A MACROECONOMIC STUDY OF THE COSTS, CONSEQUENCES AND POLICY IMPLICATIONS OF SECTORAL LABOUR REALLOCATION

by

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Abstract

This thesis uses a macroeconomic approach to study labour adjustments following sector-specific shocks. I develop a general model, investigate its dynamic adjustment process and apply it to study the Canadian economy in 2002–2006. This episode is an interesting case study because it features a significant labour reallocation to the resource sector and away from manufacturing, precipitated by an increase in global commodity prices and an associated exchange rate appreciation.

The results establish that impediments to the adjustment process are economically significant in the aggregate for this episode, imposing costs of up to three percent of output during the transition. These findings augment several studies that suggest individual workers can face large and persistent earnings losses during job turnover. However, unlike previous research, I use the search and matching approach — which incorporates explicit labour market frictions — to uncover the sources of these costs for the macroeconomy. The findings emphasize that job loss itself is not particularly important quantitatively, but rather the non-transferability of skills during job turnover is a key concern.

Finally, I investigate how labour market policy impacts the economy's response to sector-specific shocks by analyzing a counterfactual policy change in unemployment benefits and improved skill acquisition through faster learning and training subsidies. The

results reveal interesting policy trade-offs. First, I find that increasing unemployment benefits prolongs the economy's adjustment, reduces employment, output and welfare and increases unemployment incidence and duration. However, because this policy impacts high-productivity and low-productivity sectors differently, it shifts the composition of the remaining jobs towards high-productivity sectors, thereby raising aggregate productivity and also reduces wage inequality. Second, I find that faster skill acquisition has the potential to deliver large economic gains in the long-run, but requires up-front investment costs which entail reduced economic performance in the short-run.

Acknowledgements

Dedication

To Colette: For allowing me the freedom to follow my dreams, believing in me through this journey and providing unwavering support.

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Chapter 1

Introduction

1.1 Motivation

The economy continually reallocates productive resources. Labour adjustment is an important part of this reallocation and involves significant job turnover through the ongoing destruction and creation of jobs. For firms, profit opportunities provide incentives for production and these incentives respond to factors such as new technologies, macroeconomic developments and government policy. For workers, people often move around between jobs, between employment and unemployment and in and out of the labour market, based largely on their opportunities, ambitions, skills and luck.

The continual churn of labour markets is well known and well documented. Less well known, however, is that sectoral job changes play an integral part of this recurrent labour adjustment. Recent empirical evidence finds that workers frequently change sectors.[1] In the U.S., for example, more than 10 percent of workers do so annually. Moreover, this phenomenon has increased significantly in recent decades, as workers today are more than

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[1]See Kambourov and Manovskii (2008). The term 'sector' can represent industries or occupations.

twice as likely to change sectors, as compared to similar workers 30 years ago.

The prevalence and rising importance of sectoral job changes is remarkable in light of the long-standing evidence that, for individuals, these job changes often result in large and persistent earnings losses — particularly for those with intervening unemployment spells.[2] If the costs of switching sectors can be high and have remained so, then what explains the rising sectoral mobility of workers? One nascent explanation is that sector-specific shocks have become more frequent and more severe (Kambourov and Manovskii, 2008). For the purpose of this thesis, a 'sector-specific shock' can be defined quite broadly as any unanticipated change in the relative profitability of production across sectors. This includes disturbances hitting a particular sector, but also aggregate developments that directly affect sectors differently. Examples include: demand shocks; technological change; persistent commodity price or exchange rate movements; new government regulation or policies such as trade liberalization.

These types of shocks raise several compelling issues that will play an important part of the analysis in this thesis. For individuals, such shocks can entail a costly adjustment process and often have differential effects on low-skill and high-skill workers. At the sectoral level, labour reallocation can lead to equilibrium wage spillovers between sectors. And at the aggregate level, because sectors can differ significantly in their productive capacities, the resulting reallocation can have important impacts on output and productivity. However, there is currently only scant evidence to assess the aggregate importance of sectoral labour reallocation costs. Such evidence is interesting in its own right, but

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[2]For U.S. evidence, see *e.g.* McLaughlin and Bils (2001), Fallick (1996), Jacobson et al. (1993), Topel (1993). For Canadian evidence, see Morissette et al. (2007) and Galarneau and Stratychuk (2002).

would also be policy-relevant because policymakers are often called on to compensate losing individuals and sectors during acute labour adjustments.

For all of these reasons, it is crucial to improve our understanding of the sectoral labour reallocation process. This thesis, therefore, investigates the process of labour market adjustments driven by sector-specific shocks, the costs these adjustments entail and potential policy prescriptions to deal with them.

1.2 Key Research Questions and Main Results

This thesis contains three essays that study sectoral labour adjustment. The first essay addresses two questions: How does the economy reorganize production after sector-specific shocks? And what are the equilibrium implications of these shocks for other sectors? To answer these questions, I develop a multi-sector equilibrium search and matching model. I demonstrate that the model is useful for studying sectoral labour adjustments driven by various factors, such as persistent relative price shocks, trade liberalization and technological change. The salient effect of these 'shocks' is simply that they change the relative profitability of production across certain sectors.

Explaining the adjustment process is straight-forward. In sectors where production becomes more profitable, there is relatively more entry and over time employment increases. Typically, a positive shock makes high-skill production in these sectors more attractive, so additional resources are devoted to productivity-improving, innovative efforts to chase these new profits. This results in relatively more high-skill production and rewards these

high-skill workers with larger wage gains. In the model, sector-specific productivity shocks capture these effects by changing the relative match surpluses across and within sectors, generating a labour reallocation process that is consistent with those observed in many actual labour adjustments.

The model's *reservation wage effect* is an important feature which describes the equilibrium interactions between sectors, such as how sector-specific shocks can propagate across the economy. Essentially, workers' ability to search for jobs in other sectors represents their 'outside option', which is conveniently summarized by their reservation wage. A positive shock in one sector will raise workers' outside option, causing them to raise their reservation wages. This ultimately increases bargained wages and the higher cost of labour acts as a negative spillover for firms' hiring decisions in other sectors.

The second essay applies this general model to a specific case study of a recent labour adjustment in the Canadian economy. The model application is motivated by the rapid and persistent relative price changes in commodities and exchange rates that began in 2002, affecting the sectoral compositions of many countries. Canada's adjustment is particularly attractive to study because it features a dramatic sectoral labour reallocation due to large employment shares in the resource and manufacturing sectors — both of which were highly responsive to these developments.

The goal of this essay is to quantify the magnitude and sources of adjustment costs in the most affected sectors. The results reveal that impediments to the adjustment process are economically significant in the aggregate for this episode, imposing costs of up to

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three percent of output during the transition. These costs occur mainly in the first three years after the shock. I consider two potential sources of costs — search frictions and non-transferable skills between jobs. The findings show that the non-transferability of skills is the predominant contributor to these aggregate costs, while search frictions play a relatively minor role.

Intuitively, these results can be thought of in the following manner: In the aggregate, the main cost to society is not that a worker loses her job. A typical worker is re-employed reasonably quickly and the associated earnings losses and foregone production are relatively small. What is much more important, however, is that she may potentially be re-employed at a lower wage in her new job because she has difficulty fully transferring her skills to a new work environment. As a result, she will likely require some time on the job before her productivity improves, so her lower output and wage may persist for a significant period of time. In this sense, what matters for the economy, is not the job loss *per se*, but rather the skills that are lost in the job transition.

Given that the costs of labour adjustment episodes can be important in the aggregate, the third essay investigates the role of labour market policy in addressing the situation. I use the model to perform a counterfactual policy experiment to assess how changes in unemployment benefits would have impacted allocations, welfare and the speed of the Canadian economy's adjustment to the shocks. The results show that increasing the replacement rate of unemployment benefits from 55 to 65 percent of earnings would have prolonged the adjustment process by roughly two years, making the adjustment 23 percent longer. Furthermore, because increasing unemployment benefits lessens the incentives

for job creation, this policy would have reduced employment, output and welfare and increased unemployment incidence and duration.

The results also highlight that labour market policy can have asymmetric sectoral effects that impact aggregate productivity. In the example considered, higher unemployment benefits crowd out jobs in low-productivity sectors more than high-productivity sectors. This shifts the composition of the remaining jobs towards high-productivity sectors, which raises aggregate productivity. Finally, I investigate improved skill acquisition through faster learning and training subsidies and find that the associated economic gains are potentially quite large.

1.3 Related Literature and Contributions

The sectoral labour adjustment literature related to this thesis can be classified into two broad strands: the more micro-focused labour economics approach and the more macro-focused search and matching approach.

The labour economics approach typically takes the individual worker or job as the unit of analysis and exploits rich microlevel data using empirical techniques, such as reduced-form econometrics, adjustment cost models, and more recently, structural estimation.[3] This work has provided valuable insights to our understanding of the job turnover process. There are, however, two important limitations of this research approach and its findings. First, while the fates of individuals have received significant attention, much less is known

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[3]For references from reduced-form see footnote 2; adjustment cost models see Hamermesh (1989) or Caballero et al. (1997); and structural approaches see Lee and Wolpin (2006).

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about the aggregate implications of sectoral labour adjustment as such research remains rare. Second, and more fundamental, this research generally fails to give an explicit role to important frictions in the labour market. This oversight is particularly unsatisfying because it is precisely these frictions which are responsible for the costly individual labour adjustment findings in the first place. This omission occurs because reduced-form econometrics lacks a theoretical model foundation, while the well-founded structural model approaches are often so complex that they need to assume frictionless Walrasian labour markets for tractability purposes. For the latter approach to match the model to the data, researchers often require unrealistically high non-pecuniary costs of switching sectors for individual workers, which essentially stand in for the labour market frictions at the heart of the matter.

My thesis contributes to improving our knowledge of the macroeconomic aspects of sectoral labour reallocation, using an equilibrium framework that gives an explicit role to key labour market frictions. This framework is the search and matching approach, which is now a standard tool macroeconomists use to analyze labour market fluctuations and the impacts of labour market policies. This approach was formalized by Diamond (1982a,b); Mortensen (1982a,b); Pissarides (1979, 1985); and Mortensen and Pissarides (1994).[4] Search and matching models have been useful in analyzing a variety of macro, labour and monetary issues such as: unemployment, vacancies and worker flows; business cycles; wage dispersion; and the welfare costs of inflation.

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[4]Pissarides (2000) provides a thorough overview of the basic model and various extensions. Rogerson, Shimer and Wright (2005) and Yashiv (2006) survey the recent labour market search literature.

Pissarides' (2000) baseline labour search and matching model emphasizes the importance of decentralized, frictional trade for understanding aggregate labour market dynamics, through the resource-intensive and uncertain process of recruitment and job search. In this environment, search frictions generate equilibrium unemployment because despite the simultaneous efforts of firms looking to hire workers and people looking for jobs, it requires time, money and luck to find productive matches to begin new production.

My thesis contributes two key extensions to this baseline model. The first extension is multisector production and search. This is important because it demonstrates how sector-specific shocks propagate to the rest of the economy through the reservation wage effect described above.[5] This propagation mechanism is interesting in its own right theoretically and can also be viewed as a potential explanation for recent empirical findings by Beaudry et al. (2007). Their paper finds that the sectoral composition in U.S. cities have equilibrium spillovers on the level of real wages, after controlling for observable characteristics. In other words, *ceteris paribus*, it may be that higher real wages are paid in cities with a higher proportion of good jobs, because these workers' outside options are superior to those of similarly-situated workers in other cities where good jobs are relatively more scarce.

The second extension is an 'innovation' process that allows matches to acquire skills

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[5]There are other examples in the search and matching literature that develop multi-sector production, such as Davis (2001) and Acemoglu (2001). These papers are concerned with the theoretical efficiency of the decentralized search equilibrium, when firms can freely enter into jobs of different quality (which is a 'sector' in my model) and matching occurs through a single aggregate matching function. They independently demonstrate that an equilibrium may feature too few high-productivity jobs. My model differs in the objective (I am interested in the economy's adjustment process after sector-specific shocks) and modeling choices (e.g. my model features sector-specific: matching functions; separation rates; and productivity shocks.) The relevant chapters provide more details.

and become more productive. This extension accomplishes two tasks. First, it parsimoniously models low-skill and high-skill workers in this environment to analyze how they might be impacted differently by sector-specific shocks, as suggested from empirical work by Keane and Prasad (1996), Autor et al. (1998), and Trefler (2004), among others. Second, the innovation process amplifies the model's response to productivity shocks and captures how reallocation within a sector can impact aggregate output and productivity. The amplification occurs through an *innovation effect* which works as follows: Because high-skill production becomes more profitable after a positive sector-specific shock, firms in this sector attempt to take advantage of this by increasing their productivity-enhancing investments. With new investment in this sector, over time, the composition of production gradually shifts favorably to higher-skill jobs. As a result, the production increase is larger than the direct effect of the sector's productivity shock.

To my knowledge, this model mechanism is new to the literature, and is particularly relevant given the recent controversy regarding the baseline model's amplification properties.[6] Shimer (2005) prompted intense research interest in this topic by arguing that a reasonably-calibrated version of the baseline model does not come close to exhibiting the volatility in unemployment and vacancies observed in the data in response to productivity shocks. The within-firm and within-sector innovation process in my model extension offers a potential avenue for reasonably-sized productivity shocks to produce realistic model responses within this class of models.

Mortensen (2000) also develops a search model where firms can make match-specific

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[6]E.g. see Shimer (2005); Hagedorn and Manovskii (2006); and Mortensen and Nagypal (2007).

investments. A key modeling difference between this paper and my work is how wages are determined. Mortensen uses wage-posting, whereas I use Nash bargaining. He demonstrates that firms' different equilibrium wage offer strategies can result in endogenous productivity differences across jobs for ex-ante homogeneous workers. Overall, his main result is that including match-specific investments gives a more empirically-plausible shape for the equilibrium wage distribution. My focus is quite different. I primarily investigate the model's adjustment to sector-specific shocks for employment, unemployment and the relative wages of high and low-skill workers.[7]

More generally, my model extensions incorporate heterogeneous jobs and skill acquisitions so the model captures several facts identified by empirical labour studies which are absent in the baseline model: 1) separated workers commonly switch sectors in their subsequent job; 2) separated workers can experience wage losses or gains in their subsequent job; 3) high wage earners are more likely to suffer wage losses in their subsequent job; and 4) wages rise with job tenure.[8]

Overall the contribution of the first essay is to develop a general, flexible model that captures several important features of sectoral labour reallocation in a unified, tractable, equilibrium framework that explicitly describes the transition dynamics. This model allows one to simultaneously study the aggregate, sectoral, and distributional impacts of labour adjustment following sector-specific disturbances.

In the second essay, the quantitative application of the model to study the Canadian

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[7] I also focus on the equilibrium where all firms in a sector make the same investment decision.

[8] For U.S. evidence see, e.g. Kambourov and Manovskii (2008), Farber (1999) and Topel (1993); for Canadian evidence: Garlarneau and Stratychuck (2002).

economy demonstrates there can be significant aggregate adjustment costs during sectoral labour reallocation. This is an important finding because while several studies find that sectoral adjustment costs may be large for individuals, there are few studies which establish their aggregate importance in an equilibrium framework.[9] Lee and Wolpin (2006) is an exception. However, because they do not explicitly model labour market frictions their results do not shed light on the sources of these aggregate costs. Relative to this work, my results suggest that non-transferable skills are an important contributor to the aggregate costs of labour adjustment and that search frictions are much less important quantitatively.

The third essay performs counterfactual policy analysis of Canada's sectoral adjustment and shows that raising unemployment benefits prolongs the economy's adjustment to shocks. This result is consistent with empirical findings from OECD data (Scarpetta, 1996) and computational results by Ljungqvist and Sargent (1998), but the mechanism driving my results is new. Ljungqvist and Sargent (1998) argue that relative to the U.S., European labour markets — which offer higher unemployment benefits — are inflexible and more susceptible to what they describe as the increase in 'economic turbulence' since the 1980's. They model this turbulence as an exogenous (and *ad hoc*) increase in the mean and variance of skill loss during unemployment. Workers respond by lowering their search intensity which prolongs the adjustment process. In my model, worker search intensity is fixed, which highlights the effects of unemployment benefits on search activity on the other side of the market. Absent any change in workers' behavior, higher unemployment

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[9]Trefler (2004) is tangentially-related research which studies the impacts of the Canada–U.S. Free Trade Agreement, and suggests that the transitional costs of labour adjustment may have been significant for the Canadian manufacturing sector.

benefits reduce the match surplus, which lowers the return to job posting. With firms recruiting less, the economy takes longer to reach its new steady-state after a shock occurs.

My model results also emphasize that unemployment benefits can impact the sectoral composition of jobs, and therefore, aggregate productivity. This basic result occurs in other search models, but again the mechanism here is different. In Acemoglu (2001), unemployment benefits help mitigate a hold-up problem because firms make capital investments prior to matching. Furthermore, in Acemoglu and Shimer (2000), unemployment benefits encourage riskier search strategies and increase the average quality of matches. The basic intuition for the mechanism in my model carries over from recent amplification controversy for the one-sector search model noted above (e.g. Shimer, 2005). A shock of a given size – in this case an increase in workers' reservation wages because of more generous unemployment benefits – has a larger impact when the match surplus is smaller. Less productive sectors have smaller surpluses, so their job creation decisions are affected more than those of high productivity sectors.

The remainder of the thesis proceeds as follows: Chapter 2 presents the model, which I apply to Canadian data in Chapter 3. Chapter 4 investigates the role of labour market policy in the adjustment process and Chapter 5 concludes.

Chapter 2

The Dynamics of Sectoral Labour Adjustment

2.1 Introduction

Sectoral issues are becoming increasingly important. Recent evidence suggests sector-specific shocks are becoming more frequent and more severe and are associated with workers making sectoral job changes more often. At the same time, policymakers in developed economies are struggling to design appropriate policies to address structural adjustments in the labour market, such as the secular decline in manufacturing employment.

With this renewed focus on sectoral concerns, it is remarkable that from an academic perspective, there is surprisingly little research that studies the mechanics of how the economy reorganizes production after sector-specific shocks, whether these shocks may impose significant adjustment costs at the aggregate level, and what labour market policies may be effective in ameliorating the situation.

To lay the foundation for my analysis into these issues, this chapter develops a model to

study the aggregate, sectoral, and distributional impacts of labour adjustment following unanticipated, sector-specific productivity shocks. I solve the model, derive the main analytical results and use simple quantitative examples to clearly illustrate the model's adjustment mechanisms. I demonstrate that the model's key properties are consistent with facts from sectoral labour adjustments caused by a variety of factors. The model's transition dynamics are also quite tractable, which facilitates applying the model to the data, as demonstrated in the next chapter.

The model makes two key extensions to the baseline Pissarides (2000) labour search and matching model. The first extension is multisector production and search. The second extension is an 'innovation' process that allows matches to acquire skills and become more productive. The model retains the well-studied features and short-comings of the basic one-sector model without innovation investment, and the extensions provide some important new insights from two mechanisms that generate inter-sectoral and intra-sectoral reallocation of workers during labour adjustments.

Inter-sectoral reallocation operates through a *reservation wage effect*, which describes how changes in workers' outside options cause sector-specific shocks to spillover to other sectors. In the model, workers search simultaneously in multiple sectors of the economy. Therefore, when a shock changes labour market conditions in one sector, this affects workers' value of search, causing them to update their reservation (and ultimately, their bargained) wages. This changes the cost of labour, impacts profitability and affects firms' incentives to hire workers in other sectors of the economy. The varied recruiting responses in different sectors changes the sectoral composition of job postings and ultimately result

in inter-sectoral labour reallocation.

Workers not only move between sectors after sector-specific shocks, they can also move within a sector, as firms substitute between low and high-skill production. This intra-sectoral labour reallocation operates through an *innovation effect*. In the model, all new matches begin production as low-skill, but may become high-skill through a costly and uncertain productivity-enhancing investment, which could represent spending such as research and development (R&D) or on-the-job training. After a sector receives a positive productivity shock, high-skill production becomes relatively more profitable, so firms expect a larger return from these investments. As a result, they invest more resources into innovation with their low-skill workers. This accelerates skill acquisition, endogenously raises the share of high-skill production in the sector and amplifies the model's response to productivity shocks.

Several studies relate to the model developed here. In addition to those described in the literature review of the introductory chapter, there are other approaches in the international trade literature which model sectoral reallocation.[1] These models typically ignore unemployment and labour market frictions to make long-run statements about the impacts of reallocation. In this chapter, in addition to addressing the long-run steady-state impacts, I focus on the short-run adjustment, which generates important costs for individual displaced workers and is a relevant concern for policymakers. Finally, none of

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[1]Melitz (2003) is a prominent example featuring intra-sectoral reallocation that can be contrasted with the innovation effect here. In Melitz's model increasing trade exposure improves a sector's productivity through selection effects. My model features within-firm productivity improvements, which aggregate to change the sectoral composition of production. The 'Dutch disease' literature models inter-sectoral reallocation, but not due to changes in workers reservation wages. Corden (1984) summarizes earlier contributions.

the related papers model productivity-enhancing investment and skill acquisition.

The chapter is organized as follows: Section 2 presents some facts from sectoral adjustment episodes. Sections 3 and 4 present the model and its transition dynamics. Section 5 quantitatively illustrates the model's mechanisms and Section 6 concludes. Proofs and derivations are in Appendix C.

2.2 Facts from Sectoral Labour Adjustment Episodes

As described in the introductory chapter, sectoral labour adjustments can be caused by a variety of seemingly disparate factors. This section presents some new evidence and draws on existing findings from the experiences of several countries for clearly-defined events related to: 1) persistent relative price shocks (i.e. energy prices and exchange rates); 2) trade liberalization; and 3) broader technological change. I summarize three important common elements of these adjustments regarding inter-sectoral and intra-sectoral labour reallocation and relative wage effects between low and high-skill workers.

While initially, these different episodes appear unrelated, the key uniting characteristic these events share is that they change a sector's production possibilities and the relative profitability between and within sectors. Typically, in sectors where production possibilities expand and become more profitable, there is increased entry of new firms, increased employment in the sector and firms undertake costly productivity-enhancing investments to capture the new profit opportunities.

To be more concrete, consider some examples. Both a reduction in trade barriers and

a rapid exchange rate depreciation effectively improve market access for exporters. Firms respond to these new profit opportunities by entering and undertaking investments to improve their productivity. Similarly, a large increase in energy prices makes resource sector jobs more profitable, spurring new investments and employment in the sector. Another example is improvements in computing technologies. Such improvements disproportionately benefit information-intensive sectors, so there is entry and employment growth in these sectors. Similarly, because these new technologies increase the relative productivity differences between low and high-skill workers, firms invest in these technologies and increase their share of high-skill production and workers. Overall, in these episodes there is a general flow of workers towards the positively affected sector, there are resources that flow towards high-skill production within these sectors, and the real wage gains are concentrated on these high-skill workers.

Fact 1: *Inter-Sectoral Labour Adjustment*

Consider the case of energy price shocks and the reallocation of labour across sectors that results from them. Figure 1, reproduced from Blanchard and Gali (2007), identifies four oil price shocks: 1973, 1979, 1999, and 2002.[2] These shocks are a particularly convenient way to investigate inter-sectoral labour reallocation, because they are relatively discrete episodes with some persistence. In addition, these shocks can reasonably be treated as unanticipated and exogenous from the point of view of the economies studied here. I analyze internationally-comparable employment data for the G7 countries (Canada, France, Germany, Italy, Japan, U.K. and U.S.), from the OECD's Structural

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[2]They define a shock as an increase in the real oil price of more than 50 percent which persists longer than four quarters (the real price is the West Texas Intermediate price deflated by the U.S. GDP deflator).

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Analysis Database.

Figure 2 separates employment in the G7 economies into manufacturing and non-manufacturing sectors during these oil prices shocks.[3] The figure clearly shows the asymmetric negative impact on manufacturing employment following oil price shocks. In the four years following the oil shocks, there was a substantial drop in manufacturing employment, which fell by an average of 7.6 percent.

To determine if the drop in manufacturing employment is driven by a particular country, Figure 3 disaggregates the employment dynamics for each country's manufacturing sector before and after the oil price shocks. The results hold quite generally as the drop occurred in all countries except Italy, where employment rose a mere 0.6 percent.[4]

Figure 4 disaggregates the non-manufacturing employment data by country. It shows that in the four years after the shocks, non-manufacturing employment continued to grow in all G7 economies, at or only slightly below trend. Not surprisingly, while there is a general increase in employment in the non-manufacturing sectors, using more detailed data, reveals that the largest employment gains occur in the resource sector. Figure 5 shows the average response in the U.S. economy after the four oil price shocks. Figure 6 shows the particularly dramatic response in Canada during the most recent oil price shock, which the next chapter studies in detail.

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[3]I use the dates identified by Blanchard and Gali (2007) and normalize employment to 100 at each shock, so the relative changes are comparable. The reported results are averaged over the three shocks, since the same trends occur in each episode (1973, 1979, and 1999). Due to the lag in reporting internationally-comparable employment data, the results for the 2002 shock are not yet available.

[4]There are likely two effects at play here. First, manufacturers are the most energy-intensive producers so their input costs increase more than in other sectors. Second, there is generally an endogenous monetary policy response which raises interest rates to fight the inflationary impacts of the oil price shocks. Manufacturers are more sensitive to interest rates as their sales are often financed by borrowing.

Facts 2 and 3: *Intra-Sectoral Labour Adjustment; and Relative Wage Gains for High-Skill Workers*

Not only do sector-specific shocks lead to a movement of workers between sectors, but there is also often a shift from low to high-skill workers within sectors that become relatively more profitable after the shock. Keane and Prasad (1996) find such a shift following oil price shocks, as the relative employment and wages of high-skill workers increased. They use individual-level panel data from the National Longitudinal Survey of Youth covering 1966–1981 and control for individual fixed effects and sample selection bias. In the next chapter, I also find that wage gains were concentrated in the upper end of the distribution in the Canadian resource sector following the most recent global commodity price shock.

Verhoogen (2008) studies another important relative price change: the exchange rate. In 1994, a rapid depreciation of the Mexican peso expanded opportunities for exporters by lowering the price of their output in international markets. Firms responded by increasing the quality of goods produced to export abroad. This quality upgrading, resulted in a relative increase in employment and wages of high-skilled workers in the Mexican manufacturing sector.

Other research in the international trade context provides similar results of so-called, 'skill-upgrading' or 're-tooling' following trade liberalizations. Using detailed plant-level data, Trefler (2004) finds a relative increase in the employment of high-skill relative to low-skill workers in Canadian manufacturing industries following the Canada-U.S. Free

Trade Agreement. For this episode, the relative employment shift to high-skill workers is associated with investments that increased productivity within plants, particularly for those that entered export markets after trade liberalization (Lileeva and Trefler, 2007; and Lileeva, 2007). Several other recent papers for a variety of countries suggest that trade liberalization increases firms' incentives to invest in productivity-enhancing investments (e.g. on-the-job training, R&D, technological adoption) and raises productivity within plants.[5]

Finally, similar employment dynamics occurred with technological changes from computerization and general R&D, where considerable intra-sector employment shifts occurred towards high-skill labour. These effects were largest in computer-intensive industries, particularly after 1970 (Autor et al. 1998). Indeed, in the U.K. most of the aggregate economy's skill upgrading was due to employing more skilled workers within continuing establishments and was related to computer usage (Haskel and Hayden, 1999). Similar results hold in the manufacturing sector and are correlated with computer and R&D investment (Berman et al. 1994). Finally, Machin and Reenen (1998) link the within-industry increases in the proportion of skilled-workers in several OECD countries to broader technological change through R&D intensity.

2.3 Multisector Search Model with Innovation

This section presents a general search and matching model of labour reallocation following unanticipated sector-specific productivity shocks. In this environment, search

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[5]See Costantini and Melitz (2007); Aw et al. (2007); and Bustos (2005).

frictions result in equilibrium unemployment because firms and workers use resources and take time to locate partners before new production can begin. I add two key extensions relative to the baseline model of Pissarides (2000, Ch. 1). The first is multisector production and search, which effectively links labour market conditions across sectors and generates sectoral wage and hiring spillovers (leading to inter-sectoral labour reallocation). The second extension is a process of innovation and skill acquisition, which is motivated by the empirical evidence provided in section 2.2 that suggests an upgrading process may be important part of the labour adjustment after sector-specific shocks. This extension also formalizes the idea that acquiring skills in a job typically involves a costly investment process, where successful skill acquisition is uncertain and the match-specific component of the skills are not transferable to new jobs. Including innovation amplifies the model's response to productivity shocks through endogenous shifts in the skill-intensity of production (generating intra-sectoral labour reallocation). Unlike previous multisector versions of the model, I focus not only on the steady-state, but also on transition dynamics between steady-states. In addition, I allow for sector-specific separation rates and use sector-specific matching functions to capture the fact that job-finding and job-filling rates vary significantly by sector.

2.3.1 Environment and General Overview

This subsection provides a basic overview of the model's key ingredients and timing of events. The details are described in subsequent sections. I focus first on the model's steady state; later sections consider sector-specific shocks and the model's transition dynamics.

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Time is discrete with an infinite horizon. There are multiple sectors of the economy indexed by $i \in \{1, 2, \ldots, I\}$ that produce a non-storable good. The model features two types of agents: workers and firms. Each type of agent is *ex ante* identical, infinitely-lived and risk-neutral, discounting future payoffs at rate δ.[6] Agents are either matched and productive, or searching for a partner to begin production.

Figure 7 describes the timing of events in a given period for unmatched agents. A recruiting stage begins the period when unemployed workers collect unemployment benefits and search for jobs, and firms post vacancies in decentralized labour markets. The matching stage follows when a subset of firms with vacancies and unemployed workers are brought together in pairwise matches. Once matched, the pair bargain over the worker's wage and the firm declares its intended innovation level. If there is agreement, production begins next period as a low-skill match.

Figure 8 describes the timing for producing agents. Production begins the period and wage payments follow. Firms in low-skill matches can then attempt to innovate to improve their productivity. At the end of each period, some low-skill matches successfully acquire match-specific skills and become high-skill. Also at the end of the period, some low and high-skill matches terminate exogenously.

2.3.2 Workers

The labour force consists of a measure one continuum of potential workers. At any point in time, a given worker is in one of the following $(2 \times I + 1)$ states: *Unemployed*

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[6]There will be heterogeneity *ex post* in the sectors in which agents work and their match skill levels, based on the luck associated with job search and skill acquisition.

— receiving unemployment benefits, z, and searching for a job; or, *working* — receiving a wage in sector i in a low-skill match of w_i^L or in high-skill match of w_i^H. The expected present values in these states are denoted U, W_i^L and W_i^H, respectively. Workers maximize the expected present value of their lifetime income subject to the random arrival of job offers when unemployed.

The unemployed search for jobs at no cost. As a result, their search is not directed to a particular sector, but rather simultaneous in all sectors. There is no on-the-job search or quits.[7] Workers do not value leisure. Therefore, when unemployed they allocate all their time to search and when employed they inelastically supply one unit of labour each period. There are no savings in the model; workers simply consume their current income.[8]

2.3.3 Firms

There is a large measure of potential firms. Firms can be in one of the following $(3 \times I)$ states: posting a *vacancy* to recruit in sector i; or producing in sector i in a low or high-skill *job* match. The expected present values in these states are denoted V_i, J_i^L and J_i^H, respectively.

There is free entry and exit of vacancies and firms incur recruiting cost, c, each period their vacancy remains unfilled. In low-skill matches, firms engage in innovation activities,

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[7]Evidence from the U.S. and Canada finds a significant number of workers who change sectors experience an intervening unemployment spell. For the U.S., see Kambourov and Manovskii (2008) and for Canada, see Osberg (1991). The model abstracts from job-to-job transitions, so all movements are between employment and unemployment. The assumption ruling out quits simplifies things. It is also reasonable in the model environment, because in equilibrium, workers' wages compensate them for their value of search, so working in any sector is strictly preferred to unemployment.

[8]Goods are not storable, so they have no value next period. Borrowing and lending contracts are ignored because agents are risk neutral and no one will lend at a rate higher than the real interest rate, r, so workers will not prefer promised future consumption over current consumption because of discounting.

$x_i \in \mathbb{R} \, [0,1]$, at cost $\chi(x_i)$ each period, where $\chi(0) = 0$ and $\chi'(x_i) > 0$. Innovation is a costly and uncertain process, where firms make a match-specific investment in an attempt to improve the match's productivity. This can be interpreted in several ways. First, it can represent the lower productivity of a new worker while learning match-specific skills. Second, it can represent an on-the-job training program, for which, the available empirical evidence suggests training costs can be substantial and are mainly paid by the firm.[9] Third, it can represent R&D to improve the production technology.

Innovation is beneficial because it makes skill acquisition more likely, reducing the expected time to become a high-skill match. Successful innovation transforms the match from low-skill into high-skill, and occurs with probability $\lambda_i x_i$, where λ_i is the exogenous skill arrival rate and x_i is innovative investment. High-skill matches are desirable because they produce more output and provide higher profits and wages.

The model captures the fact that labour adjustments can be costly for individual workers. Empirical work finds that following job loss, workers can suffer significant and persistent earning losses in their subsequent jobs, particularly those workers with longer tenure.[10] These findings suggest that some skills which are accumulated are useful only in the current match. The model captures this in a stark and stylized way. Skills are match-specific and therefore are lost when the match terminates.

Matches produce output using only labour with constant returns to scale, skill-specific

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[9]For estimates of training costs see, for example, Barron et al. (1989, 1999); Bartel (1995); and Dolfin (2006). Loewenstein and Spletzer (1998) analyze National Longitudinal Survey of Youth data and find employers pay the explicit cost of on-site training over 90 percent of the time.

[10]For U.S. evidence, see *e.g.* Fallick (1996), Jacobson et al. (1993), Topel (1993). For Canadian evidence, see Galarneau and Stratychuk (2002) and Morissette et al. (2007).

technologies. Each period sector i matches produce: $y_i^{SK} = A_i p_i^{SK} l_i^{SK}$, where y is output; $i \in \{1, 2, ..., I\}$ subscripts the sector; $SK \in \{L, H\}$ superscripts low and high-skill matches; A_i is a sector-wide productivity parameter, which is constant and normalized to one in the steady state, but will later serve as the source of the sector-specific shock; p is productivity, with $p_i^H > p_i^L$; and l is labour. To simplify the exposition, I assume each firm employs one worker. Thus, in the steady-state, p_i is output per worker in sector i.

Finally, each period all sector i matches face exogenous probability s_i of job destruction, where s_i is the sector i separation rate.

2.3.4 Matching Process

Unmatched firms post vacancies to attract unemployed workers in one of I sectors. The unemployed search simultaneously in all sectors. Search is costly for two reasons: 1) firms explicitly use resources to attract workers; and 2) workers and firms implicitly forego the higher wage earnings and profits they would be receiving if they were matched. Search is also time-consuming because each period some agents are unsuccessful in finding a match. Sector-specific matching functions capture this feature by determining the measure of pairwise matches per period in each sector. The matching functions have the Cobb-Douglas functional form:[11] $m_i(u, v_i) = \mu_i u^\alpha v_i^{1-\alpha}$, where m_i is the measure of sector i matches; u is the measure of unemployed workers; v_i is the measure of vacancies in sector i; μ_i is the recruiting effectiveness in sector i; and α is the elasticity of matches with respect to unemployment.

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[11]Petrongolo and Pissarides (2001) survey the empirical literature on estimating matching functions. They conclude that existing evidence generally supports the Cobb-Douglas specification.

In previous labour search papers with multiple sectors, such as Acemoglu (2001) and Davis (2001), matching occurs through an aggregate matching function. My formulation is more general. Sectors are allowed to vary in their recruiting effectiveness, μ_i's, because some sectors can assess applicants more easily than others. This means that market tightness, and therefore job-finding and job-filling rates, can vary by sector. This formulation brings the model closer to the data which feature clear differences in search outcomes across sectors.[12]

Because the model is set in discrete, rather than continuous time, this more general matching process implies that workers could potentially receive multiple offers in a period. This is an interesting and complex issue, which is explored in detail in several recent papers.[13] To keep the model's labour adjustment mechanisms transparent and comparable to the baseline Pissarides (2000) model, matching is determined in the following manner to avoid multiple offers. At the beginning of the matching stage the number of matches in each sector is determined. In each sector, these pairwise matches are randomly allocated. Once matched, the pair exits immediately to the bargaining stage. Define $\theta_i \equiv \frac{v_i}{u}$ as market tightness in sector i from the firm's perspective, so in a 'tighter' labour market it is harder for a firm to find a worker; $f_i(\theta_i) = \frac{m_i}{u}$ denotes an unemployed worker's job-finding probability in sector i;[14] and $q_i(\theta_i) = \frac{m_i}{v_i}$ denotes the job-filling probability for a sector i vacancy, where $\sum_{i=1}^{I} f_i(\theta_i), q(\theta_i) \in [0,1] \quad \forall i$.

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[12]U.S. data from the Job Openings and Labor Turnover Survey and recent research by Davis et al. (2007), for instance, find significant heterogeneity in vacancy-filling rates across sectors.

[13]See Julien et al. (2006) and Albrecht et al. (2006) among others.

[14]The probability of matching in sector i is the product of the probability of finding a job and the probability of that job being in sector i, $f_i = \frac{\sum m_i}{u} \times \frac{m_i}{\sum m_i} = \frac{m_i}{u}$.

2.3.5 Value Functions in the Steady-State

In the steady-state, the worker's Bellman equations are as follows. The expected present value of being unemployed, U, is:

$$U = z + \delta[\sum_{i=1}^{I} f_i(\theta_i)W_i^L + (1 - \sum_{i=1}^{I} f_i(\theta_i))U] \tag{2.1}$$

In the current period the worker receives unemployment benefits. With probability $f_i(\theta_i)$ the worker matches with a firm and receives an offer in sector i. In equilibrium she accepts all job offers,[15] and thus will begin next period working as a low-skill match — the present value of which is W_i^L. Next period's payoffs are discounted by δ and the summation is over all sectors. With complementary probability the worker does not match and remains unemployed.

The expected present value of being a worker in a low-skill sector i match, W_i^L, is:

$$W_i^L = w_i^L + \delta[s_i U + \lambda_i x_i W_i^H + (1 - s_i - \lambda_i x_i)W_i^L] \tag{2.2}$$

The current return is the low-skill wage in sector i. With probability s_i, the match separates and the worker becomes unemployed next period. With probability $\lambda_i x_i$, the match acquires skill and produces next period as high-skill. With complementary probability the worker keeps his current job.

The expected present value of working in a high-skill sector i match, W_i^H, is:

$$W_i^H = w_i^H + \delta[s_i U + (1 - s_i)W_i^H] \tag{2.3}$$

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[15]Section 2.3.9 derives the equilibrium wages, confirming this assertion.

The worker receives the high-skill wage in the current period. The job terminates with probability s_i, leaving the worker unemployed next period, otherwise the job continues.

The value functions for the firm are given by the following: The expected present value of posting a sector i vacancy, V_i, is:

$$V_i = -c + \delta[q_i(\theta_i)J_i^L + (1 - q_i(\theta_i))V_i] \tag{2.4}$$

The firm incurs the recruiting cost in the current period. With probability $q_i(\theta_i)$, the job-filling rate, the firm matches with a worker and begins producing with a low-skill job next period, else the firm continues recruiting.

The expected present value for a firm in a low-skill match in sector i, J_i^L, is:

$$J_i^L = A_i p_i^L - w_i^L - \chi(x_i) + \delta[s_i V_i + \lambda_i x_i J_i^H + (1 - s_i - \lambda_i x_i)J_i^L] \tag{2.5}$$

The first term is the firm's current profit: the firm produces output $A_i p_i^L$, pays the worker wage w_i^L and provides investment of x_i at cost $\chi(x_i)$. The match separates with probability s_i, leaving the firm with a vacancy next period. With probability $\lambda_i x_i$, the match becomes high-skill next period. The expected present value for a firm in a high-skill match in sector i, J_i^H, is:

$$J_i^H = A_i p_i^H - w_i^H + \delta[s_i V_i + (1 - s_i)J_i^H] \tag{2.6}$$

The firm's current profit is its output less the wage, since the firm no longer invests in the worker, because output cannot be increased beyond the high-skill level. With probability s_i, the match terminates becoming a vacancy next period, otherwise high-skill production continues.

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2.3.6 Wage Determination Through Bargaining

When unmatched firms and workers first meet, they begin producing next period in a low-skill match only if they agree on how to split the expected surplus from their partnership. This is done by generalized Nash Bargaining with full information where the threat points are the continuation values from no-agreement — which leaves the worker unemployed, with value U, and the firm with a vacancy, valued at V_i. Agreement allows production to begin in a low-skill match giving the worker W_i^L and the firm J_i^L. Agreement requires a non-negative return for each agent, $W_i^L \geq U$ and $J_i^L \geq V_i$. The new match surplus, S_i, is what the pair gains from producing less what they give up, $S_i \equiv W_i^L - U + J_i^L - V_i$.

The wage paid each period to a worker in a low-skill match in sector i is set efficiently to split the weighted product of worker's and firm's net gains from the match:

$$w_i^L = \arg\max[W_i^L(w_i^L) - U]^\beta [J_i^L(w_i^L) - V_i]^{1-\beta}$$

where β is the worker's bargaining power and $\beta \in (0,1)$ so both sides have an incentive to produce. First order conditions for these maximization problems imply:

$$W_i^L - U = \beta S_i; \quad \text{and} \quad J_i^L - V_i = (1-\beta)S_i. \tag{2.7}$$

Therefore, the low-skill wage in sector i, which I derive explicitly later, gives workers share β, and firms share $(1-\beta)$, of the new match surplus.

If the match becomes high-skill, the pair once again splits the surplus via Nash Bargaining. The threat points are the values of continuing production as a low-skill match.[16] Define the sector i skill premium, SP_i, as the incremental surplus generated when moving from a low to high-skill match, where $SP_i \equiv W_i^H - W_i^L + J_i^H - J_i^L$. Similarly, the high-skill wage in sector i is:

$$w_i^H = \arg\max[W_i^H(w_i^H) - W_i^L]^\beta (J_i^H(w_i^H) - J_i^L)^{1-\beta}$$

The high-skill wage is set so the worker receives share β of the skill premium and the firm receives the rest:

$$W_i^H - W_i^L = \beta SP_i; \quad \text{and} \quad J_i^H - J_i^L = (1-\beta)SP_i. \tag{2.8}$$

2.3.7 Equilibrium

Definition: Given a set of constant exogenous parameters, $\{A_i, p_i^L, p_i^H, s_i, \lambda_i, \mu_i, \alpha, c, \delta, z, \beta\}_{i=1}^I$, a *symmetric steady-state rational expectations equilibrium* is a set of value functions $\{U, W_i^L, W_i^H, V_i, J_i^L, J_i^H\}_{i=1}^I$; transition probabilities $\{f_i(\theta_i)\}_{i=1}^I, \{q_i(\theta_i)\}_{i=1}^I$; wages $\{w_i^L, w_i^H\}_{i=1}^I$; investment policies $\{x_i\}_{i=1}^I$ and a labour allocation $\{e_i^L, e_i^H, u\}_{i=1}^I$, such that, in all sectors:

1. **Optimality**:

   (a) Taking job-filling probabilities and wages as given, firms maximize expected profit, (i.e. J_i^L, J_i^H and x_i solve the firm's problem).

---

[16]Since both agents strictly prefer participating in a low-skill match to being unmatched in equilibrium, threats to 'endogenously' separate the match by either side are not credible.

(b) Taking job-finding probabilities and wages as given, workers maximize expected income, (i.e. U, W_i^L and W_i^H solve the worker's problem).

2. **Free Entry and Exit of Vacancies:** In all sectors, zero profit conditions hold for the expected value of posting a vacancy (net of recruiting costs).

3. **Nash Bargaining:** Generalized Nash Bargaining splits the low and high-skill match surpluses.

4. **Rational Expectations:** Firms and workers correctly anticipate transition probabilities, wages and innovation investment.

5. **Stationary Labour Distribution:** There is a stationary distribution of workers over employment states.

A stationary distribution of labour has three requirements. First, in each sector, the flow of workers into unemployment equals the flow of workers out of unemployment. Second, the flow of workers into high-skill sector i matches equals the flow out. Finally, the labour force sums to one, the total measure of potential workers. These conditions are:

$$s_i(e_i^L + e_i^H) = f_i(\theta_i)u; \quad \text{and} \quad \lambda_i x_i e_i^L = s_i e_i^H; \quad \text{and} \quad \sum_{i=1}^{I}(e_i^L + e_i^H) + u = 1. \quad (2.9)$$

An equilibrium solves for $\{x_i^*, \theta_i^*, w_i^{L*}, w_i^{H*}, e_i^{L*}, e_i^{H*}, u^*\}_{i=1}^{I}$. A representative firm in each sector makes two crucial decisions which drive the results. When unmatched, firms

decide whether to post a vacancy; and once in a low-skill match, firms decide how much to invest in innovation. While these actions are sequential, in equilibrium, firms correctly anticipate the innovation policies offered once a meeting occurs. Since, the firm's vacancy posting decision takes the innovation decision into account, I discuss the innovation decision first.

2.3.8 Intra-Sectoral Labour Reallocation: The Innovation Effect

Firms in low-skill matches in sector i optimally choose their innovation policies taking as given wages, the skill arrival rate, and other firms' innovation decisions:

$$J_i^L = \max_{0 \leq x_i \leq 1} A_i p_i^L - w_i^L - \chi(x_i) + \delta[s_i V_i + \lambda_i x_i J_i^H + (1 - s_i - \lambda_i x_i) J_i^L]$$

The first order condition for an interior solution is (Appendix C considers corner solutions):

$$
\begin{aligned}
\chi'(x_i^*) &= \delta \lambda_i (J_i^H - J_i^L) \\
&= \delta \lambda_i (1 - \beta) SP_i
\end{aligned}
$$

The LHS is the marginal cost and the RHS is the expected discounted marginal benefit of increasing innovation. The second equality uses the Nash Bargaining solution, equation (2.8). The benefit of innovating is the increase in the arrival rate λ_i, multiplied by the firm's share $(1 - \beta)$ of the skill premium — the increased production from becoming a high-skill match plus the savings on the investment costs, because high-skill matches require no further investment.

I assume a linear innovation cost function, which yields a simple closed-form solution for firms' optimal innovation investment, given in the following proposition:

Proposition 2.3.1 (Optimal innovation policies) *When the innovation investment cost function is linear, $\chi(x_i) = k_i x_i$, a threshold skill arrival rate, $\overline{\lambda}_i$, characterizes firms' innovation decisions. The optimal symmetric innovation policy in sector i is:*[17]

$$
x_i^* = \begin{cases} 0 & \text{if } \lambda_i \leq \overline{\lambda}_i \\ \min\{\frac{(1-\beta)}{k_i \beta} A_i(p_i^H - p_i^L) - \frac{r+s_i}{\lambda_i \beta}, 1\} & \text{if } \lambda_i > \overline{\lambda}_i \end{cases} \tag{2.10}
$$

where: $\overline{\lambda}_i = \frac{k_i(r+s_i)}{(1-\beta)A_i(p_i^H - p_i^L)}$

Firms innovate only if the skill arrival rate is sufficiently high, $\lambda_i > \overline{\lambda}_i$. Innovation is increasing in the skill arrival rate and the difference between high and low-skill productivity. Innovation is also increasing in the sector-specific productivity shock, A_i. Therefore, when a sector's productivity rises, firms innovate more. These actions accelerate skill acquisition and endogenously increase the share of high-skill matches in the sector. As a result, the output response to the productivity shock is amplified relative to the baseline model.[18] I call this the *'innovation effect'*.

Conversely, higher interest rates and separation rates reduce innovation. In both cases firms discount future payoffs more — because borrowing funds is more costly or because

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[17] *I consider only the symmetric innovation equilibrium. Equilibria may exist where some firms in a sector offer lower starting wages, but innovate more, or higher wages and innovate less.*

[18] In the steady-state, from equation (2.9), in sector i the flow of workers into high-skill jobs equals the flow out: $\lambda_i x_i e_i^L = s_i e_i^H$. Rearranging: $x_i = \frac{s_i}{\lambda_i} \frac{e_i^H}{e_i^L}$. Since the first fraction is a constant, increasing investment raises the steady-state ratio of high-to-low skill matches in sector i.

jobs are shorter-lived — so the return to innovating falls. Similarly, as worker's bargaining power, β, increases, firms receive less of the skill premium and therefore innovate less.

Finally, note a few important factors that do not affect the innovation decision. In particular, innovation does not depend on market tightness and unemployment, so the availability of new workers is irrelevant for the decision to innovate with existing workers. The firm's innovation decision simply compares the benefit from moving an existing low-skill match to high-skill, against its cost. In other words, the firm's entry decision (pre-match) does not directly influence its innovation decision (post-match), because of the timing of events. This fact simplifies solving the model.

2.3.9 Inter-Sectoral Labour Reallocation: The Reservation Wage Effect

Now consider the firm's entry decision of whether to post a vacancy. In equilibrium, free entry drives the expected value of posting a vacancy to zero, $V_i = 0$, which implies:

$$\frac{c}{q_i(\theta_i^*)} = \frac{\pi_i^L}{(r + s_i + \lambda_i x_i^*)} + \lambda_i x_i^* \frac{\pi_i^H}{(r + s_i + \lambda_i x_i^*)(r + s_i)} \tag{2.11}$$

where π is current period profit. The LHS is the total expected recruiting cost: the per-period cost, c, times the expected number of periods to fill the vacancy, $\frac{1}{q_i(\theta_i^*)}$. The RHS is the expected discounted accounting profits earned in a match. Notice this anticipates the expected gain in value if the match becomes high-skill, which occurs with probability $\lambda_i x_i^*$, for the optimal innovation choice x^*. In this way, the innovation decision influences the entry decision.

I derive equilibrium wages using the value functions, equations (2.1) - (2.6), the Nash bargaining solutions, equations (2.7) and (2.8), and the zero profit conditions $V_i = 0$ $\forall i$, giving:

$$w_i^{L*} = \overline{w} + \beta(A_i p_i^L - \chi(x_i^*) - \overline{w}) \tag{2.12}$$

$$w_i^{H*} = \overline{w} + \beta(A_i p_i^H - \overline{w}) \tag{2.13}$$

where $\overline{w} \equiv z + \delta \sum_{i=1}^{I} f_i(\theta_i^*)(W_i^L - U)$

Each period, workers receive their reservation wage, $\overline{w}$, plus their bargaining power share β of the low and high-skill per-period match values respectively. The reservation wage, as defined above, is a key concept to understand the model. It is the worker's outside option — the value of continuing to search while unemployed, or equivalently, what the worker foregoes by accepting the job since there is no on-the-job search. The option value of search is the unemployment benefits the worker would collect, z, plus the expected gain in value from accepting a job in a given sector, $(W_i^L - U)$, weighted by the probabilities of receiving offers in these sectors, $f_i(\theta_i)$, summed over all sectors and discounted because production begins next period.

A key difference relative to the basic one-sector model, is that with multisector search, the outside option includes the possibility of working in other sectors. As a result, the

worker's reservation wage updates when market conditions change in other sectors. Sectoral spillovers occur through this feature of the model, which effectively creates equilibrium linkages in labour market conditions across different sectors.

In addition to receiving their reservation wage, workers also get their share β of the joint match value. The joint match value for low-skill matches is the output generated, $A_i p_i^L$, less investment costs, $\chi(x_i^*)$, less the worker's opportunity cost of search, $\overline{w}$. High-skill matches are more valuable, since more output is produced, $A_i p_i^H$, and there are no investment costs. As a result, high-skill wages exceed low-skill wages.[19] Low-skill wages are decreasing in investment costs. Wages are increasing in the value of search and output.

Equilibrium profits are:

$$\pi_i^{L*} = (1 - \beta)(A_i p_i^L - \overline{w}) + \beta\chi(x_i^*) \tag{2.14}$$

$$\pi_i^{H*} = (1 - \beta)(A_i p_i^H - \overline{w}) \tag{2.15}$$

Substituting equilibrium profits into the vacancy posting equation (2.11), illustrates that increasing the worker's value of search, $\overline{w}$, discourages entry:

$$\frac{c}{q_i(\theta_i^*)} = \frac{(1 - \beta)(A_i p_i^L - \overline{w}) + \beta\chi(x_i^*)}{(r + s_i + \lambda_i x_i^*)} + \lambda_i x_i^* \frac{(1 - \beta)(A_i p_i^H - \overline{w})}{(r + s_i + \lambda_i x_i^*)(r + s_i)} \tag{2.16}$$

This *'reservation wage effect'* leads to sectoral spillovers. For example, positive developments in one sector raise workers' reservation wage. As wages are bid up, labour

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[19] $w_i^{H*} - w_i^{L*} = \beta[A_i(p_i^H - p_i^L) + \chi(x_i^*)] > 0.$

becomes more expensive, new jobs become less profitable, and job creation falls in other sectors. This intuition is formalized in the following proposition:

Proposition 2.3.2 (Sector-Specific Shocks and Equilibrium Market Tightness) *A positive sector-specific productivity shock in sector i, A_i, causes equilibrium market tightness to rise in sector i, θ_i^*, and fall in the other sectors, $\{\theta_j^*\}_{j \neq i}^I$. Conversely, a negative shock in sector i, reduces market tightness in that sector and increases market tightness in the other sectors.*

Finally, I define the break-even condition for a sector to engage in recruitment and production:

Proposition 2.3.3 (Necessary Condition for Sector i Production) *Production requires a non-negative new match surplus, $S_i \geq 0$. This implies the value of low-skill output net of investment costs, plus the expected present value of the skill premium, must weakly exceed the worker's value of search, otherwise production in sector i is not worthwhile:*

$$A_i p_i^L - \chi(x_i^*) + \delta \lambda_i x_i^* SP_i \geq \bar{w}$$

2.3.10   Solving the Model

The model's steady-state is solved in stages. First, I find the optimal innovation policies, $\{x_i^*\}_{i=1}^I$, using equations (2.10). As described above, these solutions are independent of market tightness. Given these innovation policies, I solve for equilibrium market

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tightness, $\{\theta_i^*\}_{i=1}^I$, using equations (2.17) below. A key feature of the model is the interdependence of labour market conditions. For example, the decision to post a vacancy in sector i depends on the expected ease of finding a worker, which in turn, depends on the vacancy posting decisions in other sectors. The model must therefore be solved simultaneously. Fortunately, the model can be distilled into the following system of I simultaneous non-linear equations in $\{\theta_i\}_{i=1}^I$:

$$\frac{r+s_i}{q(\theta_i)} + \beta \sum_{i=1}^I \theta_i = \frac{(1-\beta)}{c}[A_i p_i^L - \chi(x_i^*) - z + \lambda_i x_i^* \cdot \frac{A_i(p_i^H - p_i^L) + \chi(x_i^*)}{r + s_i + \lambda_i x_i^*}] \qquad (2.17)$$

This expression provides a straight-forward generalization of the basic one-sector model without aggregate uncertainty and innovation investment (e.g., Shimer (2005) equation 6):

$$\frac{r+s}{q(\theta)} + \beta\theta = \frac{(1-\beta)}{c}(p-z)$$

Solving the system given by (2.17), using the Newton-Raphson method to find its roots, yields equilibrium market tightness. Equilibrium wages, profits and employment shares are found using equations (2.9) and (2.12) — (2.15).

2.4 Transition Dynamics

The previous section establishes the model's steady-state properties. A fully-specified model of labour adjustment also details how the economy adjusts when it is out of the steady-state. Therefore, this section characterizes the model's transition dynamics between steady-states.

To illustrate, assume the economy is in a steady-state and consider an unanticipated sector-specific productivity shock, denoted $\hat{A}_{i,t}$, that occurs in sector i, at the beginning of period t, where the hat superscript denotes an updated value. As in the baseline Pissarides (2000) model, labour contracts are costlessly renegotiated whenever shocks hit the economy. Therefore, prior to production in period t, existing matches renegotiate low and high-skill wages using the Nash bargaining solutions and firms update their innovation policies, as described above. In addition, prior to recruitment, unmatched firms optimally update their vacancy decisions. Because there is free entry and free disposal of vacancies, the value of a vacancy is zero for all sectors at all points in time. In Pissarides' terminology, wages, innovation investment and market tightness (vacancies) are 'jump variables' updating immediately in the period the shock hits, prior to production and search. Their new values are:

$$
\hat{x}_{i,t}^* = \begin{cases} 0 & \text{if } \lambda_i \leq \hat{\overline{\lambda}}_i \\ \min\{\frac{(1-\beta)}{k_i\beta}\hat{A}_{i,t}(p_i^H - p_i^L) - \frac{r+s_i}{\lambda_i\beta}, 1\} & \text{if } \lambda_i > \hat{\overline{\lambda}}_i \end{cases}
$$

$$
\frac{1+r}{q(\hat{\theta}_{i,t}^*)} = \frac{(1-\beta)}{c}[\hat{A}_{i,t}p_i^L - \chi(\hat{x}_{i,t}^*) - z + \lambda_i\hat{x}_{i,t}^* \cdot \frac{\hat{A}_{i,t}(p_i^H - p_i^L) + \chi(\hat{x}_{i,t}^*)}{r + s_i + \lambda_i\hat{x}_{i,t}^*}] + E_{\hat{t}}\{\frac{1-s_i}{q(\hat{\theta}_{i,t+1}^*)} - \beta\sum_{i=1}^{I}\hat{\theta}_{i,t+1}^*\}
$$

$$
\hat{w}_{i,t}^{L*} = \hat{\overline{w}_t} + \beta(\hat{A}_{i,t}p_i^L - \chi(\hat{x}_{i,t}^*) - \hat{\overline{w}_t}); \qquad \hat{w}_{i,t}^{H*} = \hat{\overline{w}_t} + \beta(\hat{A}_{i,t}p_i^H - \hat{\overline{w}_t})
$$

where $\hat{\overline{\lambda}}_i = \frac{k_i(r+s_i)}{(1-\beta)\hat{A}_{i,t}(p_i^H - p_i^L)}$ and $\hat{\overline{w}_t} = z + \delta E_{\hat{t}}\{\sum_{i=1}^{I} f_i(\hat{\theta}_{i,t}^*)(\hat{W}_{i,t}^L - \hat{U}_t)\}$

Notice these variables can jump to their new values because they do not depend directly on employment and unemployment levels. Given these new wages and equilibrium transition probabilities, the value functions also discretely update in period t. For example, in period t prior to the shock, the present value of being unemployed is:

$$U_t = z + \delta E_t[\sum_{i=1}^{I} f_i(\theta^*_{i,t+1})(W^L_{i,t+1} - U_{t+1}) + U_{t+1}]$$

After the shock in period t, the value of unemployment updates immediately to:

$$\hat{U}_t = z + \delta E_{\hat{t}}[\sum_{i=1}^{I} f_i(\hat{\theta}^*_{i,t+1})(\hat{W}^L_{i,t+1} - \hat{U}_{t+1}) + \hat{U}_{t+1}]$$

Similarly, the other value functions update to:

$$\hat{W}^L_{i,t} = \hat{w}^{L*}_{i,t} + \delta E_{\hat{t}}[s_i(\hat{U}_{t+1} - \hat{W}^L_{i,t+1}) + \lambda_i \hat{x}^*_{i,t+1}(\hat{W}^H_{i,t+1} - \hat{W}^L_{i,t+1}) + \hat{W}^L_{i,t+1}]$$

$$\hat{W}^H_{i,t} = \hat{w}^{H*}_{i,t} + \delta E_{\hat{t}}[s_i(\hat{U}_{t+1} - \hat{W}^H_{i,t+1}) + \hat{W}^H_{i,t+1}]$$

$$\hat{V}_{i,t} = -c + \delta E_{\hat{t}}[q_i(\hat{\theta}^*_{i,t+1})(\hat{J}^L_{i,t+1} - \hat{V}_{i,t+1}) + \hat{V}_{i,t+1}]$$

$$\hat{J}^L_{i,t} = \hat{A}_{i,t}p^L_i - \hat{w}^{L*}_{i,t} - \chi(\hat{x}^*_{i,t}) + \delta E_{\hat{t}}[s_i(\hat{V}_{i,t+1} - \hat{J}^L_{i,t+1}) + \lambda_i \hat{x}^*_{i,t+1}(\hat{J}^H_{i,t+1} - \hat{J}^L_{i,t+1}) + \hat{J}^L_{i,t+1}]$$

$$\hat{J}^H_{i,t} = \hat{A}_{i,t}p^H_i - \hat{w}^{H*}_{i,t} + \delta E_{\hat{t}}[s_i(\hat{V}_{i,t+1} - \hat{J}^H_{i,t+1}) + \hat{J}^H_{i,t+1}]$$

Free entry and exit of vacancies imply $\hat{V}_{i,t} = \hat{V}_{i,t+1} = 0$. Nash Bargaining implies

$\hat{J}^L_{i,t} = (1-\beta)\hat{S}_{i,t}$ and $\hat{W}^L_{i,t} - \hat{U}_{i,t} = \beta\hat{S}_{i,t}$, so one can succinctly write the updated joint value of a low-skill match in sector i as $\hat{S}_{i,t} = \frac{c}{(1-\beta)\delta q_i(\hat{\theta}^*_{i,t})}$ or equivalently:

$$\hat{S}_{i,t} = \hat{A}_{i,t}p^L_i - \chi(\hat{x}^*_{i,t}) - z + \delta E_{\hat{t}}\{\lambda_i\hat{x}^*_{i,t+1}\hat{SP}_{i,t+1} + [1-s_i-f_i(\hat{\theta}^*_{i,t+1})]\hat{S}_{i,t+1} - \sum_{j\neq i}^{I} f_j(\hat{\theta}^*_{j,t+1})\hat{S}_{j,t+1}\}$$

Other variables, such as employment and unemployment, evolve more slowly to their new steady-state values according to the following difference equations:

$$\hat{e}^L_{i,t+1} = f_i(\hat{\theta}^*_{i,t})u_t + (1-s_i-\lambda_i\hat{x}^*_i)e^L_{i,t}$$

$$\hat{e}^H_{i,t+1} = \lambda_i\hat{x}^*_i e^L_{i,t} + (1-s_i)e^H_{i,t}$$

$$\hat{u}_{t+1} = \sum_{i=1}^{I} s_i(e^L_{i,t} + e^H_{i,t}) + [1 - \sum_{i=1}^{I} f_i(\hat{\theta}^*_{i,t})]u_t$$

Finally, output moves along with changes in employment during the transition:

$$\hat{Y}_t = \sum_{i=1}^{I}\sum_{SK=L}^{H} \hat{A}_{i,t}p^{SK}_i e^{SK}_{i,t}$$

A stable transition requires that each sector's market tightness updates immediately to its new steady-state value, $\hat{\theta}^*_{i,t}$. However, since market tightness is $\theta_{i,t} \equiv \frac{v_{i,t}}{u_t}$, vacancies overshoot their steady-state level and move in the same direction as unemployment so that market tightness remains constant at its new steady-state value during the transition. See Pissarides (1985) or (2000, Ch. 1.7).

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2.5 Inspecting the Model Mechanisms: General versus Sector-Specific Productivity Shocks

This section presents simple quantitative examples to illustrate the key model mechanisms through the innovation and reservation wage effects.

2.5.1 Quantitative Approach

To illustrate the model's labour adjustment mechanisms, I compare the model economy's response to an equal-sized productivity shock in two scenarios. The first scenario is a general shock that affects all sectors equally. As a result, there is intra-sectoral labour reallocation but not inter-sectoral reallocation in the model's new steady-state. The second scenario is a sector-specific shock, which *directly* affects only one sector. This results in intra-sectoral reallocation in the sector where the shock occurs as well as inter-sectoral reallocation between sectors.

To keep the results transparent and emphasize the model's adjustment mechanisms, I parameterize a benchmark economy consisting of two perfectly symmetric sectors. Each sector uses the same production technologies and each has half of the economy's employed workers, of which half are in low-skill and half are in high-skill matches. Table 1 reports the parameter values for the benchmark model. In these examples, the only parameters that change are the sector-specific productivity terms, A_1 and A_2.

To quantify a reasonable size for the productivity shocks, Table 2 reports summary statistics using Canadian data for sectoral and aggregate output per worker, expressed

in log deviations from their HP-filtered trends.[20] The table shows that productivity is considerably more volatile at the sectoral level than the aggregate level. In the resource and manufacturing sectors, productivity is often 3-4 percent or more away from its trend growth. Furthermore, these deviations from trend are quite persistent with autocorrelations of 0.86 and higher. In the numerical example, I use 3 percent for the sector-specific shock. The equivalent-sized general productivity shock in the two-sector economy is 1.5 percent, since the 3 percent shock directly affects half of the economy. The shock is unanticipated and permanent.

2.5.2   Quantitative Results

Table 3 compares the results in the new steady-states following the general productivity shock to the equal-sized, sector-specific productivity shock. While the overall differences for social welfare are small, there are important distinctions for the sectoral and skill composition of production, aggregate productivity and the wage distributions.

First, consider the model economy's response to the general productivity shock. This case isolates the innovation effect and demonstrates that firms' endogenous innovation responses amplify the impacts of productivity shocks. The productivity shock was an increase of 1.5 percent, however, aggregate output rises by 2.4 percent because the economy invests more resources in innovation to substitute toward high-skill production (whose share of overall production increases from 50 percent to 51.2 percent after the shock).

The economy's response to the sector-specific productivity shock is quite different

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[20]Output per worker proxies productivity here because labour is the only factor of production in the model. These sectors are chosen to be consistent with the data application in Chapter 3.

due to the asymmetric nature of the shock. The sector-specific shock raises aggregate output and output per worker more than the general shock (2.7 percent rather than 2.4 percent). The reason is that the economy concentrates production in high-skill jobs in the more productive sector, through inter-sectoral and intra-sectoral labour reallocation. While the shock directly affects Sector 1, there are negative equilibrium wage and hiring spillovers on Sector 2 through the reservation wage effect. This result is consistent with recent empirical findings by Beaudry et al. (2007) who show that changes in the sectoral composition in U.S. cities have equilibrium spillovers on the level of wages, after controlling for observable characteristics.

The mechanism here works as follows: Firms post vacancies and increase investment in Sector 1 to take advantage of the now-more-productive workers. The increase in Sector 1 vacancies changes the composition of job postings, making matches with Sector 1 firms more likely. These firms are now more productive and invest more resources in becoming high-skill to take advantage of the improved productivity. Therefore, workers in Sector 1 generally receive higher starting wages and also expect to earn high-skill wages sooner because, on average, they will acquire skills faster in this sector. The value of search for the unemployed rises because of the improved probability of getting these better paying jobs, pushing up the reservation wage.

The increase in the reservation wage has second-round equilibrium effects. Wages are re-bargained in Sector 2 to reflect workers' improved outside option. With more expensive labour in Sector 2 and no change in the productivity of their workers, these

jobs become less profitable so recruiting falls in this sector. Thus in the new steady-state, the asymmetric recruiting responses — vacancies rise in Sector 1 and fall in Sector 2 — lead to inter-sectoral reallocation, shifting labour into the more productive sector. These productivity-enhancing labour movements between sectors are reinforced by the shift within the more productive sector to high-skill matches due to a larger innovation effect after the sector-specific shock.

Finally, the sector-specific shock has larger distributional consequences for wages. Relative to the general shock scenario, high-skill workers in Sector 1 are the major winners and high-skill workers in Sector 2 are the major losers (as wages rise by 1 percent and fall by 0.9 percent respectively).

Theses effects are steady-state comparisons. Figure 9 shows the transition dynamics to illustrate the sectoral employment responses. After the sector-specific shock, the composition of vacancies shifts immediately and a larger proportion of new hires work in Sector 1 each period. Over time, employment rises in Sector 1 and falls in Sector 2.

2.5.3 Discussion

Now consider the model's labour adjustment after sector-specific shocks relative to the general process described from the empirical facts presented in Section 2.

Fact 1 is that labour flows towards the sector which experienced a positive sector-specific shock and away from the sector which experienced a negative shock. Compare Figure 2, the employment levels after the oil price shocks and Figure 9, the model's

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employment response following a relative sector-specific shock. In the world generating the results in Figure 2, the increasing price of oil raises the profitability of non-manufacturing production relative to manufacturing production. Given that manufacturing production is more energy-intensive, its production costs are more adversely affected. Over time, as the incentives to hire shift toward non-manufacturing jobs, labour is reallocated.[21] The model's results are in the third column of Table 3, where Sector 1 receives the positive shock. Employment flows to this sector where employment rises by over 18 percent after the shock.

The model's predictions are also consistent with empirical Facts 2 and 3 — that there is a relative increase in the employment and real wages of high-skill workers in sector which receives a positive shock. Once again, the model's results are in the third column of Table 3, where Sector 1 receives the positive shock. High-skill employment rises in that sector from 50 percent to 52.3 percent after the shock. Wages gains are concentrated for high-skill workers in Sector 1, rising 2.8 percent.

The quantitative results in this particular example show that increasing a sector's productivity leads to increased innovation investment, an increased share of high-skill workers, and larger wage gains for these workers. In fact, it is straight-forward to show these general results analytically. The intra-sectoral reallocation result is the following: In the steady-state, from equation (2.9), in sector i the flow of workers into high-skill jobs equals the flow out: $\lambda_i x_i^* e_i^{L*} = s_i e_i^{H*}$. Rearranging this equation shows that a sector's

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[21]This is consistent with findings by Davis and Haltiwanger (2001) who analyze plant-level data within the manufacturing sector. They find larger employment reductions in more energy-intensive plants following oil price increases.

optimal innovation investment in the steady-state is:

$$x_i^* = [\frac{s_i}{\lambda_i}] \cdot [\frac{e_i^{H*}}{e_i^{L*}}]$$

We also know that from Proposition 2.3.1, innovation investment, x^*, increases with a sector's productivity, A_i. This implies that higher sector-specific productivity increases innovation investment, which in turn, raises the steady-state ratio of high-to-low skill workers in sector i.[22] Furthermore, the relative wages of high-skill to low-skill workers rise as productivity increases. The wage differential can be expressed as: $w_i^{H*} - w_i^{L*} = \beta[A_i(p_i^H - p_i^L) + \chi(x_i^*)] > 0$. This expression is directly increasing in a sector's productivity A_i, which in turn, also increases innovation costs, $\chi(x_i)$, and causes further wage dispersion.

2.6 Conclusions

This chapter presents a general model of sectoral labour reallocation. I demonstrate that the model's implications are consistent with the results from several labour adjustment episodes after sector-specific shocks. This analysis suggests that the widely-used search and matching framework is well-suited to tackle, not only the aggregate and distributional issues to which it is generally applied, but also to study issues at the sectoral level such as labour reallocation.

The model's transition dynamics are quite tractable, which facilitates taking the model to the data to study particular labour adjustment episodes. In the next chapters, I

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[22]As A_i increases, the LHS of the above equation increases. The first fraction on the RHS is an exogenous constant, therefore the second fraction on the RHS must increase in the steady-state.

apply this model to Canadian data to quantify the aggregate costs of labour adjustment following a global commodity price shock and analyze how labour market policies affect social welfare, allocations and the speed of adjustment.

Chapter 3

Lost in Transition: The Aggregate Costs of Canada's Sectoral Labour Adjustment and Their Sources

3.1 Introduction

In 2002, global commodity prices began a rapid ascent. In Canada, this development was accompanied by a concurrent increase in the effective exchange rate. Over the next five years, these persistent relative price movements were associated with a dramatic sectoral reallocation of resources in the Canadian economy. During this period, significant amounts of labour moved to the resource sector (mining, oil and gas extraction) and away from manufacturing.

This high-profile adjustment process has been a major concern for individual workers, labour unions and policymakers alike. Existing empirical labour studies that exploit microdata provide convincing evidence that individual workers who lose their jobs and/or change sectors can suffer large and persistent earnings losses.[1] These costs are attributable

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[1]For U.S. evidence, see e.g. McLaughlin and Bils (2001), Fallick (1996), Jacobson et al. (1993), Topel

to the lower incomes and foregone output during unemployment spells. These costs are also attributable to lower wages upon re-employment, which may occur because workers have trouble transferring some skills to their new job, and/or because there is some learning and skill acquisition required in the new job that takes some time. In these situations, earnings losses can persist for several years as workers adjust to their new jobs.

While there is a wealth of research on individuals' experiences, comparatively little is known about the aggregate costs of sectoral labour reallocation episodes and the key contributors to these costs.[2] I contribute to this area by studying the Canadian economy in 2002-2006 during a particularly acute sectoral labour adjustment. The goals of this chapter are to quantify these aggregate adjustment costs in an equilibrium model framework, and to identify the relative contributions of specific labour market frictions to these aggregate costs.

First, I use microlevel Labour Force Survey data as well as Payroll Survey data to document the adjustment process in the most affected sectors. I find that employment shifted towards the resource sector and away from manufacturing. Resource sector employment rose because of increased hiring and retention rates, while in manufacturing, labour turnover stagnated due to fewer hirings and separations. Finally, I find that wage gains were concentrated in the resource sector, and particularly in the upper end of the distribution.

(1993). For Canadian evidence, see Morissette et al. (2007) and Galarneau and Stratychuk (2002).

[2]Trefler (2004) studies the impacts of the Canada–U.S. Free Trade Agreement. His results suggests that the transitional costs of labour adjustment may have been significant for the Canadian manufacturing sector in this period.

I then apply the search and matching model developed in Chapter 2 to quantify the aggregate costs of adjustment and isolate their sources.[3] The model formalizes two labour market frictions, which are impediments to adjustment that are natural candidates to study. The first is search frictions that can result in the intervening unemployment spells. The second is the non-transferability of skills between jobs and the associated learning process involved in adapting to a new work environment.

The model estimates there were significant adjustment costs during this episode, accounting for roughly three percent of output in the most affected sectors. These costs occur mainly in the first three years after the shock and are largely attributable to the non-transferability of skills, rather than search frictions — with contributions of roughly 90 percent and 10 percent respectively.

The approach to derive the model's cost estimate involves first calibrating the model to match 2002 Canadian data on sectoral employment shares for the resource and manufacturing sectors, relative wages of high-to-low skill workers and unemployment. I then infer the magnitude of the sector-specific shocks to the resource and manufacturing sector using data on wages and output per worker. After imposing these sector-specific shocks on the model, I compare the 2006 Canadian data to the model's new steady-state. The model successfully matches key features of the adjustment, such as the sectoral employment movements and relative wage effects among high and low-skill workers in the resource sector.

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[3]Recall that the model extends Pissarides (2000) to include multisector production and search, and an 'innovation' process. In this application, the costly and uncertain innovation investment is interpreted as the skill acquisition process associated with on-the-job training.

I then use the model's transition dynamics between the steady-states before and after the shocks to infer the aggregate adjustment costs. The notion of 'costs' here is not one of explicit costs, but rather a model-based opportunity cost for the economy. In this situation, changing global conditions allow the Canadian economy to benefit by moving workers and firms from less-productive to more-productive sectors (i.e. from manufacturing to resources). Impediments to this beneficial adjustment, therefore, imply an opportunity cost as the difference between what the economy produces along its transitional adjustment path, versus the increased production in the new steady-state, once the adjustment process is complete. I then isolate how much each friction contributes to the aggregate cost of adjusting labour, by turning on and off the skill acquisition process.

This analysis contributes to the on-going policy discussions of these events that often stress the potential benefits of increasing the 'flexibility' of Canada's labour markets.[4] More generally, the results demonstrate that factors impeding labour market adjustments can be costly not only for individual workers, but can also have first-order impacts on aggregate output and social welfare. These results are also instructive for other countries experiencing similar sectoral adjustments where policymakers face pressure to ease the burden on the individuals and sectors that disproportionately bear the costs of reallocating production. Canada's experience provides a particularly attractive and timely case study because it features a dramatic sectoral labour reallocation due to large employment shares in the resource and manufacturing sectors — both of which were highly responsive to these relative price movements.

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[4]As illustrated by comments by the Bank of Canada's, then Governor, David Dodge: "labour markets need to be flexible enough to facilitate the movement of workers from sector to sector as the economy adjusts" (New York, 29 March 2006).

Other literature relates to the adjustment costs to reallocating labour. One strand is the reduced-form estimation of adjustment cost models such as Caballero et al. (1997). Another strand is an empirical literature that uses regression analysis to study employment and wage responses to exchange rate movements.[5] Finally, there are structurally-estimated labour models of occupational choice such as Lee and Wolpin (2006). Relative to this research, the key contribution here is to apply an equilibrium multisector model environment where adjusting labour is costly because of explicit labour market frictions. As a result, the analysis sheds new light on the relative importance of these frictions and their respective contributions to the aggregate labour reallocation costs.

The outline for this chapter is as follows: Section 2 documents Canada's recent labour adjustment. Section 3 applies the model to match the data. Section 4 uses the model to estimate the overall adjustment costs, isolating the contributions from search frictions and the non-transferability of skills and assessing the sensitivity of the quantitative results to pre-selected parameter values. Section 5 concludes.

3.2 Documenting Canada's Labour Market Adjustment

This section presents some important empirical facts from Canada's labour adjustment during 2002–2006, in the wake of rising global commodity prices and an associated exchange rate appreciation.

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[5]E.g. see, Leung and Yuen (2005), Campa and Goldberg (2001) and Burgess and Knetter (1998).

3.2.1 Energy Price Shock and Associated Exchange Rate Movement

Figure 10 shows that global commodity prices rose dramatically starting in 2002, led by strong gains in energy prices. The energy component of the Bank of Canada's Commodity Price Index doubled in 2002 and rose 300 percent during 2002–2005.

Empirical evidence finds the Canadian exchange rate responds to movements in commodity and energy prices, particularly in the long-run.[6] As suggested by this relationship, Figure 11 shows a concurrent, persistent increase in Canada's nominal effective exchange rate.[7]

3.2.2 Asymmetric Sectoral Responses Expected

For the purposes of the quantitative analysis, identifying the sources of these shocks is not important. I simply take proxies for these sector-specific developments as exogenous and investigates their consequences in a model calibrated to represent the Canadian economy. What will drive the results is simply that these relative price changes had different impacts on profitability in particular sectors, beginning in 2002.[8]

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[6]See Amano and Van Norden (1995); Chen and Rogoff (2003); Issa, Lafrance and Murray (2006) and Bayoumi and Mühleisen (2006). This literature finds that real non-energy commodity export prices are associated with an appreciation of the Canada-U.S. real exchange rate over the post-Bretton Woods era. Since the early 1990's, real energy prices are also associated with a stronger Canadian dollar.

[7]Canada's real effective exchange rate tracks the nominal series almost exactly after 1992, because the consumer price index has been stable relative to nominal exchange rates movements, see Ong (2006).

[8]While several factors undoubtedly contributed to these price movements, a significant part of this global commodity price increase is attributable to stronger demand — as opposed to earlier episodes in the 1970s which were driven mainly by reduced supply. This stronger demand is concentrated in developing Asian economies where commodities and energy are a key input to the industrialization process which is rapidly expanding manufactured goods production. This phenomenon is illustrated by the fact that developing Asian economies accounted for 63 percent of the global growth in primary energy consumption during 2001–2006. (Author's calculations from *BP Statistical Review of World Energy*, June 2007, available at: www.bp.com.)

In fact, commodity price and exchange rate movements generally impact sectors of the economy differently. The exogenous increase in commodity demand and energy prices has clear benefits for the Canadian resource sector, which can now sell more output at a higher price since demand is inelastic in the short run. Conversely, sectors with more energy-intensive production, such as manufacturing, will be adversely affected by higher energy input costs.[9]

At the same time, the associated exchange rate shock will similarly generate sectoral winners and losers. Table 4 reports trade exposure estimates, which are a useful proxy for Canadian sectors' sensitivity to exchange rate movements. The table shows that the Canadian manufacturing sector stands to be the most adversely affected by the appreciation. In 2002, this sector had the highest trade exposure measure, 0.76, since roughly half of its final goods are exported, and imports make up nearly half of the domestic market. However, manufacturers benefit more than other sectors on the cost side because they import nearly one-quarter of their inputs. The resource sector was about as exposed as the overall Canadian economy's private sector (0.50 versus 0.48 respectively). The direct effects of an appreciation on services will likely be more modest because they trade less internationally.

The Bank of Canada's *Business Outlook Survey* provides additional evidence of the impact this appreciation on Canadian firms (Mair, 2005). More than three-quarters of manufacturing firms reported adverse effects from the appreciation, mainly from lower

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[9]For example, using detailed plant-level data, Davis and Haltiwanger (2001) find that within the U.S. manufacturing sector, there are larger employment reductions at more energy-intensive plants following positive oil price shocks.

profit margins on foreign sales. Firms reportedly responded to the appreciation by cutting labor and other costs and attempting to increase productivity. Empirical evidence from an earlier period, 1981–1997, by Leung and Yuen (2005) finds significant labour market adjustments in response to real exchange rate movements for Canadian manufacturing industries. They find Canadian appreciations are associated with falling labour input in manufacturing. Overall then, this evidence suggests resource employment gains and manufacturing employment losses following the shocks, which is precisely what occurred.

3.2.3 Labour Adjustment

Fact 1: *Employment shifted from manufacturing to the resource sector following the shock.*

Canadian data from both the payroll and labour force surveys provide stark evidence of sectoral labour reallocation since 2002. Of all the sectors in Canada during this time, the strongest employment growth was in the resource sector (mining, oil and gas), while the biggest employment losses were in manufacturing. Figure 12 shows the employment dynamics from the *Survey of Employment, Payroll and Hours* data. In the five years after the shock, resource sector employment rose more than 35 percent. This was more than double the growth in the rest of the Canadian economy, excluding the poor performance in manufacturing, where employment fell more than six percent. As a result, the sectoral composition of employment shifted from manufacturing to resources. Such sectoral real-location can potentially have aggregate impacts, given the sizeable differences in output per worker observed across sectors prior to the shock (Figure 13). It is worth noting that

Canada's sectoral reallocation is typical of the general labour adjustment over this period in developed economies in North America, Western Europe and the South Pacific.[10]

Fact 2: *The resource sector employment boom featured increased hiring and retention rates. In manufacturing, labour turnover stagnated as both job-finding and separation rates fell.*

While these employment changes are easily documented, how they were achieved remains an open issue. Firms have two extensive margins to adjust their workforce: hiring and firing. To examine the relative importance of these two margins, I estimate job-finding and separation rates in each sector as follows. The employment change is the difference between inflows and outflows:

$$\Delta e_{i,t} = f_{i,t} u_{i,t} - s_{i,t} e_{i,t} \tag{3.1}$$

where $\Delta e_{i,t}$ is the employment change in sector i at time t; u is unemployment; and f and s are the job-finding and separation rates. I estimate total outflows by aggregating individuals' employment-to-unemployment transitions using *Labour Force Survey* public use microdata. Given the employment and unemployment series, equation (3.1) gives the job-finding and separation rate estimates. Note the job-finding estimates assume all net inflows into the sector were from unemployment rather than labour force inactivity or job-to-job transitions from other sectors.

Figure 14 shows the results for the resource sector. Both series are expressed in

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[10]I find similar results for resources and manufacturing employment using U.S., Australian and New Zealand data; Macdonald (2007) also notes significant manufacturing employment losses in the U.K. and Germany during this period.

logarithms and identically-scaled so their relative movements are directly comparable.[11] The resource sector increased its employment by retaining existing workers and hiring new ones. The monthly job-finding rate in the resource sector rose from 28 percent in 2002 to 36 percent in 2006. The relative drop in the monthly rate of job separations into unemployment was even larger, falling from 3.5 percent to 2.2 percent.

Figure 15 shows that in the manufacturing sector, firms did not increase firings, instead they slowed hiring. This use of attrition is perhaps the least costly way to reduce employment since firms avoid firing costs, such as severance packages to unionized workers, and also save on recruiting and hiring costs. The entire employment adjustment in the manufacturing sector, therefore, came through a sharp drop in the job-finding rate, which fell from 32 percent in 2002 to 20 percent in 2005. Interestingly, there was actually a slight *drop* in manufacturing separations into unemployment, from 1.8 to 1.7 percent. I have disaggregated the data further into worker-initiated quits and firm-initiated layoffs; neither rose after the shock. Thus, there was a so-called 'chill' in the manufacturing sector as labour turnover slowed. My finding of a sharp drop in job-finding when the labour market in manufacturing weakened is consistent with previous research for the Canadian economy. For instance, Picot and Heisz (2000) find similar results during the weak labour market in first half of the 1990s, and Picot et al. (1998) find hires were more cyclically sensitive than permanent layoffs over 1978–1993.

Unfortunately, no reliable data are available by sector for vacancies or job training

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[11]Elsby et al. (2007) stress the appropriate comparison is the relative, rather than absolute changes in these rates. Using the U.S. data they argue that using absolute changes, as in Shimer (2005b), leads to erroneous interpretations of the relative contribution of each margin to unemployment fluctuations.

expenditures in Canada.[12] Nonetheless, it is reasonable to expect that vacancy posting is closely related to firm's implied hiring behavior, reported above, and profitability. Both rose strongly in resources, suggesting an increase in resource sector vacancies. In manufacturing, I estimate hiring fell sharply, while profit data show little change over this period, suggesting weak vacancy posting activity.[13]

3.2.4 Wage Adjustment

Fact 3: *Resource sector workers enjoyed the largest wage gains after the shock, with workers in the upper end of the wage distribution benefitting the most.*

Table 5 reports the gains in real hourly wages and annual wages between 2001, the year before the shocks, and 2006, the latest available data.[14] I report the quartiles to highlight the differences within a given sector along the wage distribution. Since the shocks, real average annual wages of resource workers increased by over $5,400 (in 2001 Canadian dollars). While the entire distribution benefitted, the gains were concentrated in the upper end.[15] Also see Figure 16, which plots the estimated resource sector wage distribution. Real wage growth in the manufacturing sector was more modest, though still substantial, averaging roughly $1,600. As opposed to the resource sector, gains in the lower and upper quartiles were roughly equal. Figure 17 plots the estimated wage

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[12]The usual proxy for firms' recruiting intensity, the Help Wanted Index, is no longer available for Canada. After 2003, the Conference Board stopped collecting it because job posting increasingly uses the Internet so the print space of employment ads is no longer a useful indicator of firms' recruiting efforts.

[13]Finally, if workers require training to operate new machinery and equipment (M&E), then M&E per worker provides a rough proxy for training. During 2002–2006, M&E per worker rose by 25 percent in resources and only 6 percent in manufacturing. This suggests a much stronger increase in resource training relative to manufacturing.

[14]Similar results hold for weekly earnings and when restricting the sample to full-time employees.

[15]Other studies for the U.S., such as Keane and Prasad (1996), using NLSY micro panel data find that oil price increases raised the relative wages of skilled workers.

distribution.

3.3 Calibration: Applying the Model to the Canadian Data

This section applies the model developed in Chapter 2 to analyze Canada's labour market adjustment during 2002–2006. I calibrate the benchmark model's steady-state to match the Canadian data in 2001 prior to the shocks. Intuitively, this environment corresponds to 'low' commodity prices and a 'weak' Canadian currency. I use additional data to infer the sector-specific shocks. After imposing these shocks, the benchmark model economy adjusts to a new steady-state that I compare with 2006 data, corresponding to the 'high' commodity prices and a 'strong' Canadian dollar environment. I demonstrate that given reasonable proxies for the sector-specific shocks, the model's labour adjustment quantitatively matches the data for sectoral employment movements and relative wage effects among high and low-skill workers in the resource sector.

3.3.1 Approach

Since the resource and manufacturing sectors had the largest proportional employment responses following the shocks (Fact 1), I focus the analysis by considering a model economy consisting of only these two most affected sectors. Together, these sectors accounted for a significant 23 percent of Canada's output in 2001. Two sectors yield 18 model parameters: $\{A_i, p_i^L, p_i^H, s_i, \lambda_i, \mu_i, \alpha, c, r, z, \delta, \beta\}_{i=r}^m$, where r and m subscript the resource and manufacturing sectors. I select parameter values to match time-series sample means and

values from the empirical literature. The remaining parameters are chosen so the model's endogenous variables match targets from the 2001 data for sectoral employment shares, unemployment and the ratio of high-to-low skill wages in each sector. The parameter values are described in detail below and summarized in Table 6.

3.3.2 Calibration/Parameter Selection

The model period represents one month.

Real Interest Rate, Discount Factor (r, δ)**:** The monthly real interest rate is set to $r = 0.29$ percent, which annualizes to 3.50 percent. Since the per-period discount rate is $\delta = \frac{1}{1+r}$, the monthly discount factor is $\delta = 0.9971$. The annual real interest rate target of 3.50 percent is the sample mean, ex ante real interest rate over 1991–2001, during the Bank of Canada's inflation targeting regime before the shock.[16]

Separation Rates (s_i)**:** The separation rates for resources and manufacturing of 3.50 percent and 1.97 percent are sample averages of the 1987–2001 time-series estimated using the *Labour Force Survey* microdata, as calculated in Section 3.2.

Productivities (p_i^L, p_i^H)**:** The model features 'low' and 'high' skill workers in each sector. In the benchmark calibration, low-skill productivity is set to match the 25th percentile (lower quartile) of the wage distribution in 2001, to represent the lower-half of the distribution. Manufacturing is the least productive sector of the two; I normalize its low-skill productivity to 1, $p_m^L = 1$. From Table 5, the lower quartile manufacturing

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[16]I proxy a typical Canadian firm's borrowing cost, beginning with the prime corporate three month nominal interest rate (Cansim v122491) and subtracting the year-over-year percentage change in the total CPI (Cansim v735319). This assumes agents expect no change in inflation.

wage in 2001 is \$12/hr. This wage, together with data for average hours worked in manufacturing, implies a normalized unit of output represents \$2064.40 in 2001 Canadian dollars. The lower quartile resource sector wage is \$15/hr, which is 25 percent higher than in manufacturing. Therefore, the low-skill resource productivity is $p_r^L = 1.25$. High-skill productivities are set so the model's ratio of high-to-low skill wages in each sector matches the 2001 data for the upper quartile divided by the lower quartile. This requires $p_m^H = 2.31$ and $p_r^H = 2.47$. In a steady-state there are no sector-specific productivity shocks, so $A_r = A_m = 1$.

Skill arrival rates (λ_i): The skill arrival rates are set such that, given the training response, in the benchmark model's steady-state half of the workers are low-skill and half are high-skill, to represent the two ends of the wage distribution. This requires $\lambda_r = .09$ and $\lambda_m = .05$.

Unemployment Income (z): Rather than model Canada's complex unemployment insurance system (which among other things, distinguishes eligibility by employment histories), I exploit the model's representative unemployed worker construct for a simple approach. The typical replacement rate in Canada for unemployment income is 55 percent of maximum annual insurable earnings — the latter remained constant at \$39,000 during 2002–2006. *Labour Force Survey* data show the average annual wages of full-time manufacturing and resource workers were roughly at or above the \$39,000 threshold over this period.[17] Moreover, the average job durations implied by the separation rates estimated above (of 50.7 and 28.6 months respectively for manufacturing and resources) are sufficient

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[17]To be precise, average annual manufacturing wages were \$38,940 in 2001. All other relevant wages exceeded the threshold.

to ensure the average worker who becomes unemployed in the model is eligible for benefits — in which case she collects monthly unemployment benefits of $1787.50 = 0.55 \cdot \frac{\$39,000}{12mns}$.

From the normalization above, one unit represents $2064.40, so $z = 0.87 = \frac{\$1787.50}{\$2064.40}$.

Recruiting Costs (c): Data on recruiting costs were collected in two large firm-level surveys in the U.S. (the 1982 Employment Opportunity Pilot Project and the 1992 Small Business Administration survey). From this evidence, Barron et al. (1997) and Dolfin (2006) estimate that firms use, on average, between 11 and 16 labour hours to recruit, screen and interview each new hire. Given the 2001 *Labour Force Survey* hours data for resource and manufacturing sectors, this implies recruiting costs of roughly ten percent of monthly output, so I set $c=0.10$. As several others have demonstrated — including Shimer (2005a); Hagedorn and Manovskii (2006); and Mortensen and Nagypál (2007), etc. — the baseline model's response to productivity shocks does not depend on the cost of posting a vacancy. Rather, the key determinant of amplification of productivity shocks in the baseline model is the difference between the value of market production and unemployment income. This model feature remains intact here, so the model dynamics and steady-state results are not sensitive to the choice of this parameter.

Matching Functions (μ_i, α): Petrongolo and Pissarides (2001) review the empirical literature on matching function estimation. For the Cobb Douglas specification, $m(u, v) = \mu u^\alpha v^{1-\alpha}$, when m measures the outflow from unemployment, as in the model, they report a "plausible" range of point estimates for α of $0.5 - 0.7$. I choose the midpoint, $\alpha = 0.6$.

The scale parameters on the matching functions, μ_i, are selected so the model generates

the target sectoral employment shares and unemployment rate from the 2001 data. For the two-sector economy considered, resource and manufacturing employment shares are 11 percent and 89 percent, respectively, and the unemployment rate is 7.7 percent. See Table 7.

Hitting these targets requires setting $\mu_r = 0.07$ and $\mu_m = 0.26$ and is computed as follows: Steady-state conditions for each sector require the labour flows into and out of unemployment are equal: $f_i(\theta_i)u = s_i e_i$, or $f_i(\theta_i) = \frac{s_i e_i}{u}$. Substituting in the targets gives equilibrium job-finding probabilities in each sector of $f_M^* = 0.21$ and $f_r^* = 0.05$. Thus, in the model, an unemployed worker's monthly job-finding probability is $f_M^* + f_r^* = 0.26$. This value is reassuringly close to the 0.289 independently estimated for Canada by Hobijn and Sahin (2007) using GMM. Given α, these job-finding probabilities, f_i^*, and a sector's equilibrium market tightness, θ_i^*, the scale parameters on matching function are solved by re-arranging the matching function to get $\mu_i^* = f_i^*/\theta_i^{*(\alpha-1)}$.

Worker's Share of the Match Surplus (β): I set $\beta = \frac{1}{2}$, so that the firm and worker share equally all surpluses and examine the sensitivity of the results in a subsequent section.[18]

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[18]For the basic model, the early literature often set $\beta = \frac{1}{2}$. More recently, it is common to set $\beta = \alpha$ to satisfy the Hosios (1990) condition so that in the decentralized equilibrium, job creation, and hence production, maximize social welfare given the matching frictions. This is no longer applicable in my model because of the extensions of heterogenous jobs and firm-provided training. Davis (2001) shows, with heterogeneous jobs and a single aggregate matching function, a tension exists between the worker's bargaining power, β, needed for the efficient *level* of jobs and for the efficient *composition* of jobs. While $\beta = \alpha$ provides the correct level of jobs, too few good jobs created in the decentralized equilibrium. The rationale is similar to here: because firm's bear the full cost of training, but only receive share $(1 - \beta)$ of the increase in value their training produces, training is less than socially-efficient in the decentralized equilibrium. As $\beta \to 0$, training will increase and shift the composition of jobs towards high-skill, however, there will be too few jobs created, so unemployment will be higher than socially optimal.

3.3.3 Comparing the Model to the Data

This section compares the model and data for the steady-states before and after shocks, and considers transition dynamics. The analysis demonstrates that a reasonably parsimonious model's labour market adjustment quantitatively captures key features in the Canadian data, given shocks of a reasonable magnitude.

The model is general and stylized. Commodity prices and exchange rates are not explicitly modeled. What matters for the model to feature sectoral labour reallocation is simply that the relative prices changes made one sector relatively more profitable. In the quantitative exercises, I model the shocks as sector-specific productivity changes and assume that for the Canadian economy they were exogenous, unanticipated and permanent.[19] I use data for real wages and real output per worker as two proxies to infer the unobserved sector-specific productivity shocks, $\hat{A}_i$:

Shock 1: (Wage Proxy) In the model's new steady-state, real wage growth is proportional to labour-augmenting productivity changes because free entry exhausts economic profits. Therefore, using the real wage data in Table 5, one can infer productivity changes since the shock. These data show that average resources and manufacturing wages grew by 9.7 percent and 4.9 percent over this period, respectively. I use these to proxy the productivity shocks, $\hat{A}_r = 1.097; \hat{A}_m = 1.049$.

Shock 2: (Output per Worker Proxy) As another proxy for the productivity shock, I

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[19]For Canada, it is reasonable to view as exogenous, changes in global demand and supply in commodity and currency markets and geopolitical factors. In addition, these dramatic price movements were largely unanticipated by commodity and foreign exchange markets, as they were not reflected in the 2001 prices and futures contracts. Finally, these relative price movements have proven persistent thus far.

use average sectoral output per worker in the five years before the shock, 1997–2001, and five years after the shock, 2002–2006. In the latter period, output per worker rose by 6.7 percent and 4.6 percent in the resource sector and manufacturing sectors, so the second proxy is: $\hat{A}_r = 1.067; \hat{A}_m = 1.046$.

Table 7 shows the results comparing the 2006 data to the model's new steady-states after shocks 1 and 2. Overall, the model is broadly consistent with the facts identified in Section 3.2. The wage proxy, shock 1, performs best, so I focus on these results and use this shock in the next section to quantify the aggregate labour reallocation costs. Consistent with Fact 1, labour is reallocated from manufacturing to resources. For the wage proxy, the model features exactly the correct amount of labour reallocation. Figures 18 and 19 compare the model's employment dynamics to payroll and labour force survey data. The model's employment adjustment captures the broad trends reasonably well, particularly for the payroll survey. However, the employment movements in the labour force survey data feature a delay of roughly two years, before the adjustment begins in earnest.

The model's labour adjustment works through increased hiring in the resource sector and reduced hiring in manufacturing, which is consistent with Fact 2 (Recall Figures 14 and 15). By construction, separations are exogenous and constant, so the model has no predictions on this adjustment margin.[20]

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[20]In the data, however, separations fell in both sectors after the shocks. I can address this, albeit unsatisfactorily, by including the observed separation rate declines to 3.0 percent and 1.7 percent in the resources and manufacturing sectors, averaged over the five years after the shock. This lowers the unemployment rate to 6.7 percent in the new steady-state, bring the model closer to the data. However, because separation rates fell more in resources, more workers move to the resource sector, whose employment share rises to 15.5 percent, so the model over-predicts the sectoral labour reallocation.

The model's performance for wages is also respectable. The model's wage gains are larger for the resource sector and concentrated in the upper end of the wage distribution, as in Fact 3. Table 8 shows the results, which compares the *Labour Force Survey* data to an artificial cross-section generated by model simulation. Using the model's equilibrium transition probabilities, I simulate the corresponding Markov chain to generate artificial data for $10,000$ workers' employment histories. The model does a good job explaining wage gains in the resource sector. As Table 7 shows, using the wage proxy, shock 1, the model's change in the high-low wage ratio in resources is close to that of the data, rising from 1.73 in the benchmark to 1.80 in the new steady-state versus the 1.81 in the data.

Overall, the model economy's provides a promising framework to investigate the role of the frictions in generating aggregate labour adjustment costs. Notwithstanding these successes, using these shocks, the model cannot generate the observed fall in the unemployment rate over this period. This is an issue raised by Shimer (2005a) and several others, though in a different context, since I consider a multisector version of the model. The reason unemployment does not fall in this application is that employment shifts to the resource sector which has a higher separation rate than the manufacturing sector. In addition, the model over-estimates the wage gains for the manufacturing sector, particularly for high-skill workers, whose actual wage gains were quite modest in the data, see Table 8.

3.4 Results: Quantifying the Costs from Search Frictions and Non-Transferable Skills

This section uses the model's transition dynamics (which were characterized in Section 2.4) to quantify the overall costs of adjustment and to isolate the importance of particular labour market frictions in the process. I essentially address the following question: What is the relative quantitative importance of the following two features of the labour adjustment: 1) *Search Frictions:* Workers who lose their job take time to find a new one; Or 2) *Skill non-transferability between matches and retraining:* Upon finding a new job, workers may be re-employed at a lower wage in their new job, and this may persist for some time before sufficient skills are acquired to increase production and the wage? I find that the skill transferability problem is much more important quantitatively.

I obtain this result by comparing the transition path in the benchmark model economy without these frictions — which adjusts to its new steady-state in one period — to the model economy hit by the same shock which adjusts subject to these search and skill non-transferability frictions. Figure 20 graphically demonstrates the intuition for the calculations. This is the appropriate comparison because society's opportunity cost attributable to these labour market frictions is what the economy produces during the adjustment versus what it is capable of producing after sectoral adjustment — the difference in the model's results are entirely due to these impediments to adjustment.

The calculations report three summary welfare measures to quantify the model economy's aggregate reallocation costs.

1) Social Planner's Value: the steady-state, per-period aggregate output net of training and recruiting costs, plus unemployment benefits: $= \sum_{i=r}^{m} y_i^L e_i^L + y_i^H e_i^H - \chi(x_i) e_i^L - cv_i + zu$

2) Social Net Production: aggregate production less training and recruiting costs:

$$= \sum_{i=r}^{m} y_i^L e_i^L + y_i^H e_i^H - \chi(x_i) e_i^L - cv_i$$

3) Worker's Expected Income: wages plus unemployment benefits:

$$= \sum_{i=r}^{m} w_i^L e_i^L + w_i^H e_i^H + zu$$

The social planner's value is often used in search models as a societal welfare measure. I prefer to focus on the social net production measure because it excludes unemployment benefits, which are not explicitly funded by tax collections. The final measure gives a view of the impact on workers. The basic results in this chapter are invariant to the welfare measure used.

Table 9 reports the adjustment costs attributable to both the search and non-transferable skill frictions — when both frictions are activated in the model. The numbers reported are the annual averages of the monthly deviations of variables during the labour market adjustment, relative to their values in the new steady-state. All values are discounted to the period of the shock, and expressed as a percent of the new steady-state.

The main finding is that the costs of reallocating labour across sectors following the shocks are economically significant and are incurred mainly in the first three years. Because these frictions impede the adjustment, social welfare measures — the social planner's value and social net production — are four percent, and aggregate output nearly three

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percent below their new steady-state values in the first year after the shock. On-the-job training costs are over seven percent above their eventual steady-state value in the first year, as low-skill (particularly resource sector) workers are trained more intensely until the stationary distribution of low-to-high skill jobs is obtained. Finally, notice that the full economic adjustment is a time-consuming process, taking over five years to complete.

Table 10 isolates the adjustment costs attributable to search frictions alone, by computing the transition for the model without skill accumulation. This allows me to infer the relative importance of each friction in the overall adjustment. The estimated costs in this scenario are significantly smaller, suggesting that search frictions are a minor contributor to the overall adjustment costs. Intuitively, this occurs because, in the model, the average worker finds a new job relatively quickly so search frictions have small transitory effects. Each month roughly one quarter of unemployed workers find a job, so workers are re-employed in $\frac{1}{\sum_i f(\theta_i)} = \frac{1}{0.25} = 4$ months, on average. What matters most for society, however, is the skills that are lost in the job turnover and the foregone production as workers to re-develop new skills in their subsequent work environment to become more productive.

Finally, recall the amplification properties of the model described in Chapter 2 from the 'innovation effect', which here corresponds to learning new skill through on-the-job training. Comparing the model with and without this skill accumulation re-enforces the point that the innovation effect is the model's key source of amplification, which is needed in these class of search models to match the data.

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3.4.1 Robustness of Results to Parameter Selection

This subsection assesses the sensitivity of the results to different parameter choices for values that were taken from the literature or pre-selected, such as α, c, and β.

I find that varying the matching function elasticity (with respect to unemployment), α, in the range found in Petrongolo and Pissarides' (2001) survey of the empirical literature has negligible impacts on the estimated adjustment costs. The welfare measures rise or fall by at most 0.2 percent during the transition. Large changes in the cost of posting a vacancy, c, also do not materially change the results. They simply scale vacancies but does not change their proportional response.

Finally, I analyze the sensitivity of the results to the worker's bargaining power parameter, β. This change directly impacts the firm's share of the surplus and, therefore, affects the incentives for job creation. If workers bargaining power rises above 0.6, then workers' reservation wages increase to the point that manufacturing production is no longer profitable. So in this parametrization, a large β is inconsistent with the data. Alternatively, Hagedorn and Manovskii (2006) choose a much smaller value of $\beta = 0.05$, based on the cyclicality of real wages. This parametrization gives firms the vast majority, 95 percent, of match surpluses. Overall this change moves the model farther away from matching the employment and wage data. Nonetheless, the welfare and output costs from labour adjustment remain sizeable. However, there is much less sectoral reallocation following the shocks, so the implied adjustment costs fall. With a small β, workers' wages are lower and the high-low wage ratio is much more compressed. Because firms keep almost

all of the skill premium — the gain in match value when moving from a low to high-skill match — they increase job creation and training in the benchmark model, prior to the shocks. In fact, in the benchmark model, firms train workers as much as possible (there is a corner solution at 1). As a result, there is no amplification following the productivity shock because training cannot increase further. With less amplification, the steady-state impacts are reduced. In addition, without the training effect, the economy reaches its new steady state much quicker, which implies lower adjustment costs. For example, in the first year following the shock, the welfare costs (as measured by the social planner's value) fall from 4 percent when $\beta = 0.5$, to 1.2 percent when $\beta = 0.05$. The complete results are in Table 11.

3.5 Conclusions

This chapter studies the process of sectoral labour reallocation at an aggregate level. I find that there can be considerable adjustment costs during the transition for particular sectors and the aggregate economy. Researchers generally accept that sectoral job changes can be costly for individual workers, largely because some skills are lost in the transition. A key contribution of this chapter is to quantitatively demonstrate a logical implication of this fact: During sectoral reallocations, large numbers of workers undergo job changes and this inability to transfer skills between jobs is a key contributor to the aggregate costs of sectoral labour adjustments.

I analyzed the sectoral labour adjustment in Canada during 2002–2006, after an increase in commodity prices and associated exchange rate appreciation. I used a multi-sector labour search and matching model to analyze factors which impede adjustment. The model did a good job explaining key features of the adjustment. When calibrated to the Canadian data, the model estimated that the costs of adjustment during this episode were as high as three percent of output. These costs were mainly attributable to skill loss due to job turnover, while the costs attributable to search frictions were relatively minor.

Chapter 4

Analyzing Labour Market Policy to Address Sectoral Adjustment

4.1 Introduction

The previous chapter demonstrates that impediments to labour reallocation resulted in economically significant costs for the Canadian economy during a recent sectoral adjustment. In light of this finding, this chapter investigates the impacts of labour market policies that may be considered to potentially improve the situation. In particular, I use the model to quantitatively investigate how changes in unemployment benefits impact economic allocations, social welfare, and the speed of adjustment to shocks. I find that more generous unemployment benefits discourage job creation, prolong the adjustment process and ultimately lower social welfare. However, because production is reallocated towards more productive sectors, aggregate productivity rises. I also investigate improved skill acquisition through faster learning and training subsidies and find that the associated economic gains are potentially quite large.

4.2 Counterfactual Policy Analysis: Increased Unemployment Benefits

To address these significant labour adjustment costs, a policy response often advocated is to compensate displaced workers with increased unemployment benefits. Such policy options are often discussed during particularly acute labour adjustments and argued for on the basis of equity considerations.[1] The argument is that workers who become unemployed following shocks bear much of the burden of adjustment, while society ultimately benefits when labour reallocates to more productive uses. To assess the implications of such a policy change, as an illustrative example, I estimate the impacts of increasing unemployment benefits following the shocks, from Canada's current replacement rate of 55 percent to 65 percent of maximum annual insurable earnings. As social spending typically becomes entrenched, I assume the policy change is permanent.

Table 12 compares the new steady-states after the shocks to the benchmark model, for the status quo and increased unemployment benefit replacement rates. The last column isolates the impact of increasing unemployment benefits. While this policy has some perhaps expected qualitative effects from a search model (e.g. unemployment incidence and duration increase), quantifying the overall impacts is important to focus the policy debates and compare the trade-offs involved. There are three key results to highlight. First, the policy significantly prolongs the economy's adjustment. Second, the policy

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[1]A related policy is Trade Adjustment Assistance in the U.S. which aids manufacturing workers who lost their jobs as a result of foreign competition. The U.S. Senate has for some time debated significantly expanding this program to include service sector workers.

encourages sectoral reallocation to the more-productive sector, generating aggregate productivity gains. Third, all things considered, the policy ultimately lowers social welfare.

The model mechanism driving these results is the reservation wage effect identified in Chapter 2. These quantitative results shed further light on this mechanism. The worker's reservation wage conveniently summarizes the worker's situation:

$$\overline{w} \equiv \quad z \quad + \quad \delta \sum_{i=1}^{I} f_i(\theta_i^*)(W_i^L - U)$$

The first term is what the worker gets 'at home', the second term is what the worker expects to gain from working in the market. Jointly, they represent the expected value of search to an unemployed worker, or simply the per-period unemployment value.[2] The increase in unemployment benefits has two opposing effects on the reservation wage — increasing the first term, but decreasing the second term. That is, the home, non-working option improves, while the market search value deteriorates. Quantitatively, in the new equilibrium, the first effect dominates causing the reservation wage to rise for unemployed workers (by 1.3 percent). Similarly, currently employed workers have an improved threat point in the wage bargain, so they renegotiate for higher wages. As a result, labour becomes more expensive, so given a match's productivity, jobs are less profitable. This, in turn, discourages job creation, so labour demand, recruiting costs, aggregate employment fall (by 1.8 percent) as does labour market tightness. Fewer workers produce less aggregate output (1.4 percent) and cost less to train (though training intensity per worker is unchanged). With less job creation, unemployment incidence and duration both rise

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[2]That is, the present value of unemployment is equal to indefinitely receiving the reservation wage each period. $U = \overline{w} + \delta\overline{w} + \delta^2\overline{w} + \ldots = \frac{\overline{w}}{1-\delta}$.

dramatically (by 21 percent and roughly 3.5 weeks respectively), resulting in a significant increase in the total unemployment benefits collected (over 40 percent). Further, lower job creation slows the adjustment process by two years. Stated differently, with more generous benefits the adjustment is 23 percent longer. As discussed in the introductory chapter, my results are consistent with empirical work for OECD countries by Scarpetta (1996) and computational results by Ljungqvist and Sargent (1998).

Another important result is that more generous unemployment benefits increase aggregate output per worker. In the model, the economy is more productive due to a compositional effect. Recruiting and production shift towards the resource sector, which is more productive than manufacturing. As workers raise their reservation wages, one might expect this to impact both sectors symmetrically. In fact, the job discouraging effect of the policy is stronger in less producitive/profitable sectors. The intuition for this result carries over from the on-going debates regarding the one-sector model.[3] A shock of a given size has a larger proportional impact on firms' profits, and therefore their vacancy posting decision, when the match surplus is smaller. In this case, the shock is a change in the worker's reservation wages and the manufacturing firms are less productive, so their match surplus is smaller and more responsive to the shock. As Table 12 shows, profits fall in both sectors with more generous benefits, but they fall more in the manufacturing sector (29 percent versus 6 percent for the resource sector). As a result, the composition of remaining job postings shifts towards the more-productive resource sector. Over time, as the resource sector hires a larger share of new workers, employment and production

[3]See Shimer (2005a); Hagedorn and Manovskii (2006); and Mortensen and Nagypál (2007), among others.

shift to resources making the economy more productive. Output per worker rises by 0.6 percent with the higher unemployment benefits.

All things considered, do increased unemployment benefits improve social welfare? Using the preferred social net production measure, the more generous benefits lower welfare by over one percent. In fact, these results understate the welfare losses because the taxes needed to fund the benefits — and the distortions they induce — are absent in the model.[4]

While society overall is worse off with increased unemployment benefits, not all agents are made worse off by the policy change. Despite less aggregate production and income, workers take a larger share of overall income, as wages rise. Indeed, those who are employed are better off and those that are unemployed are receiving higher benefits, so labour clearly benefits from the policy. The policy also has mild distributional effects, compressing the wage structure, as low-skill workers' wages rise relative to those of high-skill workers.

In this example, the model's unemployment response to changes in the replacement rate is quantitatively consistent with empirical estimates that use cross-country regression for panels of OECD economies. The estimates of the semi-elasticity of unemployment rate with respect to unemployment benefit replacement rate range from .011–.024.[5] In my model the result is .016, falling safely in the range of plausible estimates. When the replacement rate increases by 18 percent, (10 percentage points, from 55 percent to 65

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[4]The social planner's value is one percent higher, however, this is misleading because it arises solely from higher unemployment income.

[5]Nickell and Layard (1999) and Costain and Reiter (2006).

percent) the unemployment rate rises by 21 percent, or 1.6 percentage points.

This is not only reassuring that the quantitative result are reasonable, but relates to a general problem with the baseline one-sector search and matching model. Essentially, the calibrated model can either match unemployment's response to productivity *or* unemployment's response to unemployment benefits, but not both. For instance, if the model's unemployment responds enough to productivity shock to match the data, then it is much too sensitive to changes in unemployment benefits. This is issue was recently noted by several authors including: Hornstein, Krusell, and Violante (2005); Costain and Reiter (2006); and Silva and Toledo (2007). Section 3.3 demonstrates that my results are consistent with the sectoral employment data. It is noteworthy then, that my model simultaneously matches sectoral employment responses to productivity shocks and unemployment's response to unemployment benefits.

4.3 The Importance of Faster Learning and Skill Acquisition

Chapter 3 demonstrates that factors inhibiting sectoral labour adjustments can be costly for both individuals and the aggregate economy. The corollary of this finding is that factors that facilitate reallocation are potentially quite beneficial. Relevant policy measures include strengthening the incentives for job creation and on-the-job training for firms (such as by lowering marginal effective corporate tax rates) and acquiring transferable skills for workers (such as post-secondary education and other advanced training).

Serious consideration of these issues require several extensions to the baseline model environment, including adding taxes collections to fund unemployment benefits and government subsidies to firms' training investments, and distinguishing between match-specific and sector-specific skills, which in turn would require one to track workers' job histories. Nonetheless, some simple quantitative exercises can be instructive as to how responsive the adjustment costs estimates are to skill acquisition rates and emphasize the results of Chapter 3 — that the skill acquisition process is crucially important for the overall economy.

The exogenous skill acquisition rate in the model is given by the parameter λ. In the first scenario, I consider the model's response to the same shocks, when workers can acquire skills twice as fast ($\lambda_r = 0.18.\lambda_m = .10$), which strengthens firms' incentives to offer training. Table 13 compares the results in the baseline model versus the case where workers learn twice as fast after the shocks. The results suggest the potential for policies that improve the learning and skill acquisition process may be extremely large and economically important. This speeds up the adjustment by nearly 3 years, making it 30 percent faster. Social net production and aggregate output both increase dramatically by over 30 percent and 25 percent, respectively in the new steady-state, as firms increased training intensity shifts the composition of production towards high-skill jobs, which rises to 82 percent of production from 54 percent. Despite the increased training intensity, aggregate training costs fall by 24 percent with faster learning. This occurs for two reasons. First, faster-learning workers require less time training to become high-skill, on average. Second, because learning is faster, there are fewer low-skill workers to train in

the new steady-state.

Figure 21 shows the transition dynamics. They reveal that society incurs a small up-front cost as training increases dramatically, lowering social net production in the first four months. The increased training and faster learning payoff quickly though as social net production increases, to deliver a large transitional and steady-state benefit.

Indeed, in this environment there is a strong rationale to subsidize training because the decentralized equilibrium features training that is less than the socially-efficient level. This occurs because Nash bargaining splits the joint match surpluses. Therefore, firms bear the full cost of training, but only receive share $(1 - \beta)$ of the increase in value their training produces. Stated differently, the private return on training is less than the social return because firms fail to internalize the positive externality their training choice has on workers' wages. As workers' bargaining power falls, $\beta \to 0$, firms keep more of the return on their investment, so training increases. In the limit, wages collapse to the reservation wage, $\overline{w}$, leaving all workers indifferent between working and unemployment.[6]

The second scenario considers a hypothetical training subsidy to increase firms' invest-ment. Firms original investment choices are now 'topped-up' each period by a lump-sum subsidy that increases the effective training choice. (This could in principle be financed with a lump-sum tax on output.) Such a policy is worthwhile if it increases social net production. Figure 22 shows the percentage gain in social net production in the new steady-state after the shocks for various levels of the subsidy. The largest social gain of 12 percent occurs at the corner solution with both sectors investing fully in training their

[6]See the equilibrium wage equations from (2.12) and (2.13).

workers, $x_i = 1 \ \forall i$, which requires the maximum possible subsidy of 0.5 units of output, effectively doubling firms' original choice of roughly 0.5. For a sense of the magnitude of the subsidy, 0.5 units is quite large — roughly equivalent to $6 per hour (in 2001 Canadian dollars, based on the calibration details contained in Section 3.3.2). Table 14 shows the results in more detail for this particular example.

Figure 23 shows the model's transition dynamics for each training subsidy level and depicts the similar short-run trade-off highlighted in the scenario with faster learning. As the subsidy increases, there is a larger up-front cost in terms of higher social training costs incurred for approximately the first year. After this point, however, the economy is more productive because the higher training investments result in more high-skill production.

Comparing the two scenarios, the environment with faster learning is more productive than the environment with equivalent training subsidies. The reason is that there are two sources of social gain to faster learning. The first is the exogenous increase in learning itself and the second is the endogenous increase in training intensity that it induces.

As a strong caveat, these results are only suggestive. They overlook any distortions that would be introduced, for instance by raising tax revenue to subsidize firms' investments. Furthermore, the true practical policy trade-offs are not readily apparent as there would likely be diminishing marginal gains to increased training and increasing marginal costs.

4.4 General Policy Implications and Discussion

Canada's recent sectoral adjustment studied in this thesis has received much attention in the popular press and policy discussions. Federal and provincial governments (particularly in Ontario and Quebec) are currently debating policy options in an attempt to assist the struggling manufacturing sector. The stated goals are typically to save jobs, motivated largely by the decline in the level of manufacturing employment in these areas. Generally speaking, the cause of reduced employment is almost always assumed to be increased job loss from (permanent) layoffs. In fact, this view is not supported by the data. At the national level, there was no increase in layoff or quit rates between 2002–2006. The analysis in Chapter 3 suggests instead that the problem is not that the rate of layoffs has increased, but rather the cause for concern is the weak job creation, which was entirely responsible for the fall in manufacturing employment.

With regard to actual recent policy actions, in the 2008 Federal Budget, the government announced policies to give manufacturers tax write-offs on new purchases of machinery and equipment. This policy may well be desirable to improve the sector's global competitiveness. However, whether this stimulates a rebound in *employment* depends crucially on the degree to which such investments are complementary to labour in the production process (rather than substitutes). The provincial governments, on the other hand, have argued for increased generosity of unemployment benefits, such as reducing eligibility requirements or extending the time that benefits can be collected. The results

of this chapter suggest such a policy would undoubtedly benefit some workers (particularly older workers who will typically endure longer unemployment spells). Thus, support for these policies, from labour unions for example, is completely rational. Labour clearly benefits under such policies. However, these same policies will almost certainly prolong the necessary reallocation of production.

Finally, the results highlight the potential distributional considerations that these labour reallocation episodes bring about. For example, high-skill workers may benefit relatively more than low-skill workers during such adjustments. These developments, therefore, have the potential to exacerbate individual income disparities as well as regional disparities, given the asymmetric sectoral composition of production across Canadian regions.

4.5 Conclusions

This chapter investigates the potential effects of changes to unemployment benefits on the economy and its adjustment following shocks. I find that higher unemployment benefits reduce employment, output and social welfare and prolong the adjustment process. However, such a policy would likely increase the composition of high-productivity jobs in the economy and raise output per worker. Finally, I performed some preliminary investigations of the economy's response with quicker learning and skill acquisition. The results suggest that the benefits of policies which strengthen the incentives for re-acquiring skills or facilitating skill transfer between jobs are potentially very large.

Chapter 5

General Conclusions and Future Work

> Empirical evidence on the earnings losses of displaced workers (is a) trouble-some issue for equilibrium search theories of unemployment and labor market flows. Attention to (this) issue is essential if these theories are to provide a broad analytical treatment of labor market fluctuations and their conse-quences.
>
> Davis (2005)

This thesis explores the fact that job loss is costly for some individual workers, with the focus on the aggregate economy. The main questions I address are: How costly are sectoral labour adjustment episodes for the economy? And what labour market frictions contribute to these costs?

A search and matching framework provided a tractable model environment to quanti-tatively identify the importance of some basic ideas. First, it takes workers and firms time and resources to begin new jobs. Second, when workers relocate to new jobs, they may be more or less productive than they were before, and they often have difficulty transferring some of their skills developed in previous jobs. Third, workers' outside options are an im-portant determinant of negotiated wages, and therefore, influence firms' hiring decisions.

As a result, developments in other jobs that employees can potentially work in, will act to link labour market conditions across sectors. Methodologically, the analysis expands on the baseline search and matching macro-labour model by investigating two new mechanisms of labour adjustment through the amplification and propagation of sector-specific shocks.

Overall, the quantitative findings from a case study of a recent adjustment in the Canadian economy suggest that such reallocation costs are economically significant in the aggregate. These findings complement existing empirical labour research that uses the individual as the unit of analysis. Relative to other research, my results strive to define more precisely the role of specific labour market frictions in the costly adjustment process. I find that, while the role of search frictions is relatively small, one important contributor to these aggregate costs is the inability to transfer specific skills between jobs during labour turnover. This result emphasizes the point that skills that are lost in the transition matter. Similarly, increasing the transferability of skills or quickening the learning process on new jobs has the potential for large economic gains.

Finally, the analysis reveals trade-offs faced by labour market policies designed to mitigate these reallocation costs, such as changes to unemployment benefits. For example, increasing the scale of such programs could assist workers and result in a more productive economy, but only because it crowds out low-productivity jobs more than high-productivity jobs. Aggregate job creation, employment, output and social welfare would also likely suffer as a result of a policy to increase unemployment benefits.

There are several potentially interesting extensions to the theoretical model, such as comparing the role of general, sector-specific and match-specific skills. The quantitative analysis could consider a third sector to capture movements to the rest of the economy. In the current results, restricting attention to two sectors was reasonable because workers in these sector share similar characteristics (e.g. non-university-educated males seeking full-time employment) and often move between these sectors in the real world. Indeed, if one wanted a more disaggregated approach these sectors could be viewed as specific occupations, whose labour markets are related by the potential of worker mobility between them.

Another possible application of this model is to assess whether the aggregate costs of recent energy price shocks have lessened compared to the episodes in the 1970s, as recent research by Blanchard and Gali (2007) suggests that the aggregate effects of energy price shocks have changed considerably over time.

Finally, because sectoral compositions differ significantly across regions, sector-specific shocks are often regional shocks. Future research could study regional labour market responses and migration after shocks. With suitable modifications, the basic framework developed in this thesis is well-suited to address these issues, such as making skills transferable across regions, allowing workers to choose the regions where they search for work, and including direct labour mobility costs by adding the sale and purchase of assets when workers move (to represent real estate considerations). The interaction of capital and labour markets in this environment may provide some interesting new insights into the labour adjustment process across regions.

This recent Canadian adjustment episode also provides several interesting and open questions for future research. For example: Has unemployment duration increased in the manufacturing sector? If so, what has happened to long-term unemployed workers? Are these displaced workers simply dropping out of the labour force, changing sectors or waiting for new jobs in manufacturing? Finally, how costly are the earnings losses for these workers, and what has happened to wages for workers who changed jobs relative to those who stayed?

One limitation of the set-up used here is the implicit assumption that all workers are inherently the same and any differences in lifetime earnings are entirely attributable to the luck associated with job search and the random acquisition of skills on-the-job. Such a stark assumption delivers a tractable and parsimonious model, but undoubtedly overlooks some significant features of labour markets. Explicitly modeling worker heterogeneity — particularly along life-cycle dimensions — is a difficult task that would significantly further complicate the analysis. Nonetheless, addressing the heterogeneity of workers in a satisfactory manner promises significant payoffs for future work in this area.

As Davis's quotation beginning this chapter identifies, there is currently a large gulf between the empirical micro-level research findings and the implications of search models with regard to the aggregate consequences of labour market fluctuations. I hope this thesis and future research in this area can close this gap and further improve our understanding of the aggregate costs, consequences and policy implications of labour market adjustments.

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Appendix A: Tables

Table 1: **Parameter Values for the Benchmark Model**

Variable	Parameter	Value	Rationale
Real Interest Rate	r	0.33%	4 percent annual
Discount Factor	δ	0.997	$\delta = \frac{1}{1+r}$
Separation Rate, Sector 1	s_1	3.4%	Shimer (2005)
Separation Rate, Sector 2	s_2	3.4%	Shimer (2005)
Low-Skill Productivity, Sector 1	p_1^L	1.0	
Low-Skill Productivity, Sector 2	p_2^L	1.0	
High-Skill Productivity, Sector 1	p_1^H	2.0	
High-Skill Productivity, Sector 2	p_2^H	2.0	
Recruiting Cost	c	0.1	Tapp (2007)
Investment Cost Scale, Sector 1	k_1	1.0	
Investment Cost Scale, Sector 2	k_2	1.0	
Productivity Shock, Sector 1	A_1	1.0	Steady-State
Productivity Shock, Sector 2	A_2	1.0	Steady-State
Matching Fx. Scale, Sector 1	μ_1	0.13	Sector 1 Employment Share $= \frac{1}{2}$
Matching Fx. Scale, Sector 2	μ_2	0.13	Sector 2 Employment Share $= \frac{1}{2}$
Skill Arrival Rate, Sector 1	λ_1	0.11	High-Skill Employment Share $= \frac{1}{2}$
Skill Arrival Rate, Sector 2	λ_2	0.11	High-Skill Employment Share $= \frac{1}{2}$
Unemployment Income	z	0.6	40% Replacement Rate $= 0.4(\frac{p_1^L + p_2^L}{2})$
Matching Function Elasticity	α	0.6	Petrongolo and Pissarides (2001)
Workers' Bargaining Power	β	0.5	Equal split of surplus
Model Period = 1 Month			

Table 2: **Sectoral and Aggregate Output per Worker, Summary Statistics, Canada, 1987Q1–2001Q4**

	Resources	**Manufacturing**	**Aggregate Economy**
Standard Deviation	0.043	0.030	0.012
Quarterly Autocorrelation	0.86	0.89	0.95
Correlation with Resources	1	0.52	0.30
Correlation with Manufacturing		1	0.53
Correlation with Aggregate Economy			1

Note: All variables are reported in logs as deviations from an HP trend with smoothing parameter of 10^5. The results obtained using a smoothing parameter of 1600 are similar. All data are from Cansim. Aggregate, Resource and Manufacturing output series are seasonally adjusted at annual rates expressed in 1997 constant dollars: v2036138; v2036146; and v2036171. Aggregate, Resource and Manufacturing Employment series are: v13682073; v13682076; and v13682079.

Table 3: **Steady-State Impacts of General versus Sector-Specific Shocks**

Aggregate Impacts	Benchmark	General Shock	Sector-Specific Shock	Sector-Specific Effect
Social Welfare (a+b-c-d)	100	102.3	102.5	0.2
Social Net Production (a-c-d)	100	102.4	102.6	0.1
a) Output	100	102.4	102.7	0.2
b) Unemployment Benefits	100	98.4	100.6	2.2
c) Innovation Investment Costs	100	102.5	102.7	0.2
d) Recruiting Costs	100	102.8	105.5	2.7
Employment	100	100.1	100.0	-0.2
% High-Skill	50.0	51.2	51.4	0.2
Output per Worker	100	102.3	102.7	0.4
Reservation Wage	100	102.2	102.5	0.2
Unemployment	100	98.4	100.6	2.2
Unemp. Duration (months)	2.4	2.3	2.4	0.1
Sectoral Impacts				
Output - Sector 1	100	102.4	124.1	21.7
Sector 2	100	102.4	81.2	-21.2
Employment - Sector 1	100	100.1	118.7	18.6
Sector 2	100	100.1	81.2	-18.9
% High Skill - Sector 1	50.0	51.2	52.3	1.1
Sector 2	50.0	51.2	50.0	-1.2
Profits - Sector 1	100	102.7	128.2	25.5
Sector 2	100	102.7	72.5	-30.2
Market Tightness - Sector 1	100	104.5	151.3	46.8
Sector 2	100	104.5	58.5	-46.0
Distributional Impacts				
Low-Skill Wages - Sector 1	100	101.4	101.6	0.1
Sector 2	100	101.4	101.6	0.1
High-Skill Wages - Sector 1	100	101.8	102.8	1.0
Sector 2	100	101.8	100.9	-0.9

Note: Steady-state comparison following unanticipated, permanent productivity shocks which are general versus sector-specific. The relevant variables in the benchmark steady-state are normalized to 100. In the Benchmark model $A_1 = A_2 = 1$; General Shock $A_1 = A_2 = 1.015$; Sector-Specific Shock for Sector 1: $A_1 = 1.03, A_2 = 1$. The sector-specific effect of the shock is the specific shock minus the general shock.

Table 4: **Exposure to Exchange Rate Movements by Industry, Canada 2002**

Industry	(1) Export Orientation	(2) Import Competition	(3) Imported Inputs	Trade Exposure (1)+(2)-(3)
Manufacturing	0.52	0.48	0.24	**0.76**
Primary	0.44	0.25	0.08	0.61
Resources	0.40	0.24	0.14	**0.50**
Accommodation & Food	0.17	0.19	0.05	0.31
Business Services & Transportation	0.14	0.09	0.04	0.19
Construction	0.00	0.00	0.12	-0.12
Private Sector	0.27	0.31	0.11	**0.48**

Source: Dion (2000) and updated Bank of Canada calculations. Export orientation and imported inputs are expressed as a share of the sector's gross output (which includes domestic and foreign sales). Imported competition measures imports as a share of the domestic market. With an appreciation, the change in relative prices makes exports more expensive and imports cheaper. Therefore, sectors are more exposed to exchange rate movements when exporting more of their goods, and when facing more import competition in the domestic market. A benefit of the appreciation is cheaper imported inputs, so this is subtracted in the overall trade exposure measure.

Table 5: **Distribution of Real Wage Gains, 2006 vs. 2001**

	Annualized Wage Gain	Hourly Wage 2001	2006	Percentage Change
Resources				
Lower Quartile	$1,929	$ 15.00	$ 15.59	4.0%
Median	$4,750	$ 20.19	$ 21.97	8.8%
Upper Quartile	$5,980	$ 25.96	$ 28.19	8.6%
Mean	$5,435	$ 21.30	$ 23.37	9.7%
Number of Observations		16, 407	18, 241	
Manufacturing				
Lower Quartile	$646	$ 12.00	$ 12.37	3.1%
Median	$971	$ 16.40	$ 16.95	3.4%
Upper Quartile	$663	$ 22.50	$ 22.91	1.8%
Mean	$1,594	$ 18.04	$ 18.92	4.9%
Number of Observations		96, 260	84, 714	

Note: Lower quartile, median and upper quartile are the 25th, 50th and 75th percentiles respectively. Source: *Labour Force Survey* (LFS) Public Use Microdata files. Observations weighted by LFS frequency weights. Real hourly earnings, 2001 Canadian dollars deflated using the CPI. Annualized Wage Gain is the difference in annual wage earnings in 2001 and 2006. Annual wage earnings multiply average actual hours worked per year in the sector by the real hourly wage. The hours series are from Cansim and cover all workers (Manufacturing, v2641791; Resources, v2641755)

Table 6: **Parameter Values for the Benchmark Model**

Variable	Value	Target
Real Interest Rate, r	0.29%	Sample mean Canadian data
Discount Factor, δ	0.997	$\delta = \frac{1}{1+r}$
Resource Separation Rate, s_r	3.50%	Labour Force Survey (LFS) microdata
Manuf. Separation Rate, s_m	1.97%	LFS microdata
Resource Low-Skill Productivity, p_r^L	1.25	LFS wage data
Manuf. Low-Skill Productivity, p_m^L	1.0	LFS wage data, normalization
Unemployment Income, z	0.87	55% Maximum Insurable Earnings
Matching Function Elasticity, α	0.6	Petrongolo and Pissarides (2001)
Recruiting Cost, c	0.1	Dolfin (2006); Barron et al. (1997)
Workers' Bargaining Power, β	0.5	Equal split of surplus
Resource Productivity Shock, A_R	1.0	Steady-state
Manuf. Productivity Shock, A_M	1.0	Steady-state
Scale Parameter on Matching Fx., μ_r	0.07	LFS Resource Employment
Scale Parameter on Matching Fx., μ_m	0.26	LFS Manufacturing Employment
Resource High-Skill 'Output', p_r^H	2.47	LFS High-low wage ratio
Manuf. High-Skill 'Output', p_m^H	2.31	LFS High-low wage ratio
Resource Skill Arrival Rate, λ_r	0.09	$\frac{1}{2}$ High-low skill Employment
Manuf. Skill Arrival Rate, λ_m	0.05	$\frac{1}{2}$ High-low skill Employment
Model Period = 1 Month		

Table 7: **Comparing Model to Data, Target Variables in the Benchmark and New Steady-State**

	Benchmark 2001		New Steady-State		
			2006	Shock 1	Shock 2
	Data	Model	Data	Model	Model
Employment Share					
Resources	11.0	11.0	13.9	13.9	11.8
Manufacturing	89.0	89.0	86.1	86.1	88.2
Unemployment Rate	7.7	7.7	5.4	7.7	7.3
High-Low Skill Wage Ratio					
Resources	1.73	1.73	1.81	1.80	1.77
Manufacturing	1.88	1.88	1.85	1.90	1.90

Note: First column of numbers are the 2001 benchmark targets. The second column is the calibrated benchmark model. The third column is the 2006 new steady-state data targets. The fourth column, labeled Shock 1, is the new steady-state using the wage proxy for productivity shocks: $A_r = 1.097; A_m = 1.049$. The fifth column, labeled Shock 2, is the new steady-state using the output per worker proxy for the productivity shocks: $A_r = 1.067; A_m = 1.046$.

Table 8: **Distribution of Real Wage Gains By Sector, Model-Generated vs. Data**

	Data		Model	
	Annualized Wage Gain	Percentage Change	Annualized Wage Gain	Percentage Change
Resources				
Lower Quartile	$ 1,929	4.0%	$ 1,472	5.4%
Upper Quartile	$ 5,980	8.6%	$ 4,415	9.4%
Mean	$ 5,435	9.7%	$ 4,098	11.4%
Manufacturing				
Lower Quartile	$ 646	3.1%	$ 1,252	5.2%
Upper Quartile	$ 663	1.8%	$ 2,829	6.3%
Mean	$ 1,594	4.9%	$ 2,666	7.9%

Note: Data are from Author's calculations using *Labour Force Survey* Public Use Microdata Files. See Table 5 for further details. Model: I simulate the benchmark and new steady-state models to generate artificial data on worker's employment histories. Given these work histories, I compute annual incomes for workers. Each artificial sample has 10, 000 workers.

Table 9: **Adjustment Costs Attributable to Search Frictions and Non-Transferable Skills** (Discounted and Expressed in Percent)

	Years After the Shock				
	1	**2**	**3**	**5**	**7**
Social Planner's Value (a+b-c-d)	4.0	2.1	1.1	0.2	0.0
Social Net Product (a-c-d)	4.2	2.2	1.1	0.2	0.0
Worker's Expected Income	2.1	1.1	0.5	0.1	0.0
a) Aggregate Output	2.8	1.5	0.8	0.2	0.0
b) Unemployment Benefits	1.2	1.2	0.8	0.3	0.1
c) Training Costs	7.3	4.0	1.9	0.4	0.0
d) Recruiting Costs	-1.1	-1.2	-0.8	-0.3	-0.2

Note: Compares a model economy that adjusts without frictions and training to the new steady-state following the wage proxy productivity shocks: $A_r = 1.097; A_m = 1.049$, to an economy subject to search and training frictions. The numbers reported are the average annual deviations of variables during the labour market adjustment relative to their values in the new steady-state. All values are discounted to the period of the shock, and expressed as a percent of the new steady-state.

Table 10: **Adjustment Costs Attributable to Search Frictions** (Discounted and Expressed in Percent)

	Years After the Shock				
	1	**2**	**3**	**5**	**7**
Social Planner's Value	0.3	0.1	0.1	0.0	0.0
Social Net Product	0.2	0.1	0.1	0.0	0.0
Worker's Expected Income	0.1	0.1	0.0	0.0	0.0
Aggregate Output	0.3	0.1	0.1	0.0	0.0
Unemployment Benefits	0.6	0.8	0.6	0.2	0.1
Training Costs	–	–	–	–	–
Recruiting Costs	-0.6	-0.9	-0.6	-0.3	-0.1

Note: Compares a model economy that adjusts without frictions and skill accumulation to the new steady-state following the wage proxy productivity shocks: $A_r = 1.097$; $A_m = 1.049$, to an economy subject to only search frictions, $\lambda_i = 0$; $p_i = \frac{p_i^L + p_i^H}{2}$. The numbers reported are the average annual deviations of variables during the labour market adjustment relative to their values in the new steady-state. All values are discounted to the period of the shock, and expressed as a percent of the new steady-state.

Table 11: **Sensitivity of Total Adjustment Costs to Worker's Bargaining Power, β** (Discounted and Expressed in Percent)

$\beta = 0.5$	Years After the Shock				
	1	**2**	**3**	**5**	**7**
Social Planner's Value (a+b-c-d)	4.0	2.1	1.1	0.2	0.0
Social Net Product (a-c-d)	4.2	2.2	1.1	0.2	0.0
Worker's Expected Income	2.1	1.1	0.5	0.1	0.0
a) Aggregate Output	2.8	1.5	0.8	0.2	0.0
b) Unemployment Benefits	1.2	1.2	0.8	0.3	0.1
c) Training Costs	7.3	4.0	1.9	0.4	0.0
d) Recruiting Costs	-1.1	-1.2	-0.8	-0.3	-0.2

$\beta = 0.05$	Years After the Shock				
	1	**2**	**3**	**5**	**7**
Social Planner's Value	1.2	0.1	0.0	-0.1	0.0
Social Net Product	1.3	0.1	0.0	-0.1	0.0
Worker's Expected Income	0.1	0.0	0.0	0.0	0.0
a) Aggregate Output	0.4	0.1	0.0	0.0	0.0
b) Unemployment Benefits	2.0	0.3	0.2	0.1	0.0
c) Training Costs	0.4	0.4	0.0	-0.1	-0.1
d) Recruiting Costs	2.2	-0.3	-0.2	-0.1	0.0

Note: Compares a model economy that adjusts without frictions and skill accumulation to the new steady-state following the wage proxy productivity shocks: $A_r = 1.097; A_m = 1.049$, to an economy subject to only search frictions, $\lambda_i = 0; p_i = \frac{p_i^L + p_i^H}{2}$. The numbers reported are the average annual deviations of variables during the labour market adjustment relative to their values in the new steady-state. All values are discounted to the period of the shock, and expressed as a percent of the new steady-state.

Table 12: **Steady-State Impacts of Increased Unemployment Insurance**

Aggregate Impacts	Benchmark	New Steady-State Status Quo EI	New Steady-State More Generous EI	EI Effect
Social Planner's Value (a+b-c-d)	100	108.7	109.7	1.0
Social Net Production (a-c-d)	100	109.1	108.0	-1.1
Worker's Expected Income	100	108.7	109.9	1.2
a) Output	100	109.3	108.0	-1.4
b) Unemployment Benefits	100	100.4	143.5	43.1
c) Training Costs	100	108.1	106.3	-1.8
d) Recruiting Costs	100	125.2	115.3	-9.9
Employment	100	100.0	98.2	-1.8
% High-Skill	50.0	54.2	54.2	0.0
Output per Worker	100	109.4	109.9	0.6
Reservation Wage	100	108.7	110.0	1.3
Unemployment	100	100.4	121.4	21.0
Une Duration (months)	3.9	3.8	4.6	0.8
Sectoral Impacts				
Output - Resources	100	144.5	169.9	25.4
Manufacturing	100	104.4	99.4	-5.1
Employment - Resources	100	126.2	148.4	22.2
Manufacturing	100	96.7	92.0	-4.7
% High Skill - Resources	50.0	56.7	56.7	0.0
Manufacturing	50.0	53.8	53.8	0.0
Profits - Resources	100	141.0	135.2	-5.8
Manufacturing	100	94.6	66.0	-28.6
Market Tightness - Resources	100	177.3	165.3	-12.1
Manufacturing	100	91.1	50.0	-41.1
Distributional Impacts				
Low-Skill Wages - Resources	100	105.4	106.2	0.8
Manufacturing	100	105.2	106.1	0.9
High-Skill Wages - Resources	100	109.4	109.8	0.5
Manufacturing	100	106.3	106.8	0.5
Transition Effects				
Time to Full Convergence (yrs)	–	8.6	10.6	2.0

Note: The relevant variables in the benchmark steady-state are normalized to 100. Compares steady-states with Status Quo: 55% and More Generous: 65% unemployment benefit replacement rate (of normalized output).

Table 13: **Steady-State Impacts of Faster Skill Acquisition**

Aggregate Impacts	Benchmark	New Steady-State Status Quo	New Steady-State Faster Skills Acquisition	Skill Effect
Social Welfare (a+b-c-d)	100.0	108.6	137.6	28.9
Social Net Production (a-c-d)	100.0	109.0	140.8	31.8
a) Output	100.0	109.3	134.4	25.1
b) Unemployment Benefits	100.0	100.6	73.8	-26.7
c) Training Costs	100.0	108.1	84.0	-24.1
d) Recruiting Costs	100.0	125.4	156.6	31.2
Employment	100.0	100.0	102.2	2.2
% High-Skill	50.0	54.1	82.2	28.1
Output per Worker	100.0	109.4	132.3	22.9
Reservation Wage	100.0	108.7	139.4	30.7
Unemployment	100.0	100.6	73.8	-26.7
Une Duration (months)	3.9	3.8	2.8	-1.0
Sectoral Impacts				
Output - Resources	100.0	145.1	125.2	-19.9
Manufacturing	100.0	104.3	135.7	31.4
Employment - Resources	100.0	126.7	91.9	-34.8
Manufacturing	100.0	96.6	101.0	4.4
% High Skill - Resources	50.0	56.7	82.7	26.0
Manufacturing	50.0	53.7	82.2	28.5
Profits - Resources	100.0	141.4	165.2	23.8
Manufacturing	100.0	94.2	143.6	49.4
Market Tightness - Resources	100.0	178.2	182.8	4.6
Manufacturing	100.0	90.5	230.9	140.4
Distributional Impacts				
Low-Skill Wages - Resources	100.0	105.4	105.1	-0.3
Manufacturing	100.0	105.2	103.0	-2.3
High-Skill Wages - Resources	100.0	109.4	120.2	10.8
Manufacturing	100.0	106.3	117.5	11.3
Transition Effects				
Time to Full Convergence (yrs)	–	8.6	5.9	-2.7

Note: The relevant variables in the benchmark steady-state are normalized to 100. Compares steady-states with Status Quo Skill Acquisition $\lambda_r = 0.09$, $\lambda_m = 0.05$, to Faster Skill Acquisition: $\lambda_r = 0.18$, $\lambda_m = .10$.

Table 14: **Steady-State Impacts of a Training Subsidy**

Aggregate Impacts	Benchmark	Subsidy=0	Subsidy=0.5	Subsidy Effect
Social Welfare (a+b-c-d)	100.0	108.6	119.4	10.8
Social Net Production (a-c-d)	100.0	109.0	121.0	12.0
a) Output	100.0	109.3	119.4	10.1
b) Unemployment Benefits	100.0	100.6	124.0	23.4
c) Training Costs	100.0	108.1	87.5	-20.6
d) Recruiting Costs	100.0	125.4	143.3	17.9
Employment	100.0	100.0	101.0	1.1
% High-Skill	50.0	54.1	71.0	16.9
Output per Worker	100.0	109.4	122.7	13.4
Reservation Wage	100.0	108.7	119.4	10.7
Unemployment	100.0	100.6	87.5	-13.1
Une Duration (months)	3.9	3.8	3.4	-0.5
Sectoral Impacts				
Output - Resources	100.0	145.1	139.3	-5.9
Manufacturing	100.0	104.3	121.9	17.6
Employment - Resources	100.0	126.7	110.8	-16.0
Manufacturing	100.0	96.6	99.8	3.2
% High Skill - Resources	50.0	56.7	72.3	15.6
Manufacturing	50.0	53.7	70.8	17.1
Profits - Resources	100.0	141.4	142.5	1.1
Manufacturing	100.0	94.2	121.9	27.8
Market Tightness - Resources	100.0	178.2	180.4	2.3
Manufacturing	100.0	90.5	139.2	48.7
Distributional Impacts				
Low-Skill Wages - Resources	100.0	105.4	89.2	-16.2
Manufacturing	100.0	105.2	86.8	-18.4
High-Skill Wages - Resources	100.0	109.4	113.1	3.8
Manufacturing	100.0	106.3	110.2	3.9
Transition Effects				
Time to Full Convergence (yrs)	–	8.6	5.8	-2.8

Note: The relevant variables in the benchmark steady-state are normalized to 100. Compares steady-states with Status Quo Training Investments to Subsidized Training Investments of 0.5.

Appendix B: Figures

Figure 1: **Log Real Oil Price (1970=100)**
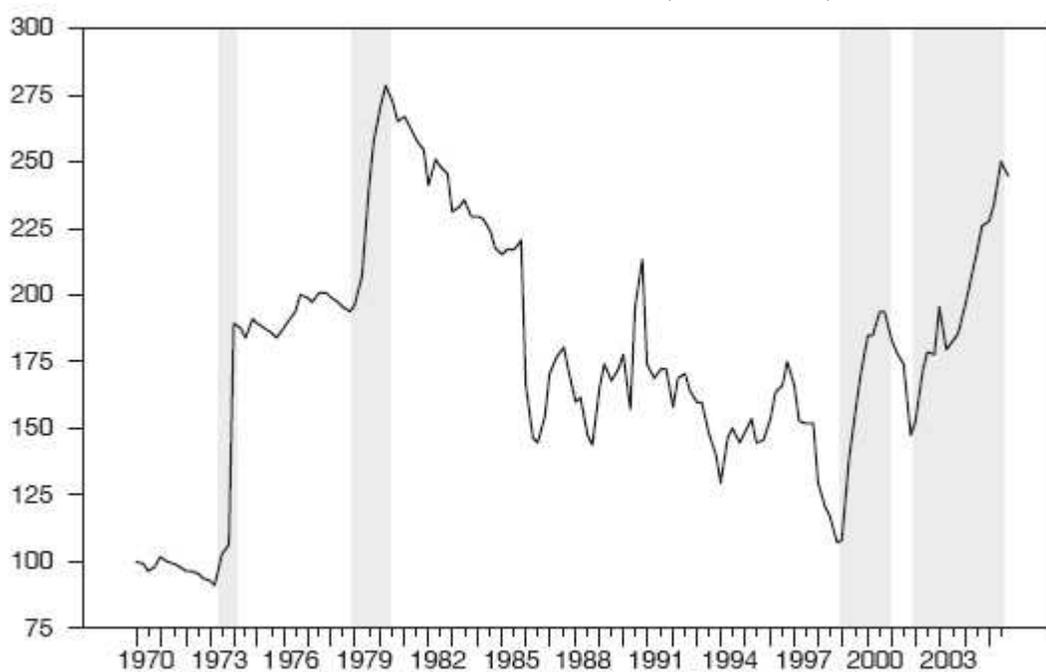
Source: Reproduced from Blanchard and Gali (2007), (Figure 3 of their paper). Shading indicates oil price shocks as defined by 50 percent increase in the real price of oil, sustained for at least four quarters.

Figure 2: **Average Employment Response After Oil Shocks, G7 Economies**
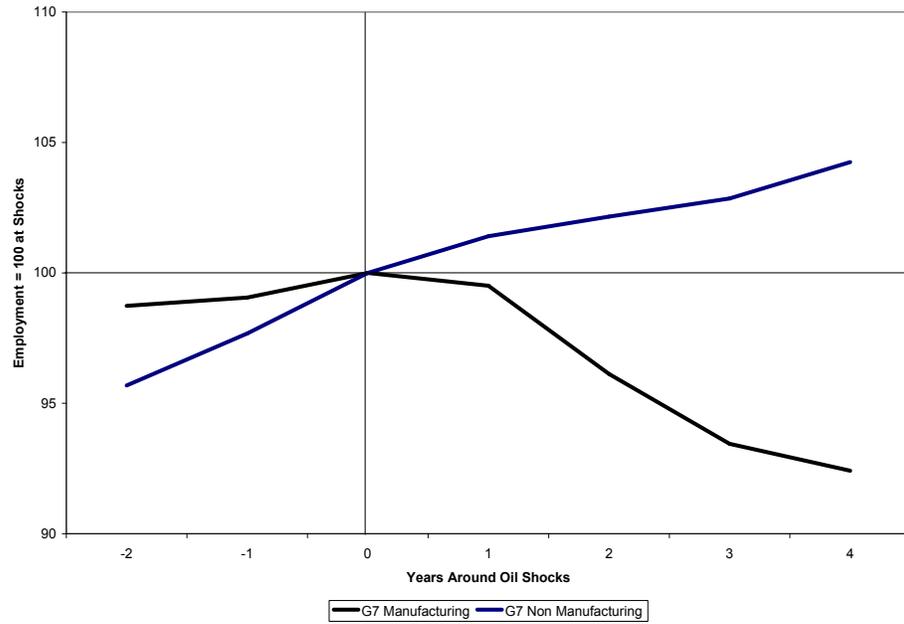
Data Source: OECD Structural Analysis (STAN) Database.
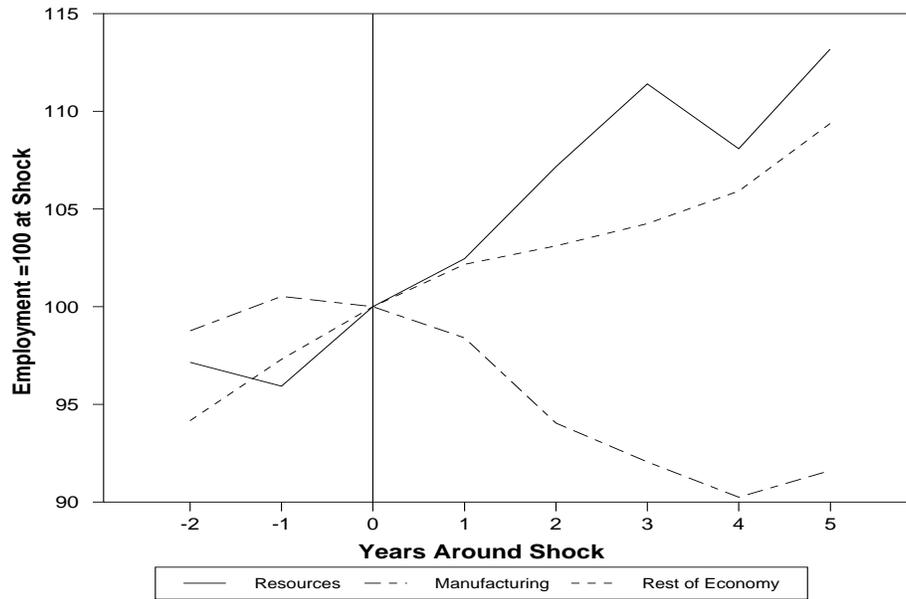
Figure 3: **Average Manufacturing Employment Response After Oil Shocks, G7 Economies**
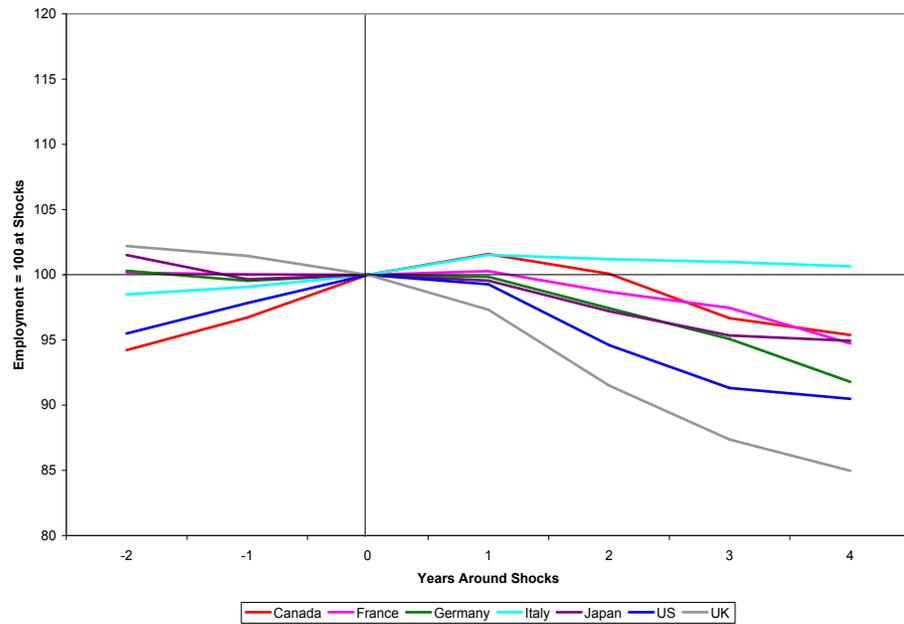
Data Source: OECD Structural Analysis (STAN) Database.

Figure 4: **Average Non-Manufacturing Employment Response After Oil Shocks, G7 Economies**
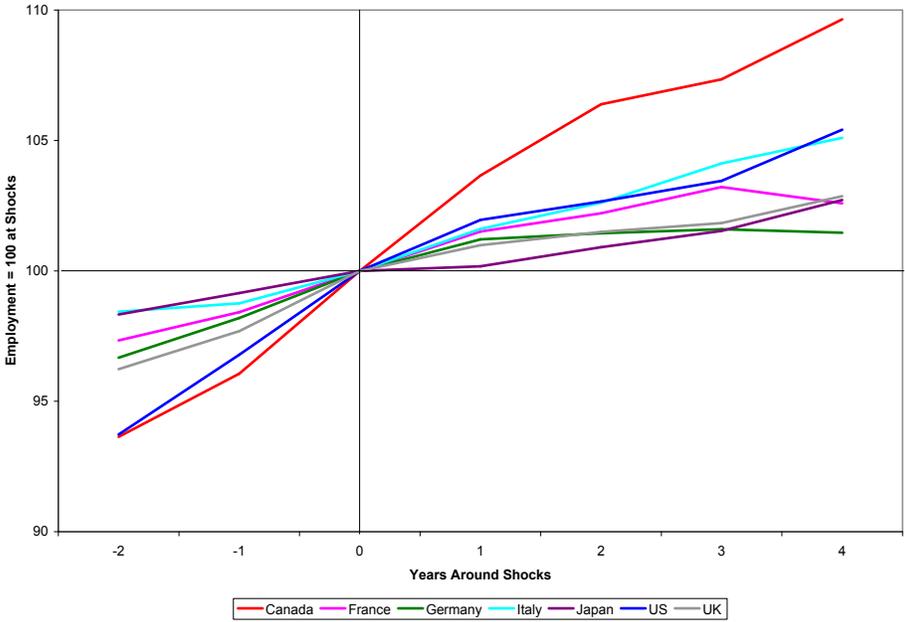
Data Source: OECD Structural Analysis (STAN) Database.

Figure 5: **Average Employment Response After Oil Shocks, U.S.**

Data Source: Current Employment Statistics (CES) Survey, Resources = Natural Resources and Mining, CES1000000001; Manufacturing CES3000000001; Rest of Economy = Total Nonfarm Employment, CES0000000001, less Resources and Manufacturing Employment.

Figure 6: **Relative Employment Responses After An Oil Price Shock, Canada**
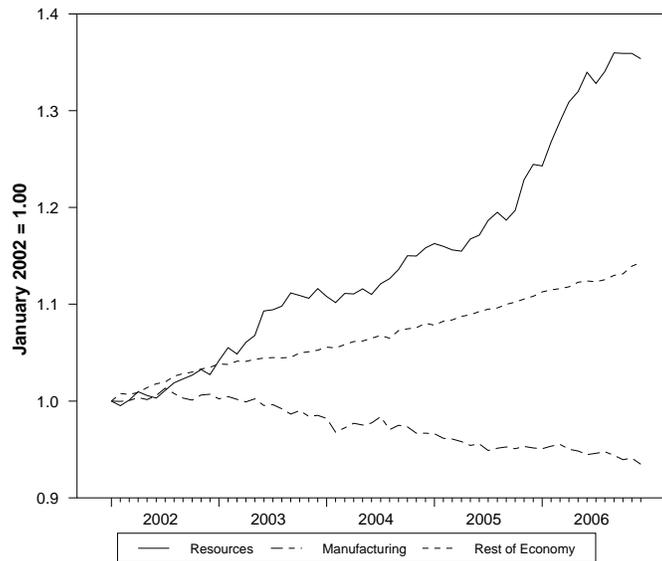
Source: Cansim, Survey of Employment, Payrolls and Hours (SEPH), seasonally adjusted employment. Manufacturing v1596771. Mining and oil and gas extraction v1596768. Rest of Economy = Industrial aggregate excluding unclassified, v1596764, less manufacturing and mining, oil and gas employment.
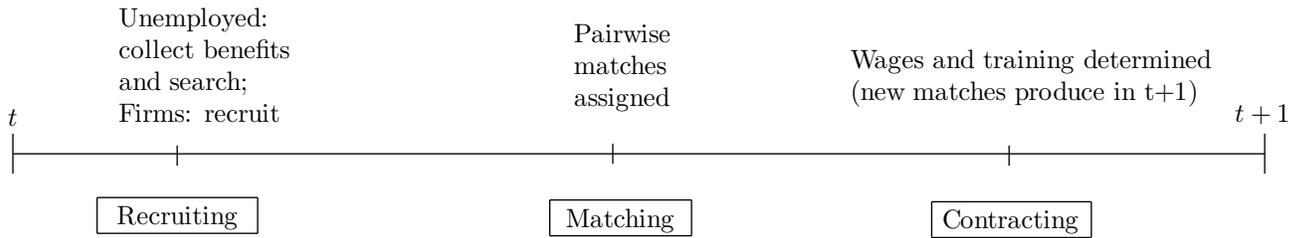
Figure 7: **Model Timing: Unmatched Workers and Firms**
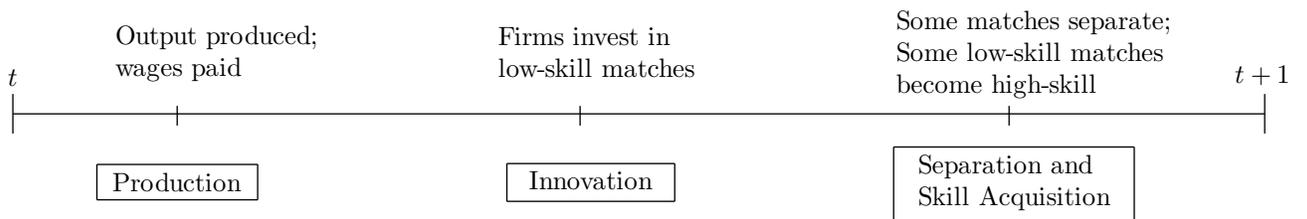
Figure 8: **Model Timing: Producing Workers and Firms**

110
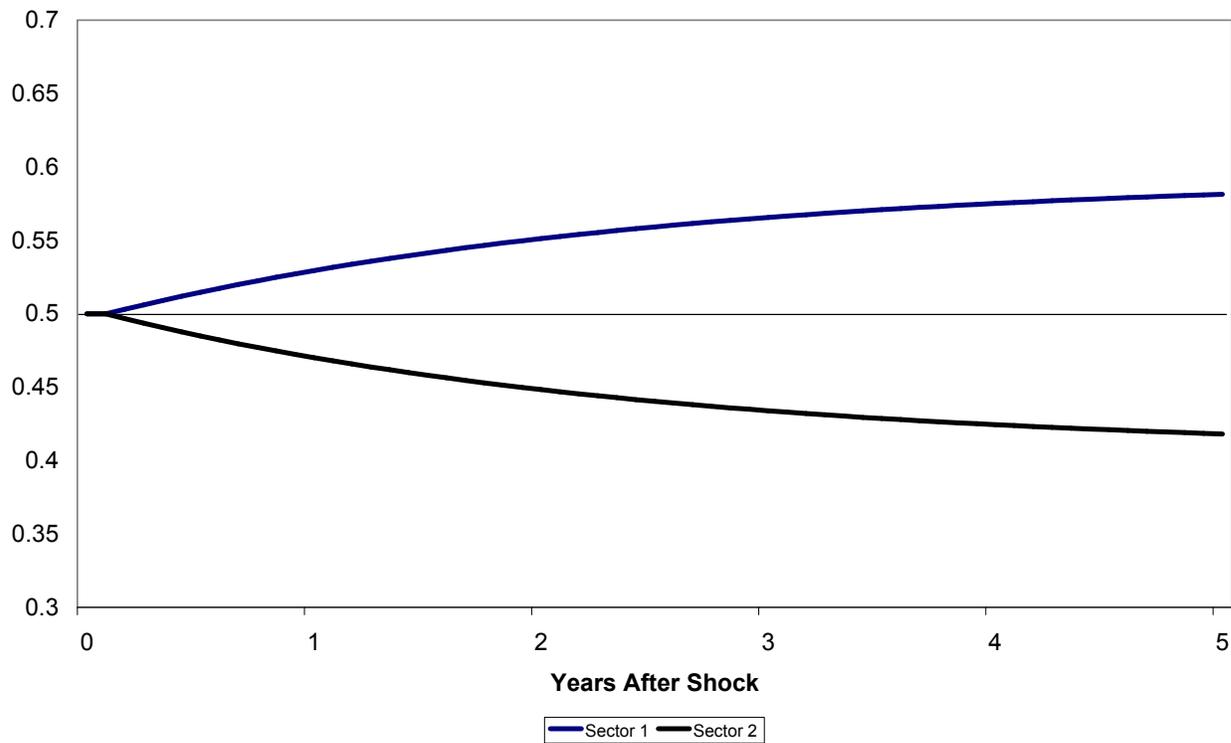
Figure 9: **Model's Employment Response After Sector-Specific Productivity Shock**

Benchmark model's dynamic response to permanent productivity shock to sector 1, $A_1 = 1.03$; $A_2 = 1$.

Figure 10: **Bank of Canada Commodity Price Index and Energy Subindex, 1981–2006**
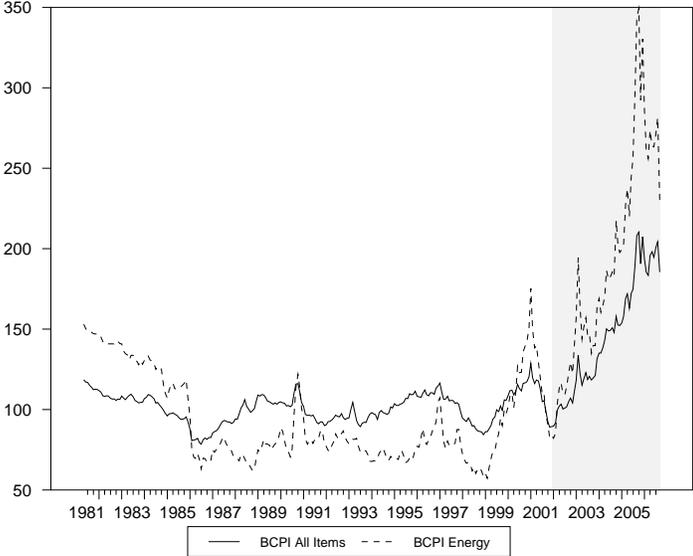
Source: Bank of Canada. The Bank of Canada Commodity Price Index is a fixed-weight index of the spot or transaction prices of 23 commodities produced in Canada and sold in world markets. Each commodity's index weight is based on the average value of its Canadian production over the 1988-1999 period. The series are indexed to 1982–1990 = 100 in U.S. dollar terms.

Figure 11: **Canadian Nominal Effective Exchange Rate, 1981–2006**
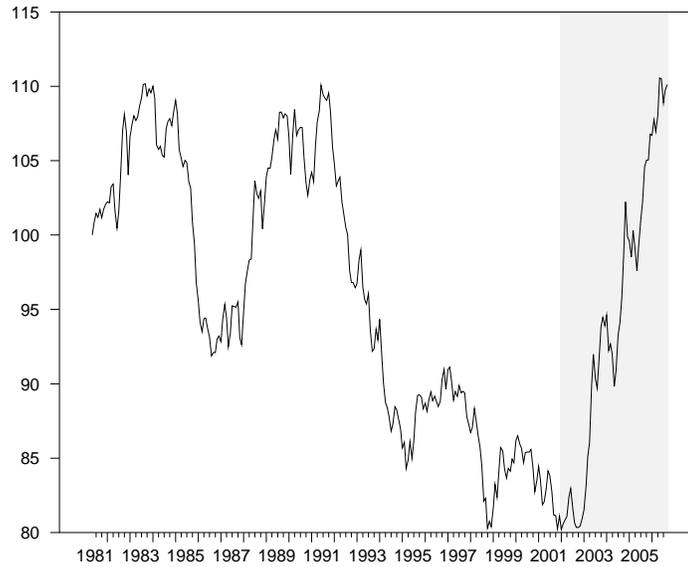
Source: Bank of Canada. The nominal effective exchange rate uses multilateral trade weights for the six currencies of countries or economic zones with the largest share of Canada's international trade. For more information on its construction see Ong (2006). The average value of the index is 100 in 1992.

Figure 12: **Relative Employment Changes, Canada 2002–2006**, SEPH Payroll Survey
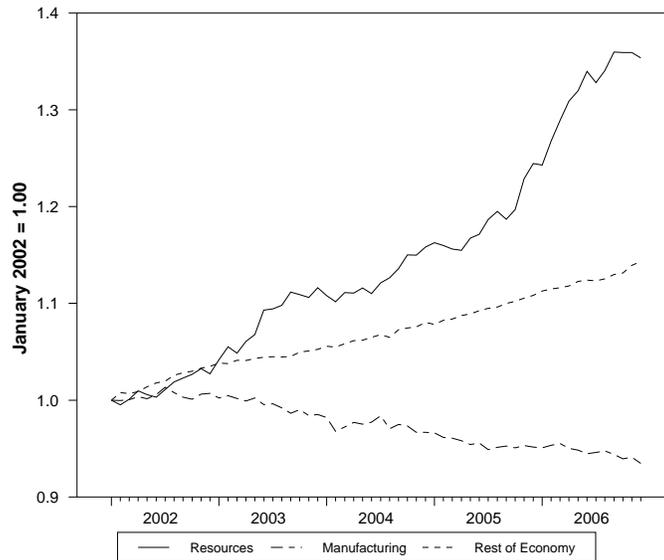
Source: Cansim, Survey of Employment, Payrolls and Hours (SEPH), seasonally adjusted employment. Manufacturing v1596771. Mining and oil and gas extraction v1596768. Rest of Economy = Industrial aggregate excluding unclassified, v1596764, less manufacturing and mining, oil and gas employment.

Figure 13: **Sectoral Output per Worker, Canada 2001**
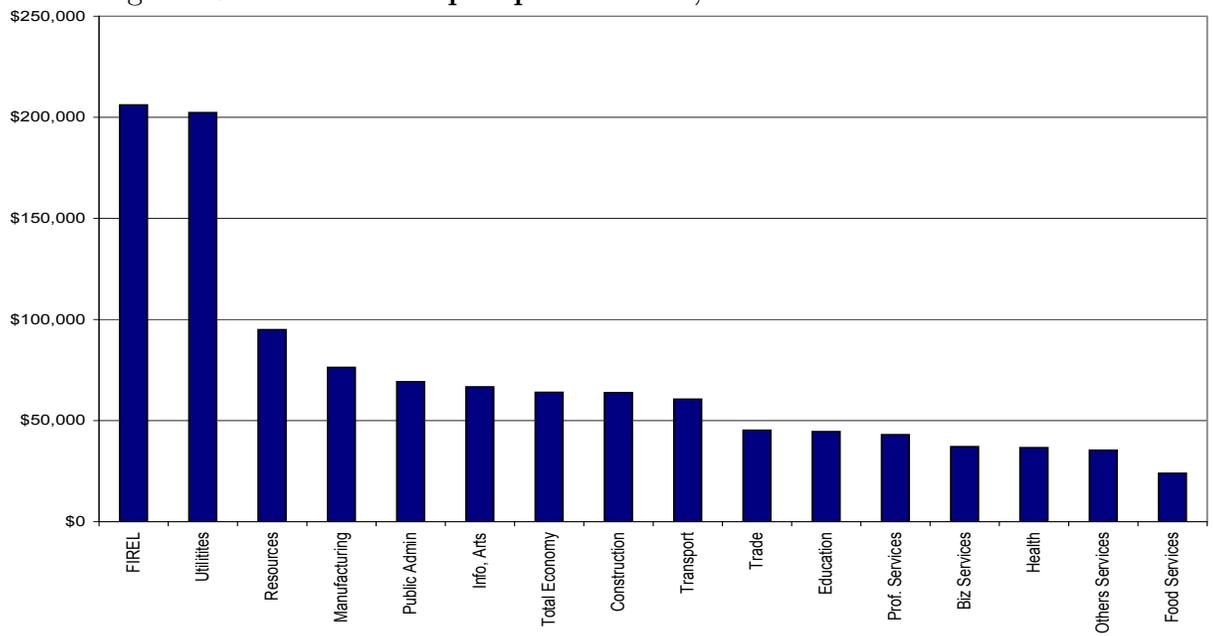
Data Source: Cansim. Output is GDP at basic prices, Table 3790019; Employment is from the Labour force survey, Table 2820094

Figure 14: **Resource Sector Job-Finding and Separation Rates, 1993–2006**
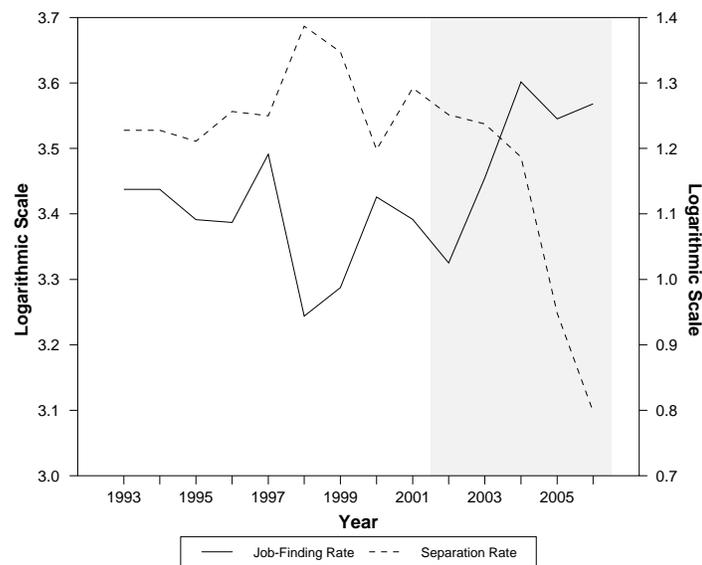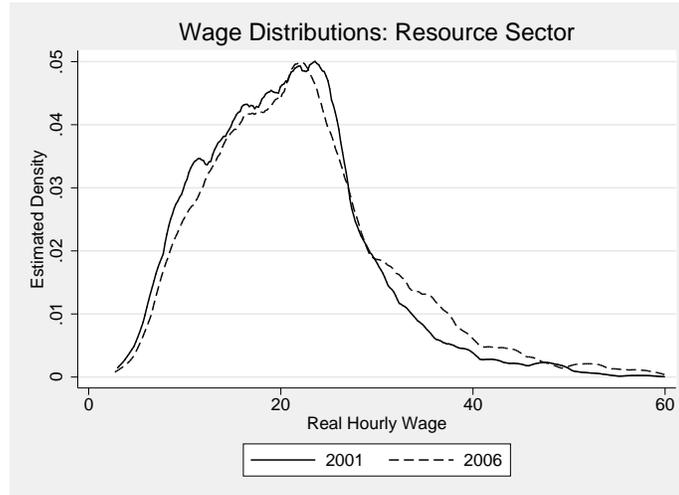

Data Source: *Labour Force Survey* Public Use Microdata files. I estimate total employment outflows in each sector by aggregating individuals' (frequency-weighted) employment-to-unemployment transitions. Given the employment and unemployment series, equation (3.1) gives the job-finding and separation rate estimates. Note the job-finding estimates assume that all net inflows into the sector were from unemployment rather than labour force inactivity or job-to-job transitions from other sectors.

Figure 15: **Manufacturing Sector Job-Finding and Separation Rates, 1993–2006**
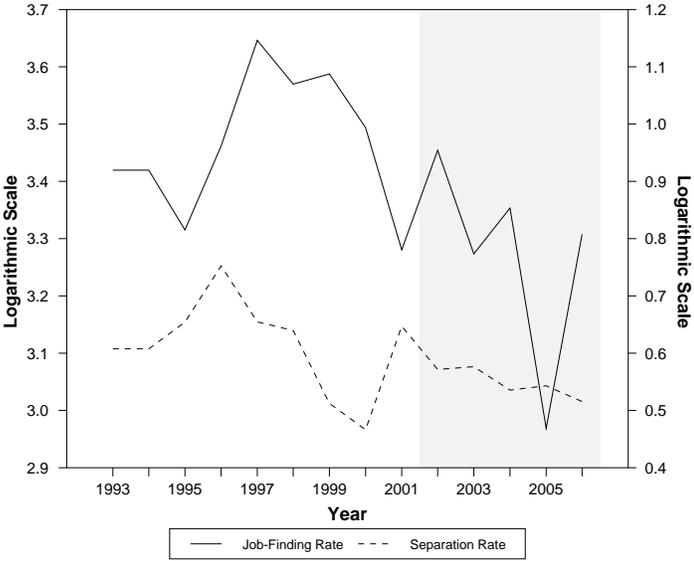
Data Source: *Labour Force Survey* Public Use Microdata files. I estimate total employment outflows in each sector by aggregating individuals' (frequency-weighted) employment-to-unemployment transitions. Given the employment and unemployment series, equation (3.1) gives the job-finding and separation rate estimates. Note the job-finding estimates assume that all net inflows into the sector were from unemployment rather than labour force inactivity or job-to-job transitions from other sectors.

Figure 16: **Real Hourly Wages in the Resource Sector**

Wage Distributions: Resource Sector

Source: *Labour Force Survey* Public Use Microdata Files. Kernel density estimates of 2001 and 2006 surveys, Hourly Earnings variable for workers in the Oil & Gas; Forestry; Fishing; and Mining sectors. The solid line shows 2001, the year prior to the shock; the dashed line shows 2006, the latest available data. I deflate nominal earning using the Consumer Price Index. The estimation applies the Epanenchiknov smoothing kernel with optimal weights from Silverman (1986).

Figure 17: **Real Hourly Wages in the Manufacturing Sector**

Wage Distributions: Manufacturing Sector

Source: *Labour Force Survey* Public Use Microdata Files. Kernel density estimates of 2001 and 2006 surveys, Hourly Earnings variable for workers in the Manufacturing sector. The solid line shows 2001, the year prior to the shock; the dashed line shows 2006, the latest available data. I deflate nominal earnings using the Consumer Price Index. The estimation applies the Epanenchiknov smoothing kernel with optimal weights from Silverman (1986).

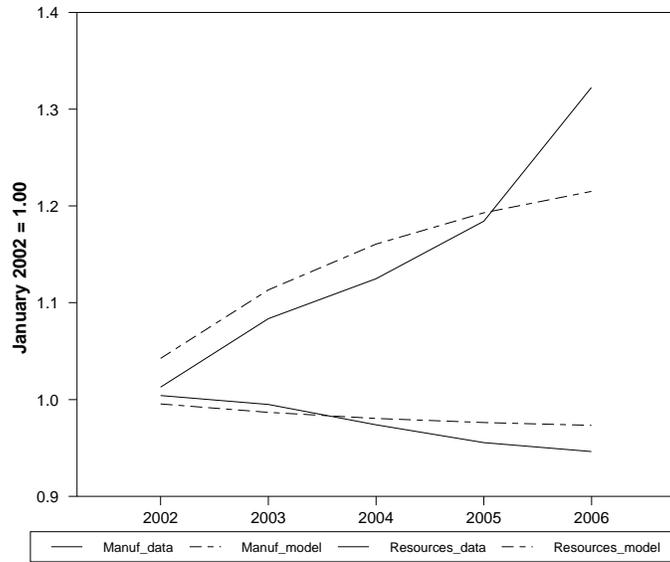Figure 18: **Employment Dynamics Model vs. Data, 2002–2006**, SEPH Payroll Survey

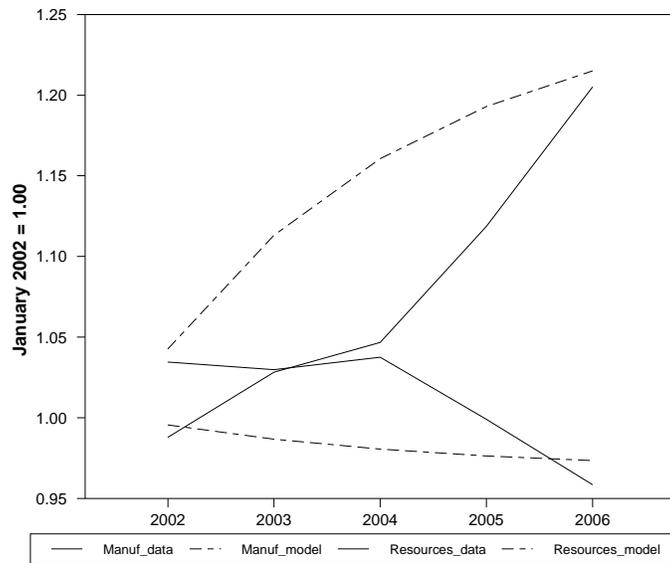Figure 19: **Employment Dynamics Model vs. Data, 2002–2006**, LFS Data

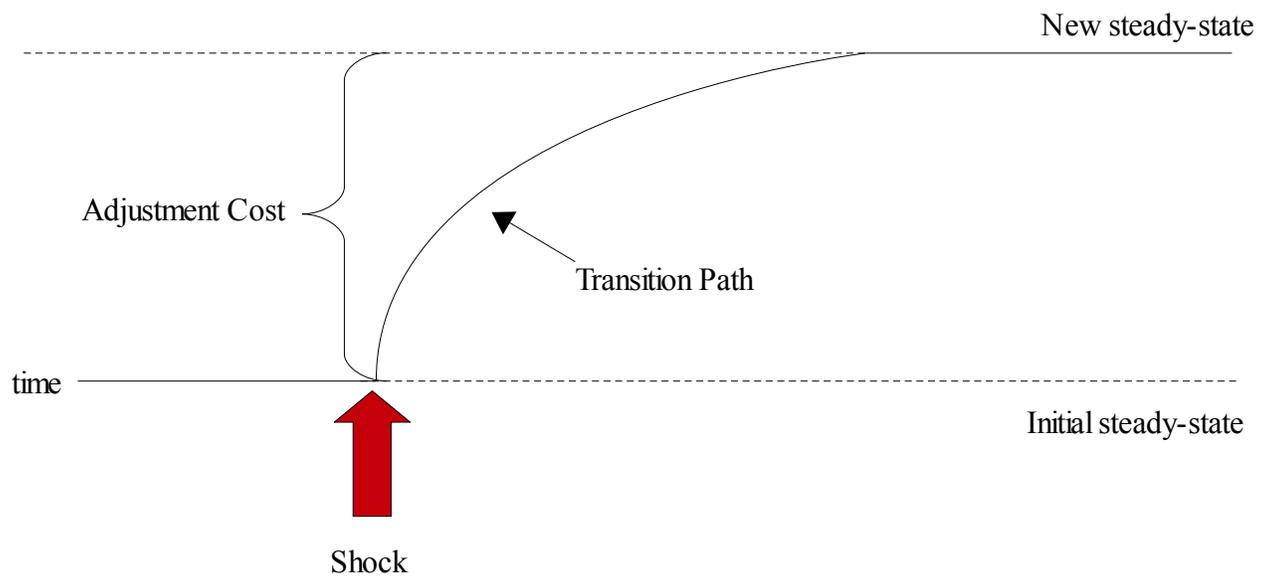Figure 20: **Calculating Adjustment Costs During the Model's Transition**

New steady-state

Adjustment Cost

Transition Path

time
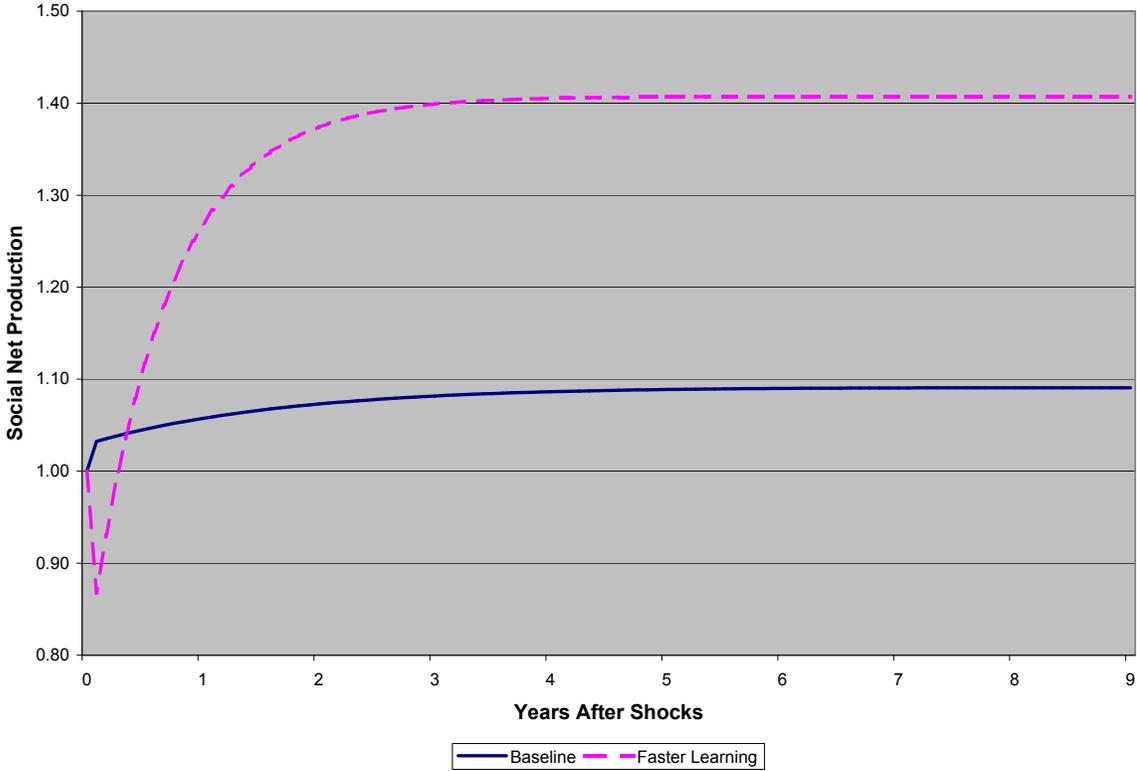
Initial steady-state

Shock

Figure 21: **Social Net Production Gain from Faster Learning, Transition Dynamics**

Note: Social Net Production equals aggregate output less social training and vacancy costs. I normalize this to 1.0 in the benchmark model in the period of the shocks. Compares transition dynamics with Status Quo Skill Acquisition $\lambda_r = 0.09, \lambda_m = 0.05$, to Faster Skill Acquisition: $\lambda_r = 0.18, \lambda_m = .10$.

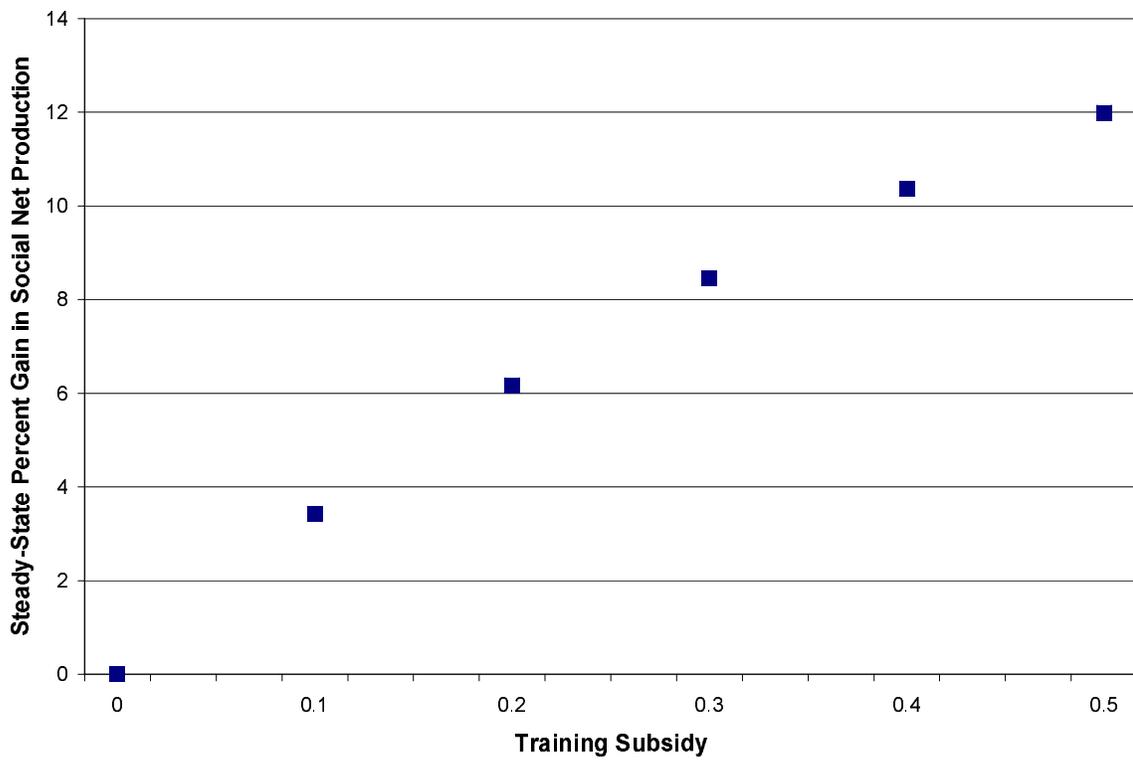Figure 22: **Social Net Production Gain from Training Subsidies, Steady-State**
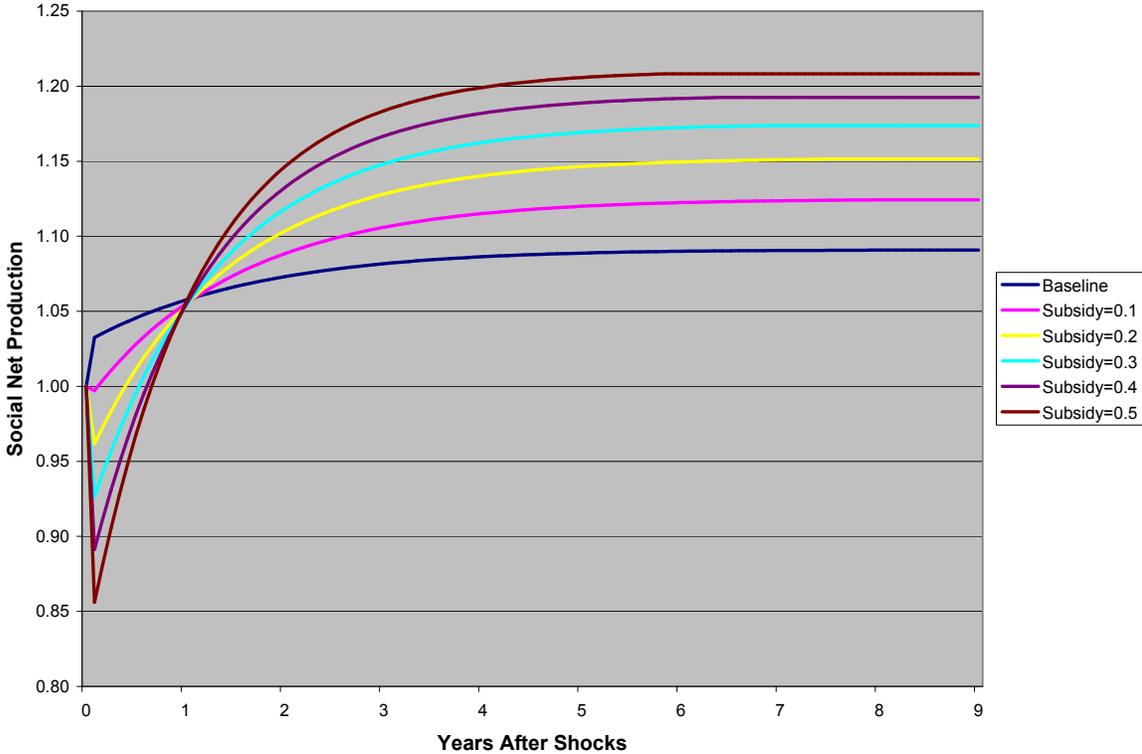
Figure 23: **Social Net Production with Training Subsidies, Transition Dynamics**

Note: Social Net Production equals aggregate output less social training and vacancy costs. I normalize this to 1.0 in the benchmark model in the period of the shocks.

Appendix C: Model Derivations and Proofs of Propositions

Proof of Proposition 2.3.1:

$$J_i^L = \max_{x_i} A_i p_i^L - w_i^L - \chi(x_i) + \delta[s_i V_i + \lambda_i x_i J_i^H + (1 - s_i - \lambda_i x_i) J_i^L(x_i)] \ \ s.t. \ 0 \le x_i; \ x_i \le 1$$

The associated optimization problem is:

$$\mathcal{L} = A_{i,t} p_{i,t}^L - w_{i,t}^L - \chi(x_{i,t}) + \delta E_t[s_i V_{i,t+1} + \lambda_i x_{i,t+1} J_{i,t+1}^H + (1 - s_i - \lambda_i x_{i,t+1}) J_{i,t+1}^L(x_{i,t+1})]$$
$$-\gamma_1(-x_{i,t}) - \gamma_2(x_{i,t} - 1)$$

I focus on stationary innovation policies, where $x_{i,t} = x_{i,t+1}$. The Kuhn-Tucker conditions are:

$$\frac{\partial \mathcal{L}}{\partial x_{i,t}} = -\chi'(x_{i,t}) + \delta E_t[\lambda_i(J_{i,t+1}^H - J_{i,t+1}^L) + (1 - s_i - \lambda_i x_{i,t+1})\frac{\partial J_i^L}{\partial x_i^*}] + \gamma_1 - \gamma_2$$

$$\frac{\partial \mathcal{L}}{\gamma_1} = x_i$$

$$\frac{\partial \mathcal{L}}{\gamma_2} = 1 - x_i$$

There are three cases to consider: the two corner solutions $x_i^* = 0, x_i^* = 1$ and interior solutions $x_i^* \in (0, 1)$.

Case 1: $x_i^* = 0$. If the first constraint holds, $x_i^* = 0$, so $\gamma_1 > 0$ by the complementary slackness condition. The second constraint is satisfied, so $\gamma_2 = 0$. Collecting terms on the first order condition for investment gives: $\frac{\partial \mathcal{L}}{\partial x_i^*}[1 - \delta(1 - s_i)] = -\chi'(x_{i,t}) + \delta\lambda_i E_t[(J_{i,t+1}^H - J_{i,t+1}^L)] + \gamma_1$. Given the boundary solution, this expression is non-positive so: $\chi'(x_{i,t}) \ge \delta\lambda_i E_t[(J_{i,t+1}^H - J_{i,t+1}^L)] + \gamma_1$. Since γ_1 is positive, this implies the marginal investment cost exceeds the expected marginal benefit at $x_i^* = 0$.

Case 2: $x_i^* = 1$. If the second constraint holds, $x_i^* = 1$, so $\gamma_2 > 0$ by the complementary slackness condition. The first constraint is satisfied, so $\gamma_1 = 0$. Collecting terms on the first order condition for investment gives: $\frac{\partial \mathcal{L}}{\partial x_i^*}[1 - \delta(1 - s_i - \lambda_i)] = -\chi'(x_{i,t}) + \delta\lambda_i E_t[(J_{i,t+1}^H - J_{i,t+1}^L)] - \gamma_2$. Given the boundary solution, this expression is non-negative so: $\delta\lambda_i E_t(J_{i,t+1}^H - J_{i,t+1}^L) \ge \chi'(x_{i,t}) + \gamma_2$. Since γ_2 is positive, the expected marginal benefit of investment exceeds the marginal cost at $x_i^* = 1$.

Case 3: $x_i^* \in (0, 1)$. Both constraints are satisfied so $\gamma_1 = \gamma_2 = 0$. By the envelope theorem, $\frac{\partial J_i^L}{\partial x_{i,t}^*} = 0$, so the first order condition for investment simplifies to:

$$\frac{\partial \mathcal{L}}{\partial x_{i,t}^*} = -\chi'(x_{i,t}) + \delta E_t[\lambda_i(J_{i,t+1}^H - J_{i,t+1}^L)] = 0$$

For interior solutions, the marginal benefit of investment equals the marginal cost. Substituting into the first order necessary condition for investment using $J_{i,t+1}^H - J_{i,t+1}^L = (1-\beta)SP_{i,t+1} = (1-\beta)\frac{A_{i,t+1}(p_i^H - p_i^L) + k_i x_i}{\delta(r + s_i + \lambda_i x_i)}$ from the Nash Bargaining solution, equation (2.8), and using the properties of investment cost function, $\chi(x_i) = k_i x_i$, gives: $k_i = \lambda_i(1-\beta)\frac{A_{i,t+1}(p_i^H - p_i^L) + k_i x_{i,t+1}}{(r + s_i + \lambda_i x_{i,t+1})}$, which after lagging one-period, simplifies to:

$$x_{i,t}^* = \frac{(1-\beta)}{k_i \beta} A_{i,t}(p_i^H - p_i^L) - \frac{r + s_i}{\lambda_i \beta}$$

Finally, when $\lambda_i \leq \overline{\lambda}_i$, the skill arrival rate is sufficiently low so no investment is offered.

Proof of Proposition 2.3.2: The sector that received the positive shock is now more productive, so its surplus from a new match increases. This in turn, means jobs in this sector are more profitable, so vacancy posting and market tightness increase in this sector.

Now, assume unemployed workers' reservation wage falls. With cheaper labour, jobs in all other sectors also become more profitable. Therefore, vacancy posting increases, raising market tightness in these other sectors, $\{\theta_j^*\}_{j\neq i}^I$. The reservation wage can be expressed as $\overline{w} = z + \frac{\beta c}{1-\beta}\sum_i \theta_i$. Therefore, because z, c, β are fixed, the reservation wage would increase. However, this contradicts the original assumption that the reservation wage falls.

Thus, it must be the case that following a positive productivity shock in sector i, workers' reservation wage increases. Jobs in the other sectors are therefore less profitable at the higher wage, so from the zero profit conditions, the RHS of equation (2.16) falls. For the zero profit condition to hold in the new equilibrium, firms expected recruiting costs must also fall — the LHS of equation (2.16). Given the cost of a vacancy, c, is fixed, the job filling rates in these other sectors must increase, $\{q(\theta_j)\}_{j\neq i}^I$, which requires that market tightness fall in the other sectors, $\{\theta_j^*\}_{j\neq i}^I$.

The same argument applies after a negative shock in sector i, but in the opposite direction.

Proof of Proposition 2.3.3:

The social present value of a low-skill match is $S_i = W_i^L - U + J_i^L - V_i$. The skill premium of a high-skill relative to a low-skill match is $SP_i = W_i^H - W_i^L + J_i^H - J_i^L$. Using the worker's and firm's value functions, equations (2.1) – (2.6), and the free entry/zero profit condition, $V_i = 0$, gives an expression for low-skill match surplus:

$$S_i = A_i p_i^L - \chi(x_i) - z - \delta \sum_i^I f_i(\theta_i)(W_i^L - U) + \delta \lambda_i x_i SP_i + \delta(1 - s_i)S_i \qquad \text{(A.1)}$$

Substituting in for the worker's reservation wage, $\bar{w} = z + \delta \sum_i^I f_i(\theta_i)(W_i^L - U)$, and rearranging using $\delta = \frac{1}{1+r}$, gives:

$$\delta(r + s_i)S_i = A_i p_i^L - \chi(x_i) - \bar{w} + \delta \lambda_i x_i SP_i$$

Production requires the match surplus be non-negative, $S_i \geq 0$. This implies the value of low-skill output, net of investment costs, plus the expected present value of the skill premium covers the worker's reservation wage:

$$A_i p_i^L - \chi(x_i) + \delta \lambda_i x_i SP_i \geq \bar{w}$$

Corollary of Propositions 2.3.1 and 2.3.3:

Case 1) A given sector will not produce if:

$$y_i^L - \chi(x_i^*) + \lambda_i x_i^* \frac{y_i^H - y_i^L + \chi(x_i^*)}{(r + s_i + \lambda_i x_i^*)} < \bar{w}$$

Case 2) A given sector produces only low-skill output if:

$$i) \quad y_i^L \geq \bar{w} \qquad \& \qquad ii) \quad \lambda_i \leq \overline{\lambda_i}$$

Case 3) A given sector produces both low-skill and high-skill output if:

$$i) \quad y_i^L - \chi(x_i^*) + \lambda_i x_i^* \frac{y_i^H - y_i^L + \chi(x_i^*)}{(r + s_i + \lambda_i x_i^*)} \geq \bar{w} \qquad \& \qquad ii) \quad \lambda_i > \overline{\lambda_i}$$

where for Case 3) $\chi(x_i^*) = k_i x_i^* = \frac{(1-\beta)}{\beta}(y_i^H - y_i^L) - \frac{k_i(r+s_i)}{\lambda_i \beta}$

Derivation of Equilibrium Wages:

Low-Skill Wage in Sector i: From (A.1) as described above, the low-skill match surplus can be expressed as:

$$S_i = A_i p_i^L - \chi(x_i) - z - \delta \sum_i^I f_i(\theta_i)(W_i^L - U) + \delta \lambda_i x_i SP_i + \delta(1 - s_i)S_i \qquad \text{(A.2)}$$

Using equation (2.5) and $V_i = 0$ gives:

$$J_i^L = A_i p_i^L - w_i^L - \chi(x_i) + \delta \lambda_i x_i (J_i^H - J_i^L) + \delta(1 - s_i) J_i^L$$

Substituting in $J_i^L = (1 - \beta) S_i$, and $J_i^H - J_i^L = (1 - \beta) SP_i$ from the Nash Bargaining solutions, equations (2.7) and (2.8), gives another expression in the low-skill surplus:

$$(1 - \beta) S_i = A_i p_i^L - w_i^L - \chi(x_i) + \delta \lambda_i x_i (1 - \beta) SP_i + \delta(1 - s_i)(1 - \beta) S_i \qquad \text{(A.3)}$$

Multiplying (A.2) by $(1 - \beta)$ gives:

$$(1 - \beta) S_i = (1 - \beta)[A_i p_i^L - \chi(x_i) - z - \delta \sum_i^I f_i(\theta_i)(W_i^L - U) + \delta \lambda_i x_i SP_i + \delta(1 - s_i) S_i] \quad \text{(A.4)}$$

Equating the RHS of (A.3) and (A.4) and simplifying gives the equilibrium low-skill wage in sector i, equation (2.12) in the paper:

$$w_i^{L*} = \overline{w} + \beta(\underbrace{A_i p_i^L - \chi(x_i^*) - \overline{w}})$$

where $\overline{w} = z + \delta \sum_i^I f_i(\theta_i^*)(W_i^L - U)$

High-Skill Wage in Sector i:

Subtracting the worker's value functions, equations (2.3) from (2.2) gives:

$$W_i^H - W_i^L = w_i^H - w_i^L + \delta[(1 - s_i - \lambda_i x_i)(W_i^H - W_i^L)]$$

Using the fact that $\delta = \frac{1}{1+r}$ and simplifying gives:

$$\delta(r + s_i + \lambda_i x_i)(W_i^H - W_i^L) = w_i^H - w_i^L$$

Substituting in $W_i^H - W_i^L = \beta SP_i$ from the Nash Bargaining solution, (2.8) gives:

$$\delta(r + s_i + \lambda_i x_i)\beta SP_i = w_i^H - w_i^L \qquad \text{(A.5)}$$

Then explicitly solve for the skill premium using the worker's and firm's value functions, equations (2.2) and (2.3) and (2.5) and (2.6) and $\delta = \frac{1}{1+r}$:

$$SP_i = \frac{A_i(p_i^H - p_i^L) + \chi(x_i)}{\delta(r + s_i + \lambda_i x_i)} \tag{A.6}$$

Substituting into (A.5) for the skill premium and the low-skill wage and simplifying gives the high-skill wage in sector i, equation (2.13) in the paper:

$$w_i^{H*} = \overline{w} + \beta(A_i p_i^H - \overline{w})$$

where $\overline{w} = z + \delta \sum_i^I f_i(\theta_i^*)(W_i^L - U)$

Equilibrium System of Equations in Market Tightness:

Using the zero profit condition, $V_i = 0$ in the firm's value of a vacancy equation, (2.4), gives $J_i^L = \frac{c}{\delta q_i(\theta_i)}$. From the firm's Nash Bargaining, (2.7), $(1 - \beta)S_i = J_i^L$. So,

$$(1 - \beta)S_i = \frac{c}{\delta q_i(\theta_i)}$$

Substitute in for $(1 - \beta)S_i$ using (A.4):

$$(1 - \beta)[A_i p_i^L - \chi(x_i) - z - \delta \sum_i^I f_i(\theta_i)(W_i^L - U) + \delta \lambda_i x_i SP_i + \delta(1 - s_i)S_i] = \frac{c}{\delta q_i(\theta_i)}$$

Use the worker's Nash Bargaining solution, (2.7), $\beta S_i = W_i^L - U$ and use $S_i = \frac{c}{\delta(1-\beta)q_i(\theta_i)}$,

$$(1-\beta)[A_i p_i^L - \chi(x_i) - z - \delta \sum_i^I f_i(\theta_i)\frac{\beta c}{\delta(1 - \beta)q_i(\theta_i)} + \delta \lambda_i x_i SP_i + \delta(1 - s_i)\frac{c}{\delta(1 - \beta)q_i(\theta_i)}] = \frac{c}{\delta q_i(\theta_i)}$$

Use the fact that $f_i(\theta_i) = \theta_i q_i(\theta_i)$ and $\frac{1}{\delta} = 1 + r$ to get:

$$(1 - \beta)[A_i p_i^L - \chi(x_i) - z - \sum_i^I \frac{\beta c \theta_i}{(1 - \beta)} + \delta \lambda_i x_i SP_i] = \frac{c(r + s_i)}{q_i(\theta_i)}$$

Divide both sides by c, substitute in for the skill premium, SP_i, from (A.6) and rearrange to get the equilibrium system of equations in $\{\theta_i\}_1^I$ given in equation (2.17) of the paper:

$$\frac{r + s_i}{q(\theta_i)} + \beta \sum_i \theta_i = \frac{(1 - \beta)}{c}[A_i p_i^L - \chi(x_i^*) - z + \lambda_i x_i^* \cdot \frac{A_i(p_i^H - p_i^L) + \chi(x_i^*)}{r + s_i + \lambda_i x_i^*}]$$

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