggregate intermediate inputs in QLUMPA  
in oil industry

\*=====

icd(C,CP) trade input of c per unit of comm'y cp produced & sold dom'ly  
ice(C,CP) trade input of c per unit of comm'y cp exported  
icm(C,CP) trade input of c per unit of comm'y cp imported  
mps01(INS) 0-1 par for potential flexing of savings rates  
mpsbar(INS) marg prop to save for dom non-gov inst ins (exog part)  
qdst(C) inventory investment by sector of origin  
qbarg(C) exogenous (unscaled) government demand  
qbarinv(C) exogenous (unscaled) investment demand  
rhoa(A) CES top level function exponent  
rhoac(C) domestic commodity aggregation function exponent  
rhoq(C) Armington function exponent  
rhot(C) CET function exponent  
rhova(A) CES activity production function exponent

\*NEW=====

rhofa(A) CES QFA function exponent  
rhofuel(A) CES intermediate energy function exponent  
rhovva(AOI) CES in crude oil function exponent

\*=====

shif(INS,F) share of dom. inst'on i in income of factor f  
shii(INS,INSP) share of inst'on i in post-tax post-sav income of inst ip  
supernum(H) LES supernumerary income  
theta(A,C) yield of commodity C per unit of activity A  
tins01(INS) 0-1 par for potential flexing of dir tax rates  
trnsfr(INS,AC) transfers fr. inst. or factor ac to institution ins

**\*Tax rates**

ta(A) rate of tax on producer gross output value  
te(C) rate of tax on exports  
tf(F) rate of direct tax on factors (soc sec tax)  
tinsbar(INS) rate of (exog part of) direct tax on dom inst ins  
tm(C) rate of import tariff  
tq(C) rate of sales tax  
tva(A) rate of value-added tax

**\*\*\*EQUATIONS' NAMES**

**\*Price block=====**

PMDEF(C) domestic import price  
PEDEF(C) domestic export price  
PDDDEF(C) dem price for com'y c produced and sold domestically  
PQDEF(C) value of sales in domestic market  
PXDEF(C) value of marketed domestic output  
PADEF(A) output price for activity a  
  
CPIDEF consumer price index  
DPIDEF domestic producer price index

**\*NEW=====**

PINTADEF1(A) Price of Aggregate Intermediate input in crude oil or energy activities  
PINTADEF(A) price of aggregate non-energy intermediate input in non-oil and non-energy activities  
  
PVADEF1(A) Value Added Price in Energy sectors  
PVADEF(A) value added price in non-oil and non-energy sector  
PFADEF(A) QFA price in non-oil and non-energy sector  
PVADEF(AOI) price of QVVA  
PLUMPAPDEF(AOI) price of QLUMP(A) in oil industry  
PVADEF2(AOI) price of total VA in oil industry

\*=====

\*Production and trade block=====

COMPRDFN(A,C)	production function for commodity c and activity a
OUTAGGFN(C)	output aggregation function
OUTAGGFOC(A,C)	first-order condition for output aggregation function
CET(C)	CET function
CET2(C)	domestic sales and exports for outputs without both
ESUPPLY(C)	export supply
ARMINGTON(C)	composite commodity aggregation function
COSTMIN(C)	first-order condition for composite commodity cost min
ARMINGTON2(C)	comp supply for com's without both dom. sales and imports
QTDEM(C)	demand for transactions (trade and transport) services

\*NEW=====

LEOAGGINT(A)	Leontief aggregate non-energy intermediate demand in non-oil and non-energy industry
LEOAGGFA(A)	Leontief QFA demand in non-oil and non-energy industry
CESVAPRD(A)	CES value-added production function in non-oil industry
CESVAFOC(F,A)	CES value-added first-order condition in non-oil industry
CESQFA(A)	CES QFA production function in non-oil and non-energy industry
CESQFAFOC(A)	CES QFA first order condition in non-oil and non-energy industry
CESFUEL(A)	Intermediate energy input CES production function in non-oil and non-energy industry
CESFUELFOC(CF,A)	Intermediate energy input first order condition in non-oil and non-energy industry
INTDEM(CNF,A)	intermediate demand for non-energy commodity CNF from non-oil and non-energy activity
VAFOC1(AOI)	Non-Crude factor Demand FOC in oil industry
QLUMPALEO1(AOI)	Leontief Demand for QVVA in oil industry
QLUMPALEO2(AOI)	Demand for aggregate intermediate input in oil industry
AGGVAOIL(AOI)	quantity of total VA in oil industry
CESCRUDEFOC(FNAT,AOI)	CES crude oil factor first order condition in oil industry

VAPRD1(FNOTNAT,AOI) Non-Crude Factor Demand and QVVA in oil industry

CESCRUDE(AOI)	CES crude oil production function in oil industry
LEOAGGVA1(A)	Leontief Aggregate Value Added Demand in Energy Sectors
INTDEM1(C,A)	Intermediate demand for commodity C (including energy) from crude oil or energy activities
CET3(C)	DOMESTIC OUTPUT AND SALES FOR CRUDE OIL (homogenous)
ESUPPLY1(C)	EXPORT SUPPLY FOR CRUDE OIL (homogenous)

\*=====

\*Institution block =====

YFDEF(F)	factor incomes
YIFDEF(INS,F)	factor incomes to domestic institutions
YIDDEF(INS)	total incomes of domest non-gov't institutions
EHDEF(H)	household consumption expenditures
TRIIDEF(INS,INSP)	transfers to inst'on ins from inst'on insp
HMDDEM(C,H)	LES cons demand by hhd h for marketed commodity c
HADEM(A,C,H)	LES cons demand by hhd h for home commodity c fr act a
INVDEM(C)	fixed investment demand
GOVDEM(C)	government consumption demand
EGDEF	total government expenditures
YGDEF	total government income

\*System constraint block=====

FACEQUIL(F)	factor market equilibrium
CURACCBAL	current account balance (of RoW)
GOVBAL	government balance
TINSDEF(INS)	direct tax rate for inst ins
MPSDEF(INS)	marg prop to save for inst ins
SAVINVBAL	savings-investment balance
TABSEQ	total absorption
INVABEQ	investment share in absorption
GDABEQ	government consumption share in absorption
OBJEQ	Objective function

\*NEW=====

COM EQUIL(C)	composite commodity market equilibrium
PETROLEFF1(A)	fuel efficiency equation for crude oil and energy industries
FUELEFF1(A)	energy efficiency equation for crude oil and energy industries

PETROLEFF2(A) fuel efficiency equation for non-oil and non-energy industries  
 FUELEFF2(A) energy efficiency equation for non-oil and non-energy industries

\*=====

### \*\*\*EQUATION DEFINITIONS<sup>73</sup>

\*Notational convention inside equations:

\*Parameters and "invariably" fixed variables are in lower case.

\*"Variable" variables are in upper case.

\*Price block=====

PMDEF(C)\$CM(C)..

PM(C) =E= pwm(C)\*(1 + tm(C))\*EXR + SUM(CT, PQ(CT)\*icm(CT,C));

PEDEF(C)\$CE(C)..

PE(C) =E= pwe(C)\*(1 - te(C))\*EXR - SUM(CT, PQ(CT)\*ice(CT,C));

PDDDEF(C)\$CD(C).. PDD(C) =E= PDS(C) + SUM(CT, PQ(CT)\*icd(CT,C));

PQDEF(C)\$CD(C) OR CM(C)..

PQ(C)\*(1 - tq(c))\*QQ(C) =E= PDD(C)\*QD(C) + PM(C)\*QM(C);

PXDEF(C)\$CX(C).. PX(C)\*QX(C) =E= PDS(C)\*QD(C) + PE(C)\*QE(C);

PADEF(A).. PA(A) =E= SUM(C, PXAC(A,C)\*theta(A,C));

CPIDEF.. CPI =E= SUM(C, cwts(C)\*PQ(C)) ;

DPIDEF.. DPI =E= SUM(CD, dwts(CD)\*PDS(CD)) ;

\*NEW=====

PINTADEF1(A)\$AOI(A) OR AFU(A).. PINTA(A) =E= SUM(C, PQ(C)\*icaa(C,A)) ;

PINTADEF(A)\$ANO(A).. PINTA(A) =E= SUM(CNF, PQ(CNF)\*ica(CNF,A)) ;

<sup>73</sup> Each equation is demarcated from the next equation by “;” Each individual equation name is followed by “..”, after which the equation is defined.

$$PVADEF1(A)\$(AFU(A)).. PA(A)*(1-ta(A))*QA(A) =E= PVA(A)*QVA(A) + PINTA(A)*QINTA(A) ;$$

$$PFADEF(A)\$(ANO(A)).. PA(A)*(1-ta(A))*QA(A) =E= PFA(A)*QFA(A) + PINTA(A)*QINTA(A) ;$$

$$PLUMPADEF(AOI).. (1-ta(AOI))*QA(AOI)*PA(AOI) =E= PLUMPA(AOI)*QLUMPA(AOI) +sum(FNAT,(WF(FNAT)*SUM(FNATP,QF(FNAT,AOI))));$$

$$PVADEF(A)\$(ANO(A)).. PFA(A)*QFA(A) =E= PVA(A)*QVA(A) + PQFUEL(A)*QQFUEL(A) ;$$

$$PVVADEF(AOI)..PLUMPA(AOI)*QLUMPA(AOI) =E= QINTA(AOI)*PINTA(AOI)+PVVA(AOI)*QVVA(AOI) ;$$

$$PVADEF2(AOI).. QVA(AOI)*PVA(AOI) =E= sum(F, (WF(F)*QF(F,AOI)));$$

\*=====

\*Production and trade block=====

$$COMPRDFN(A,C)\$(theta(A,C)).. QXAC(A,C) + SUM(H, QHA(A,C,H)) =E= theta(A,C)*QA(A) ;$$

$$OUTAGGFN(C)\$(CX(C)).. QX(C) =E= alphaac(C)*SUM(A, deltaac(A,C)*QXAC(A,C) **(-rhoac(C)))**(-1/rhoac(C));$$

$$OUTAGGFOC(A,C)\$(deltaac(A,C)).. PXAC(A,C) =E= PX(C)*QX(C) * SUM(AP, deltaac(AP,C)*QXAC(AP,C)**(-rhoac(C)) )**(-1) *deltaac(A,C)*QXAC(A,C)**(-rhoac(C)-1);$$

$$CET(C)\$(CE(C) AND CD(C) AND CNO(C)).. QX(C) =E= alphas(C)*(deltat(C)*QE(C)**rhot(C) + (1 - deltat(C))*QD(C)**rhot(C))**1/rhot(C) ;$$

$$ESUPPLY(C)\$(CE(C) AND CD(C) AND CNO(C)).. QE(C) =E= QD(C)*((PE(C)/PDS(C))* ((1 - deltat(C))/deltat(C)))**1/(rhot(C)-1) ;$$

$$CET2(C)\$( (CD(C) AND CEN(C)) OR (CE(C) AND CDN(C)) ).. QX(C) =E= QD(C) + QE(C);$$

ARMINGTON(C)\$ (CM(C) AND CD(C))..

$$QQ(C) = E = \text{alphaq}(C) * (\text{deltaq}(C) * QM(C) ** (-\text{rhoq}(C)) + (1 - \text{deltaq}(C)) * QD(C) ** (-\text{rhoq}(C))) ** (-1/\text{rhoq}(C)) ;$$

COSTMIN(C)\$ (CM(C) AND CD(C))..

$$QM(C) = E = QD(C) * ((PDD(C)/PM(C)) * (\text{deltaq}(C)/(1 - \text{deltaq}(C)))) ** (1/(1 + \text{rhoq}(C))) ;$$

ARMINGTON2(C)\$ ( (CD(C) AND CMN(C)) OR (CM(C) AND CDN(C)) )..

$$QQ(C) = E = QD(C) + QM(C) ;$$

QTDEM(C)\$ CT(C)..

$$QT(C) = E = \text{SUM}(CP, \text{icm}(C,CP) * QM(CP) + \text{ice}(C,CP) * QE(CP) + \text{icd}(C,CP) * QD(CP)) ;$$

\*NEW=====

CESQFA(A)\$ ANO(A)..

$$QFA(A) = E = \text{alphafa}(A) * (\text{deltafa}(A) * QVA(A) ** (-\text{rhofo}(A)) + (1 - \text{deltafa}(A)) * QFUEL(A) ** (-\text{rhofo}(A))) ** (-1/\text{rhofo}(A)) ;$$

CESQFAFOC(A)\$ ANO(A)..

$$QVA(A) = E = QFUEL(A) * ((PQFUEL(A)/PVA(A)) * (\text{deltafa}(A)/(1 - \text{deltafa}(A)))) ** (1/(1 + \text{rhofo}(A))) ;$$

LEOAGGINT(A)\$ (ALEO(A)\$ (ANO(A) OR AFU(A))).. QINTA(A) = E = \text{inta}(A) \* QA(A) ;

CESCRUDEFOC(FNAT,AOI)..

$$QLUMPA(AOI) = E = QF(FNAT,AOI) * (((WF(FNAT) * \text{wfdist}(FNAT,AOI))/PLUMPA(AOI)) * (\text{deltavva}(AOI)/(1 - \text{deltavva}(AOI)))) ** (1/(1 + \text{rhoava}(AOI))) ;$$

LEOAGGFA(A)\$ (ALEO(A)\$ (ANO(A))).. QFA(A) = E = \text{ifa}(A) \* QA(A) ;

LEOAGGVA1(A)\$ ((ALEO(A))\$ (AFU(A))).. QVA(A) = E = \text{iva}(A) \* QA(A) ;

CESCRUDE(AOI).. QA(AOI) = E = \text{alphavva}(AOI) \* (\text{deltavva}(AOI) \* QlumpA(AOI) \*\* (-\text{rhoava}(AOI)) + (1 - \text{deltavva}(AOI)) \* (\text{SUM}(FNAT, QF(FNAT,AOI))) \*\* (-\text{rhoava}(AOI))) \*\* (-1/\text{rhoava}(AOI)) ;

CESVAPRD(A)\$ (ANO(A) OR AFU(A))..

$$QVA(A) = E = \text{alphava}(A) * (\text{SUM}(F, \text{deltava}(F,A) * QF(F,A) ** (-\text{rhoava}(A))) ** (-1/\text{rhoava}(A)) ;$$

CESVAFOC(F,A)\$deltava(F,A)\$ANO(A) OR AFU(A))..  
 WF(F)\*wfdist(F,A) =E=  
 PVA(A)\*(1-tva(A))  
 \* QVA(A) \* SUM(FP, deltava(FP,A)\*QF(FP,A)\*\*(-rhova(A)) )\*\*(-1)  
 \*deltava(F,A)\*QF(F,A)\*\*(-rhova(A)-1);

VAPRD1(FNOTNAT,AOI)..  
 QF(FNOTNAT,AOI) =E= ivvfa(FNOTNAT,AOI)\*QVVA(AOI);

VAFOC1(AOI)..  
 PVVA(AOI) =E= SUM(FNOTNAT, WF(FNOTNAT)\*ivvfa(FNOTNAT,AOI)) ;

INTDEM1(C,A)\$(icaa(C,A) AND (AOI(A) OR AFU(A))).. QINT(C,A) =E= icaa(C,A)\*QINTA(A);

INTDEM(CNF,A)\$ica(CNF,A) AND ANO(A)).. QINT(CNF,A) =E= ica(CNF,A)\*QINTA(A);

QLUMPALEO1(AOI)..QVVA(AOI) =E= ivvva(AOI)\*QLUMPA(AOI) ;

QLUMPALEO2(AOI)..QINTA(AOI) =E= ivvint(AOI)\*QLUMPA(AOI) ;

AGGVAOIL(AOI).. QVA(AOI) =E= sum(F, QF(F,AOI));

CESFUEL(A)\$ANO(A)..  
 QQFUEL(A) =E= alphafuel(A)  
 \*(SUM(CF, deltafuel(CF,A)\*QQCF(CF,A)\*\*(-rhofuel(A))) )\*\*(-1/rhofuel(A)) ;

CESFUELFOC(CF,A)\$ANO(A) AND deltafuel(CF,A) AND rhofuel(A))..  
 PQ(CF) =E= PQFUEL(A)  
 \* QQFUEL(A) \* SUM(CFP, deltafuel(CFP,A)\*QQCF(CFP,A)\*\*(-rhofuel(A)) )\*\*(-1)  
 \*deltafuel(CF,A)\*QQCF(CF,A)\*\*(-rhofuel(A)-1);

ESUPPLY1(C)\$CE(C) AND CD(C) AND CO(C))..  
 PE(C) =E= PDS(C);

CET3(C)\$CE(C) AND CD(C) AND CO(C))..  
 QX(C) =E= alphas(C)\*(deltat(C)\*QE(C)\*\*1 +  
 (1 - deltat(C))\*QD(C)\*\*1)\*\*(1/1);

\*=====

\*Institution block =====

YFDEF(F).. YF(F) =E= SUM(A, WF(F)\*wfdist(F,A)\*QF(F,A));

YIFDEF(INSDF)\$shif(INSDF)..

YIF(INSDF) =E= shif(INSDF)\*((1-tf(f))\*YF(F) - trnsfr('ROW',F)\*EXR);

YIDEF(INSDNG)..

YI(INSDNG) =E=

SUM(F, YIF(INSDNG,F)) + SUM(INSDNGP, TRII(INSDNG,INSDNGP))  
+ trnsfr(INSDNG,'GOV')\*CPI + trnsfr(INSDNG,'ROW')\*EXR;

TRIIDEF(INSDNG,INSDNGP)\$shii(INSDNG,INSDNGP)..

TRII(INSDNG,INSDNGP) =E= shii(INSDNG,INSDNGP)  
\* (1 - MPS(INSDNGP)) \* (1 - TINS(INSDNGP))\* YI(INSDNGP);

EHDEF(H)..

EH(H) =E= (1 - SUM(INSDNG, shii(INSDNG,H))) \* (1 - MPS(H))  
\* (1 - TINS(H)) \* YI(H);

HMDDEM(C,H)\$betam(C,H)..

PQ(C)\*QH(C,H) =E=

PQ(C)\*gammam(C,H)  
+ betam(C,H)\*( EH(H) - SUM(CP, PQ(CP)\*gammam(CP,H))  
- SUM((A,CP), PXAC(A,CP)\*gammah(A,CP,H))) ;

HADEM(A,C,H)\$betah(A,C,H)..

PXAC(A,C)\*QHA(A,C,H) =E=

PXAC(A,C)\*gammah(A,C,H)  
+ betah(A,C,H)\*(EH(H) - SUM(CP, PQ(CP)\*gammam(CP,H))  
- SUM((AP,CP), PXAC(AP,CP)\*gammah(AP,CP,H))) ;

INVDEM(C)\$CINV(C).. QINV(C) =E= IADJ\*qbarinv(C);

GOVDEM(C).. QG(C) =E= GADJ\*qbarg(C);

YGDEF..

YG =E= SUM(INSDNG, TINS(INSDNG)\*YI(INSDNG))  
+ SUM(f, tf(F)\*YF(F))  
+ SUM(A, tva(A)\*PVA(A)\*QVA(A))  
+ SUM(A, ta(A)\*PA(A)\*QA(A))  
+ SUM(C, tm(C)\*pwm(C)\*QM(C))\*EXR  
+ SUM(C, te(C)\*pwe(C)\*QE(C))\*EXR  
+ SUM(C, tq(C)\*PQ(C)\*QQ(C))  
+ SUM(F, YIF('GOV',F))  
+ trnsfr('GOV','ROW')\*EXR;

EGDEF..

EG =E= SUM(C, PQ(C)\*QG(C)) + SUM(INSNDNG, trnsfr(INSNDNG,'GOV'))\*CPI;

\*System constraint block=====

FACEQUIL(F).. SUM(A, QF(F,A)) =E= QFS(F);

CURACCBAL..

SUM(C, pwm(C)\*QM(C)) + SUM(F, trnsfr('ROW',F)) =E=  
SUM(C, pwe(C)\*QE(C)) + SUM(INSND, trnsfr(INSND,'ROW')) + FSAV;

GOVBAL.. YG =E= EG + GSAV;

TINSDEF(INSNDNG)..

TINS(INSNDNG) =E= tinsbar(INSNDNG)\*(1 + TINSADJ\*tins01(INSNDNG))  
+ DTINS\*tins01(INSNDNG);

MPSDEF(INSNDNG)..

MPS(INSNDNG) =E= mpsbar(INSNDNG)\*(1 + MPSADJ\*mps01(INSNDNG))  
+ DMPS\*mps01(INSNDNG);

SAVINVBAL..

SUM(INSNDNG, MPS(INSNDNG) \* (1 - TINS(INSNDNG)) \* YI(INSNDNG))  
+ GSAV + FSAV\*EXR =E=  
SUM(C, PQ(C)\*QINV(C)) + SUM(C, PQ(C)\*qdst(C)) + WALRAS;

TABSEQ..

TABS =E=  
SUM((C,H), PQ(C)\*QH(C,H)) + SUM((A,C,H), PXAC(A,C)\*QHA(A,C,H))  
+ SUM(C, PQ(C)\*QG(C)) + SUM(C, PQ(C)\*QINV(C)) + SUM(C, PQ(C)\*qdst(C));

INVABEQ.. INVSHR\*TABS =E= SUM(C, PQ(C)\*QINV(C)) + SUM(C, PQ(C)\*qdst(C));

GDABEQ.. GOVSHR\*TABS =E= SUM(C, PQ(C)\*QG(C));

OBJEQ.. WALRASSQR =E= WALRAS\*WALRAS ;

\*NEW=====

COMEQUIL(C)..

QQ(C) =E= SUM(A, QQCF(C,A)) + SUM(A, QINT(C,A)) + SUM(H, QH(C,H)) + QG(C)  
+ QINV(C) + qdst(C) + QT(C);

\*=====

\*NEW===FUEL AND ENERGY EFFICIENCY=====

PETROLEFF1(A)\$ (AOI(A) OR AFU(A)).. PETROLEFF(A) =E=  
100\*SUM(CPETROL,QINT(CPETROL,A))/QA(A);

FUELEFF1(A)\$ (AOI(A) OR AFU(A)).. FUELEFF(A) =E= 100\*SUM(CF,QINT(CF,A))/QA(A);

PETROLEFF2(A)\$ (ANO(A)).. PETROLEFF(A) =E= 100\*SUM(CPETROL,QQCF(CPETROL,A))/QA(A);

FUELEFF2(A)\$ (ANO(A)).. FUELEFF(A) =E= 100\*SUM(CF,QQCF(CF,A))/QA(A);

**\*\*\*\*\*END OF MODEL\*\*\*\*\***

## IV.11.4 Sensitivity Analysis

**Table 23 Varying the Elasticity of Substitution Between Composite Value Added and Composite Fuel Input**

**Elasticity of Substitution Between Composite Value Added and Composite Fuel Input  
(Base = 0.4)**

	$\theta_{fa}=0.2$	Change from Base				$\theta_{fa}=0.7$	Change from Base			
	base	tax flexq	tax flexw	SI flexq	SI flexw	base	tax flexq	tax flexw	SI flexq	SI flexw
Private Consumption	3973.7	2.2	6.1	-6.7	-5.7	3973.7	3.5	7.6	-5.6	-4.6
Investment	2062.1			20.0	23.2	2062.1			20.6	24.1
EXPORTS	1577.3	11.2	12.1	13.0	13.9	1577.3	12.7	13.7	14.5	15.4
IMPORTS -	1249.8	14.2	15.3	16.4	17.5	1249.8	16.0	17.3	18.3	19.5
Real GDP	7410.7	1.2	3.3	2.0	3.4	7410.7	1.9	4.1	2.7	4.2
Skilled Labour wage			-9.7		-7.0			-10.3		-7.7
Unskilled Labour wage			-9.0		18.4			-9.3		19.1
Agricultural Mixed Income Labour wage										
Non-agricultural Mixed Income Labour Wage										
Skilled Labour Quantity Employed										
Unskilled Labour Quantity Employed										
Agricultural Mixed Income Labour Quantity Employed										
Non-agricultural Mixed Income Labour Quantity employed										

Values are presented as percentage changes from base model.

**Table 24 Varying the Elasticity of Substitution Between Individual Factors of Production**

Elasticity of Substitution Between Factors of Production (Base = 0.5)										
	$\theta_{va}=0.3$					$\theta_{va}=0.99$				
	base	Change from Base				base	Change from Base			
	tax flexq	tax flexw	SI flexq	SI flexw	tax flexq	tax flexw	SI flexq	SI flexw		
Private Consumption	3973.7	4.1	6.8	-5.1	-4.4	3973.7	0.2	6.9	-8.4	-5.8
Investment	2062.1			20.9	22.0	2062.1			19.4	25.1
EXPORTS	1577.3	12.4	13.0	14.3	14.7	1577.3	11.4	13.1	13.1	14.9
IMPORTS	1249.8	15.6	16.4	18.0	18.5	1249.8	14.4	16.5	16.5	18.8
Real GDP	7410.7	2.2	3.7	3.1	3.7	7410.7	0.1	3.7	0.9	3.9
Skilled Labour wage			-9.7		-6.7			-10.1		-8.1
Unskilled Labour wage			-8.0		38.4			-9.6		4.6
Agricultural Mixed Income Labour wage			-2.6		-14.6			-7.7		-13.9
Non-agricultural Mixed Income Labour Wage			-7.5		-0.5			-9.4		-6.2
Skilled Labour Quantity Employed		-5.0			-3.4		-11.2		-9.7	
Unskilled Labour Quantity Employed		-2.1			8.2		-6.6		2.8	
Agricultural Mixed Income Labour Quantity Employed		-2.2			-5.2		-14.1		-17.2	
Non-agricultural Mixed Income Labour Quantity employed		-4.1			-1.2		-12.1		-9.5	

Values are presented as percentage changes from base model.

## IV.11.5 Full Social Accounting Matrix<sup>74</sup>

		<b>Commodities</b>						
		agriculture, farming, and forestry	husbandry , poultry and fishery	crude oil and natural gas	mining	electricity	utility gas	water
<b>Production</b>	farming, forestry and horticulture	76202	0	0	0	0	0	0
	husbandry poultry and fishery	0	47373	0	0	0	0	0
	crude oil and natural gas	0	0	114,785	0	0	0	0
	Mining	0	0	0	4820	0	0	0
	food and tobacco	0	0	0	0	0	2	0
	textile, clothing and leather	0	0	0	0	0	0	0
	wooden products and paper	0	0	0	0	0	0	0
	chemical s and plastic	0	0	0	0	6	3	0
	Fuel	0	0	0	0	0	0	0
	non-metal minerals	0	0	0	0	0	0	0
	other industries	0	0	0	0	39	3	0
	water, electricity and gas	0	0	0	0	17141	6512	4299
	construction	0	0	0	0	0	0	0
	wholesale and retail trade	0	0	0	0	0	0	0
	hotels and restaurants	0	0	0	0	0	0	0
	communication and transportation	0	0	0	0	0	0	0
	financial intermediaries	0	0	0	0	0	0	0
	real estate and business services	0	0	0	0	0	0	0
	public services and social security	31	0	0	0	4	0	0
	education	0	0	0	0	0	0	0
healthcare	5	0	0	0	0	0	0	
others	0	0	0	0	525	0	0	

<sup>74</sup>The SAM is presented in order of rows, with the column payments to each row displayed fully before introducing new rows. Hence the row entries for production sectors are given first, followed by the row entries for commodities, etc. Sections of the SAM where by construction no entries occur (e.g. intersection of production rows and institution's columns) are omitted. For a general outline of the structure of the SAM see the diagram presented in section IV.2. Values are presented in billions of Rials.

# Commodities

		food , tobacco and textiles	Industry excluding metal and equipment	lubricants and coke	motor spirit	burning oil	gas oil	fuel oil
<b>Production</b>	farming, forestry and horticulture	0	0	0				
	husbandry poultry and fishery	6901	0	0				
	crude oil and natural gas	0	0	0				
	Mining	0	0	0				
	food and tobacco	76160	0	0				
	textile, clothing and leather	41684	0	0				
	wooden products and paper	0	8890	0				
	chemical s and plastic	0	30579	0	517			
	Fuel	0	1167	4282	6073	771	1842	3982
	non-metal minerals	0	19199	0				
	other industries	0	27990	0				
	water, electricity and gas	0	64	0				
	construction	0	0	0				
	wholesale and retail trade	1752	0	0				
	hotels and restaurants	0	0	0				
	communication and transportation	0	0	0				
	financial intermediaries	0	0	0				
	real estate and business services	0	0	0				
	public services and social security	14	12	0				
	education	0	0	0				
healthcare	0	0	0					
others	0	0	0					

# Commodities

		liquid gas	other fuels	metal products and equipment	construction	wholesale and retail trade	repairs and household sales	hotels and restaurants
Production	farming, forestry and horticulture			0	69	16	0	0
	husbandry poultry and fishery			0	13	12	3	6
	crude oil and natural gas			0	0	0	0	0
	Mining			0	8	0	0	92
	food and tobacco			0	0	87	99	255
	textile, clothing and leather			0	0	27	59	196
	wooden products and paper			0	0	17	32	37
	chemicals and plastic	2864		0	0	41	125	88
	Fuel	780	128	0	0	0	0	0
	non-metal minerals			0	0	10	168	142
	other industries			76499	0	169	327	286
	water, electricity and gas			0	372	11	0	2
	construction			0	81348	5	0	133
	wholesale and retail trade			0	0	121113	11347	0
	hotels and restaurants			0	0	470	0	12316
	communication and transportation			0	0	19	69	202
	financial intermediaries			0	0	3	0	2
	real estate and business services			0	0	547	0	0
	public services and social security			92	0	550	0	255
	education			0	0	137	0	0
	healthcare			0	0	436	0	762
others			0	653	0	371	0	

		Commodities								Total
		transportation and storage	communication	financial intermediaries	insurance	real estate	business services	public services and social security	other social services	
Production	farming, forestry and horticulture	0	0	0	0	0	183	0	0	76470
	husbandry poultry and fishery	0	0	0	0	0	171	0	0	54479
	crude oil and natural gas	0	0	0	0	0	0	0	0	114785
	Mining	18	0	0	0	0	59	0	0	4997
	food and tobacco	20	0	0	0	26	212	0	0	76861
	textile, clothing and leather	7	0	0	0	4	68	0	0	42045
	wooden products and paper	2	0	0	0	0	65	0	0	9043
	chemicals and plastic	2	0	0	0	0	82	0	0	34308
	Fuel	0	0	0	0	0	0	0	0	19023
	non-metal minerals	20	0	0	0	9	10	0	0	19558
	other industries	2	0	0	0	3	85	0	0	105403
	water, electricity and gas	0	0	0	0	49	560	0	0	29010
	construction	35	0	0	0	0	0	0	0	81521
	wholesale and retail trade	0	227	0	0	0	0	0	0	134439
	hotels and restaurants	0	52	0	0	0	0	0	0	12838
	communication and transportation	69906	8541	0	0	0	9	0	0	78746
	financial intermediaries	0	0	17838	2178	0	0	0	0	20021
	real estate and business services	0	0	0	0	84472	18362	0	8	103389
	public services and social security	418	0	0	0	0	0	58278	2	59656
	education	0	0	0	0	0	0	0	32579	32716
healthcare	0	8	0	0	0	7	0	27434	28652	
others	471	278	0	0	1022	0	0	10139	13459	

		<b>Production</b>						
		farming, forestry and horticulture	husbandry poultry and fishery	crude oil and natural gas	Mining	food and tobacco	textile, clothing and leather	wooden products and paper
<b>Commodities</b>	agriculture, farming, and forestry	7770	11778	177	3	27701	0	2092
	husbandry, poultry and fishery	62	4253	1	0	16532	6940	224
	crude oil and natural gas	0	0	460	0	0	0	0
	mining	13	23	0	31	27	0	0
	electricity	362	98	109	142	1656	1494	112
	utility gas	4	6	1	1	108	10	21
	water	679	26	29	53	43	13	4
	food, tobacco and textiles	1005	10624	314	178	6915	13716	148
	Industry excluding metal and equipment	5141	1370	1126	308	2427	1025	2219
	lubricant and coke	141	114	19	19	66	24	13
	motor spirit	114	84	9	11	18	8	5
	burning oil	13	16	0	0	17	5	2
	gas oil	332	106	28	56	113	23	10
	fuel oil	0	2	0	2	71	13	6
	liquid gas	7	18	0	1	8	3	0
	other fuels	0	2	7	8	3	2	1
	metal products and equipment	2846	127	557	198	236	151	77
	construction	11	74	8	58	33	10	7
	wholesale and retail trade	0	188	0	0	369	481	231
	repairs and household sales	232	26	2	2	67	28	17
	hotels and restaurants	249	19	31	21	116	46	15
	transportation and storage	57	27	459	151	212	57	32
	communication	10	19	67	11	20	16	18
	financial intermediaries	61	16	2	18	201	63	50
	insurance	14	20	9	3	9	6	4
	real estate	1	14	1	3	65	50	21
	business services	2344	104	27	104	584	252	126
	public services and social security	0	0	0	0	0	0	0
	other social services	640	193	51	67	80	39	23

		<b>Production</b>						
		chemical s and plastic	Fuel	non-metal minerals	other industries	water, electricity and gas	construction	wholesale and retail trade
<b>Commodities</b>	agriculture, farming, and forestry	43	1	0	0	359	313	700
	husbandry , poultry and fishery	6506	0	0	7	0	0	0
	crude oil and natural gas	18	9950	0	0	896	0	0
	mining	3	5	2885	3144	6	1347	0
	electricity	282	60	487	1124	3276	42	1207
	utility gas	148	68	131	333	1243	8	178
	water	55	8	11	29	243	58	129
	food , tobacco and textiles	765	19	329	659	206	1573	1422
	Industry excluding metal and equipment	2687	825	3476	39346	1874	32452	1515
	lubricants and coke	747	24	272	228	31	92	293
	motor spirit	559	73	20	68	28	120	301
	burning oil	101	2	9	7	0	9	9
	gas oil	243	23	72	172	96	134	320
	fuel oil	225	39	394	161	138	10	24
	liquid gas	452	14	27	27	8	0	5
	other fuels	45	114	12	15	0	0	16
	metal products and equipment	211	147	422	17760	3101	5724	1271
	construction	19	0	43	63	440	1387	227
	wholesale and retail trade	643	2	124	855	0	0	2103
	repairs and household sales	16	26	66	193	126	111	744
	hotels and restaurants	119	38	69	301	46	0	15
	transportation and storage	0	141	142	451	207	1742	6620
	communicatio n	20	6	74	122	41	4	338
	financial intermediaries	245	23	216	415	90	163	6715
	insurance	22	1	7	71	11	5	174
	real estate	48	0	18	155	1870	123	466
	business services	560	46	544	1966	267	405	424
	public services and social security	0	0	0	0	26	731	0
	other social services	87	39	74	381	210	13	1608

## Production

		hotels and restaurants	communication and transportation	financial intermediaries	real estate and business services	public services and social security	education	healthcare	others
Commodities	agriculture, farming, and forestry	1518	192	15	99	313	145	111	21
	husbandry , poultry and fishery	1909	0	0	0	92	0	108	0
	crude oil and natural gas	0	0	0	0	0	0	0	0
	mining	0	0	0	0	22	20	0	0
	electricity	23	102	115	190	838	176	206	169
	utility gas	10	111	69	19	86	29	87	66
	water	7	36	26	53	58	48	53	68
	food , tobacco and textiles	1614	621	90	80	1414	254	729	296
	Industry excluding metal and equipment	205	5193	484	7082	4544	676	1533	1760
	lubricants and coke	1	1050	5	258	8	19	45	16
	motor spirit	3	2160	44	17	161	78	52	59
	burning oil	6	6	1	4	3	23	17	26
	gas oil	8	1075	9	4	34	59	46	44
	fuel oil	0	1112	0	0	0	0	0	25
	liquid gas	37	3	2	2	21	21	9	19
	other fuels	0	0	2	0	4	2	0	5
	metal products and equipment	27	2211	0	3076	1996	551	1170	550
	construction	8	217	123	1188	132	293	51	76
	wholesale and retail trade	0	0	0	0	0	0	0	0
	repairs and household sales	33	4820	115	96	505	64	21	58
	hotels and restaurants	0	228	40	1	350	165	19	8
	transportation and storage	0	3295	83	136	419	251	565	86
	communication	14	88	102	395	776	179	92	57
	financial intermediaries	76	3877	816	277	228	65	73	69
	insurance	6	158	173	141	18	50	61	5
	real estate	2	219	46	685	214	485	418	324
	business services	3	218	254	542	407	175	97	161
	public services and social security	0	200	38	12	931	69	12	17
	other social services	8	382	616	252	418	488	892	814

	Transaction Costs			Institutions						
	Domestic	Exports	Imports	Household Urban	Household Rural	Private Enterprises	Government Enterprises	Government	Oil Fund	
Commodities	agriculture, farming, and forestry	0	0	0	24899	14054	0	0	857	0
	husbandry , poultry and fishery	0	0	0	1221	10282	0	0	0	0
	crude oil and natural gas	0	0	0	0	0	0	0	0	0
	mining	0	0	0	11	18	0	0	0	0
	electricity	0	0	0	3270	2154	0	0	0	0
	utility gas	0	0	0	2887	157	0	0	0	0
	water	0	0	0	1557	1013	0	0	0	0
	food , tobacco and textiles	0	0	0	81273	45443	0	0	0	0
	Industry excluding metal and equipment	0	0	0	25741	9215	0	0	0	0
	lubricants and coke	0	0	0	470	118	0	0	0	0
	motor spirit				4049	938				0
	burning oil				329	675				0
	gas oil				111	79				0
	fuel oil				0	8				0
	liquid gas				144	175				0
	other fuels				2	0				0
	metal products and equipment	0	0	0	17139	5610	0	0	0	0
	construction	0	0	0	617	499	0	0	0	0
	wholesale and retail trade	93525	7621	17645	75	23	0	0	0	0
	repairs and household sales	0	0	0	4315	917	0	0	0	0
	hotels and restaurants	0	0	0	10943	3184	0	0	189	0
	transportation and storage	37818	3698	7214	9288	4763	0	0	832	0
	communication	0	0	0	5313	1324	0	0	0	0
	financial intermediaries	0	0	0	485	149	0	0	0	0
	insurance	0	0	0	591	151	0	0	0	0
	real estate	0	0	0	69989	9097	0	0	0	0
	business services	0	0	0	1724	758	0	0	5484	0
public services and social security	0	0	0	872	525	0	0	54845	0	
other social services	0	0	0	13251	5477	0	0	42526	0	

		Savings/ Investme	Rest of World	Total
<b>Commodities</b>	agriculture, farming, and forestry	12368	6773	112302
	husbandry , poultry and fishery	6137	680	54954
	crude oil and natural gas	217	103654	115195
	mining	1805	1195	10555
	electricity	0	77	17771
	utility gas	0	796	6577
	water	0	0	4299
	food , tobacco and textiles	6178	14798	190663
	Industry excluding metal and equipment	5218	11815	169257
	lubricants and coke		1532	5603
	motor spirit		0	8979
	burning oil		0	1279
	gas oil		0	3194
	fuel oil		2733	4963
	liquid gas		3064	4069
	other fuels		0	241
	metal products and equipment	92807	2768	160733
	construction	76879	0	82463
	wholesale and retail trade	0	0	123886
	repairs and household sales	0	0	12600
	hotels and restaurants	0	1341	17553
	transportation and storage	0	649	79395
	communication	0	0	9106
	financial intermediaries	0	3445	17838
	insurance	0	1526	3236
	real estate	1271	0	85585
	business services	2335	2	19913
	public services and social security	0	0	58278
	other social services	997	877	70503

# Production

		farming, forestry and horticulture	husbandry poultry and fishery	crude oil and natural gas	Mining	food and tobacco	textile, clothing and leather	wooden products and paper
<b>Transaction Costs</b>	Domestic	0	0	0	0	0	0	0
	Exports	0	0	0	0	0	0	0
	Imports	0	0	0	0	0	0	0
<b>Factors of Production</b>	Skilled Labour	1594	2497	1871	801	3214	2999	838
	Unskilled Labour	108	169	197	105	113	105	30
	Agricultural labour mixed income	5008	3139	0	0	0	0	0
	Agricultural mixed income land	5009	12554	0	0	0	0	0
	Non agricultural mixed income	0	0	83	77	1329	4313	664
	Capital	46895	5633	31538	2546	14841	9957	2004
	Crude oil			74957				
<b>Taxes and Subsidies</b>	Imports	0	0	0	0	0	0	0
	Activities	-4252	1141	2645	18	-333	197	29
	Sales	0	0	0	0	0	0	0
	Income	0	0	0	0	0	0	0
<b>Institutions</b>	Household Urban	0	0	0	0	0	0	0
	Household Rural	0	0	0	0	0	0	0
	Private Enterprises	0	0	0	0	0	0	0
	Government Enterprises	0	0	0	0	0	0	0
	Government	0	0	0	0	0	0	0
	Oil Fund							
<b>Savings/ Investment</b>		0	0	0	0	0	0	0
<b>Rest of the World</b>		0	0	0	0	0	0	0
<b>Total</b>		76470	54479	114785	4997	76861	42045	9043

		<b>Production</b>						
		chemical s and plastic	Fuel	non-metal minerals	other industries	water, electricity and gas	construction	wholesale and retail trade
<b>Transaction Costs</b>	Domestic	0	0	0	0	0	0	0
	Exports	0	0	0	0	0	0	0
	Imports	0	0	0	0	0	0	0
<b>Factors of Production</b>	Skilled Labour	3237	802	2874	10476	4140	8858	8952
	Unskilled Labour	112	28	99	365	359	7443	511
	Agricultural labour mixed income	0	0	0	0	0	0	0
	Agricultural mixed income land	0	0	0	0	0	0	0
	Non agricultural mixed income	344	0	582	4302	190	8824	22786
	Capital	15747	6059	5461	17674	9338	8831	72844
	Crude oil	0	0					
<b>Taxes and Subsidies</b>	Imports	0		0	0	0	0	0
	Activities	0	440	619	4533	144	1000	2521
	Sales	0		0	0	0	0	0
	Income	0		0	0	0	0	0
<b>Institutions</b>	Household Urban	0		0	0	0	0	0
	Household Rural	0		0	0	0	0	0
	Private Enterprises	0		0	0	0	0	0
	Government Enterprises	0		0	0	0	0	0
	Government	0		0	0	0	0	0
	Oil Fund							
<b>Savings/ Investment</b>		0		0	0	0	0	0
<b>Rest of the World</b>		0		0	0	0	0	0
<b>Total</b>		34308	19023	19558	105403	29010	81521	134439

# Production

		hotels and restaurants	communication and transportation	financial intermediaries	real estate and business services	public services and social security	education	healthcare	others
<b>Transaction Costs</b>	Domestic	0	0	0	0	0	0	0	0
	Exports	0	0	0	0	0	0	0	0
	Imports	0	0	0	0	0	0	0	0
<b>Factors of Production</b>	Skilled Labour	909	10408	7940	3811	26118	23690	9999	2959
	Unskilled Labour	49	222	248	173	2333	816	559	303
	Agricultural labour mixed income	0	0	0	0	0	0	0	0
	Agricultural mixed income land	0	0	0	0	0	0	0	0
	Non agricultural mixed income	957	13383	135	2725	0	356	777	2738
	Capital	5155	25673	8066	81556	17342	3564	10504	2820
	Crude oil								
<b>Taxes and Subsidies</b>	Imports	0	0	0	0	0	0	0	0
	Activities	250	1486	363	515	-129	-95	346	-159
	Sales	0	0	0	0	0	0	0	0
	Income	0	0	0	0	0	0	0	0
<b>Institutions</b>	Household Urban	0	0	0	0	0	0	0	0
	Household Rural	0	0	0	0	0	0	0	0
	Private Enterprises	0	0	0	0	0	0	0	0
	Government Enterprises	0	0	0	0	0	0	0	0
	Government	0	0	0	0	0	0	0	0
	Oil Fund								
<b>Savings/ Investment</b>		0	0	0	0	0	0	0	0
<b>Rest of the World</b>		0	0	0	0	0	0	0	0
<b>Total</b>		12838	78746	20021	103389	59656	32716	28652	13459

# Commodities

		agriculture, farming, and forestry	husbandry , poultry and fishery	crude oil and natural gas	mining	electricity	utility gas	water
<b>Transaction Costs</b>	Domestic	23268	7368	40	3717	0	0	0
	Exports	1692	104	370	588	0	0	0
	Imports	2419	13	0	440	0	0	0
<b>Factors of Production</b>	Skilled Labour	0	0	0	0	0	0	0
	Unskilled Laobur	0	0	0	0	0	0	0
	Agricultural labour mixed income	0	0	0	0	0	0	0
	Agricultural mixed income land	0	0	0	0	0	0	0
	Non agricultrual mixed income	0	0	0	0	0	0	0
	Capital	0	0	0	0	0	0	0
	Crude oil							
<b>Taxes and Subsidies</b>	Imports	-1002	9	0	95	0	0	0
	Activities	0	0	0	0	0	0	0
	Sales	0	0	0	0	0	0	0
	Income	0	0	0	0	0	0	0
<b>Institutions</b>	Household Urban	0	0	0	0	0	0	0
	Household Rural	0	0	0	0	0	0	0
	Private Enterprises	0	0	0	0	0	0	0
	Government Enterprises	0	0	0	0	0	0	0
	Government	0	0	0	0	0	0	0
	Oil Fund							
<b>Savings/ Investment</b>		0	0	0	0	0	0	0
<b>Rest of the World</b>		9687	87	0	895	56	57	0
<b>Total</b>		112302	54954	115195	10555	17771	6577	4299

# Commodities

		food , tobacco and textiles	Industry excluding metal and equipment	lubricants and coke	motor spirit	burning oil	gas oil	fuel oil
<b>Transaction Costs</b>	Domestic	48012	31216	413	567	508	1352	417
	Exports	4187	2527	320	0	0	0	565
	Imports	2483	7207	361	484	0	0	0
<b>Factors of Production</b>	Skilled Labour	0	0	0				
	Unskilled Laobur	0	0	0				
	Agricultural labour mixed income	0	0	0				
	Agricultural mixed income land	0	0	0				
	Non agricultrual mixed income	0	0	0				
	Capital	0	0	0				
	Crude oil	0	0	0				
<b>Taxes and Subsidies</b>	Imports	696	4615	13	-2919	0	0	0
	Activities	0	0	0				
	Sales	0	0	0				
	Income	0	0	0				
<b>Institutions</b>	Household Urban	0	0	0				
	Household Rural	0	0	0				
	Private Enterprises	0	0	0				
	Government Enterprises	0	0	0				
	Government	0	0	0				
	Oil Fund							
<b>Savings/ Investment</b>		0	0	0				
<b>Rest of the World</b>		8774	35789	215	4257	0		
<b>Total</b>		190663	169257	5603	8979	1279	3194	4963

# Commodities

		liquid gas	other fuels	metal products and equipment	construction	wholesale and retail trade	repairs and household sales	hotels and restaurants
<b>Transaction Costs</b>	Domestic	65	113	14287	0	0	0	0
	Exports	360	0	607	0	0	0	0
	Imports	0	0	11452	0	0	0	0
<b>Factors of Production</b>	Skilled Labour			0	0	0	0	0
	Unskilled Labour			0	0	0	0	0
	Agricultural labour mixed income			0	0	0	0	0
	Agricultural mixed income land			0	0	0	0	0
	Non agricultural mixed income			0	0	0	0	0
	Capital			0	0	0	0	0
	Crude oil			0	0	0	0	0
<b>Taxes and Subsidies</b>	Imports	0	0	5565	0	0	0	0
	Activities			0	0	0	0	0
	Sales			0	0	0	0	0
	Income			0	0	0	0	0
<b>Institutions</b>	Household Urban			0	0	0	0	0
	Household Rural			0	0	0	0	0
	Private Enterprises			0	0	0	0	0
	Government Enterprises			0	0	0	0	0
	Government			0	0	0	0	0
	Oil Fund			0	0	0	0	0
<b>Savings/ Investment</b>				0	0	0	0	0
<b>Rest of the World</b>		0		52231	0	216	0	2779
<b>Total</b>		4069	241	160733	82463	123886	12600	17553

# Commodities

		transportation and storage	communication	financial intermediaries	insurance	real estate	business services	public services and social security	other social services
<b>Transaction Costs</b>	Domestic	0	0	0	0	0	0	0	0
	Exports	0	0	0	0	0	0	0	0
	Imports	0	0	0	0	0	0	0	0
<b>Factors of Production</b>	Skilled Labour	0	0	0	0	0	0	0	0
	Unskilled Laobur	0	0	0	0	0	0	0	0
	Agricultural labour mixed income	0	0	0	0	0	0	0	0
	Agricultural mixed income land	0	0	0	0	0	0	0	0
	Non agricultrual mixed income	0	0	0	0	0	0	0	0
	Capital	0	0	0	0	0	0	0	0
	Crude oil	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0
<b>Taxes and Subsidies</b>	Imports	0	0	0	0	0	0	0	0
	Activities	0	0	0	0	0	0	0	0
	Sales	0	0	0	0	0	0	0	0
	Income	0	0	0	0	0	0	0	0
<b>Institutions</b>	Household Urban	0	0	0	0	0	0	0	0
	Household Rural	0	0	0	0	0	0	0	0
	Private Enterprises	0	0	0	0	0	0	0	0
	Government Enterprises	0	0	0	0	0	0	0	0
	Government	0	0	0	0	0	0	0	0
	Oil Fund	0	0	0	0	0	0	0	0
<b>Savings/ Investment</b>		0	0	0	0	0	0	0	0
<b>Rest of the World</b>		8494	0	0	1058	0	40	0	341
<b>Total</b>		79395	9106	17838	3236	85585	19913	58278	70503

		Transaction Costs			Factors of Production						
		Domestic	Exports	Imports	Skilled Labour	Unskilled Laobur	Agricultural labour mixed income	Agricultural mixed income land	Non agricultrual mixed income	Capital	Crude oil
<b>Transaction Costs</b>	Domestic				0	0	0	0	0	0	
	Exports				0	0	0	0	0	0	
	Imports				0	0	0	0	0	0	
<b>Factors of Production</b>	Skilled Labour				0	0	0	0	0	0	
	Unskilled Laobur				0	0	0	0	0	0	
	Agricultural labour mixed income				0	0	0	0	0	0	
	Agricultural mixed income land				0	0	0	0	0	0	
	Non agricultrual mixed income				0	0	0	0	0	0	
	Capital				0	0	0	0	0	0	
	Crude oil										
<b>Taxes and Subsidies</b>	Imports				0	0	0	0	0	0	
	Activities				0	0	0	0	0	0	
	Sales				0	0	0	0	0	0	
	Income				0	0	0	0	0	0	
<b>Institutions</b>	Household Urban				107478	8511	0	0	51141	144524	
	Household Rural				32260	6189	8147	17563	13424	50093	
	Private Enterprises				0	0	0	0	0	133338	
	Government Enterprises				0	0	0	0	0	76093	
	Government				0	0	0	0	0	0	74390
	Oil Fund										567
<b>Savings/ Investment</b>				0	0	0	0	0	0	0	
<b>Rest of the World</b>				2891	315	0	0	0	0	0	
<b>Total</b>		131344	11319	24859	142629	15015	8147	17563	64565	404048	74957

		Taxes and Subsidies				Institutions					
		Imports	Activities	Sales	Income	Household Urban	Household Rural	Private Enterprises	Government Enterprises	Government	Oil Fund
<b>Transaction Costs</b>	Domestic	0	0	0	0	0	0	0	0	0	0
	Exports	0	0	0	0	0	0	0	0	0	0
	Imports	0	0	0	0	0	0	0	0	0	0
<b>Factors of Production</b>	Skilled Labour	0	0	0	0	0	0	0	0	0	0
	Unskilled Labour	0	0	0	0	0	0	0	0	0	0
	Agricultural labour mixed income	0	0	0	0	0	0	0	0	0	0
	Agricultural mixed income land	0	0	0	0	0	0	0	0	0	0
	Non agricultural mixed income	0	0	0	0	0	0	0	0	0	0
	Capital	0	0	0	0	0	0	0	0	0	0
	Crude oil										
<b>Taxes and Subsidies</b>	Imports	0	0	0	0	0	0	0	0	0	0
	Activities	0	0	0	0	0	0	0	0	0	0
	Sales	0	0	0	0	0	0	0	0	0	0
	Income	0	0	0	0	27353	9687	0	0	0	0
<b>Institutions</b>	Household Urban	0	0	0	0	0	0	12157	21309	3914	0
	Household Rural	0	0	0	0	0	0	1616	2154	5277	0
	Private Enterprises	0	0	0	0	0	0	0	0	0	0
	Government Enterprises	0	0	0	0	0	0	792	0	0	0
	Government	7073	11279	0	37040	0	0	3928	12948	0	0
	Oil Fund										
<b>Savings/ Investment</b>	0	0	0	0	41127	10234	114846	41493	32734	567	
<b>Rest of the World</b>	0	0	0	0	29	8	0	696	0	0	
<b>Total</b>	7073	11279	0	37040	349074	136735	133339	78600	146658	567	

		Savings/ Investme	Rest of World	Total
<b>Transaction Costs</b>	Domestic	0	0	131344
	Exports	0	0	11319
	Imports	0	0	24859
<b>Factors of Production</b>	Skilled Labour	0	3642	142629
	Unskilled Laobur	0	568	15015
	Agricultural labour mixed income	0	0	8147
	Agricultural mixed income land	0	0	17563
	Non agricultrual mixed income	0	0	64565
	Capital	0	0	404048
	Crude oil			74957
<b>Taxes and Subsidies</b>	Imports	0	0	7073
	Activities	0	0	11279
	Sales	0	0	0
	Income	0	0	37040
<b>Institutions</b>	Household Urban	0	40	349074
	Household Rural	0	12	136735
	Private Enterprises	0	1	133339
	Government Enterprises	0	1715	78600
	Government	0	0	146658
	Oil Fund			567
<b>Savings/ Investment</b>		0	-34789	206212
<b>Rest of the World</b>		0	0	128915
<b>Total</b>		206212	128915	

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