Lost in Transition: The Costs and Consequences of Sectoral Labour Adjustment

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January 2008

Abstract

This paper demonstrates that factors impeding labour market adjustments can have first-order impacts on aggregate output and social welfare. While several studies find that individual workers can face large and persistent sectoral reallocation costs, this paper shows that these costs are important at the aggregate level. Using a search and matching model, I quantify and isolate two factors that contribute to the costly and time-consuming adjustment process: search frictions and the inability to transfer skills to new jobs.

I apply the model to examine Canada's labour adjustment after a global increase in commodity prices and associated exchange rate appreciation. These developments re-organized production to the resource sector and away from manufacturing. The model quantitatively captures both the sectoral employment and wage effects and the response of unemployment to changes in unemployment benefits. The model estimates that the costs of adjustment are economically important, accounting for up to three percent of output during the transition. These costs arise mainly in the first three years of adjustment and are due largely to non-transferable skills. Finally, the analysis reveals that changes to unemployment benefits impact the economy's sectoral composition, aggregate productivity and the speed of adjustment.

Keywords: Sectoral Labour Reallocation; Adjustment Costs; Search and Matching; Skills and Training; Unemployment
JEL Classifications: E2; J6; J08, J21; J24; Q43

*E-mail: tapps@econ.queensu.ca. I thank Allen Head, Thorsten Koeppl, Gregor Smith and seminar participants at Queen's, Finance Canada, Laval and Wilfrid Laurier. The most recent version of this paper is available at: www.econ.queensu.ca/students/tapps/

1 Introduction

This paper applies an equilibrium search and matching model to study the sectoral labour adjustment in Canada following an increase in global commodity prices and associated exchange rate appreciation. I use the model to quantify the magnitude and sources of adjustment costs in the most affected sectors. The results reveal impediments to the adjustment process — due to search frictions and non-transferable skills — are economically significant, imposing costs of up to three percent of output during the transition. I also use the model to analyze the impacts of labour market policy on allocations, welfare and the speed of adjustment. I find that because more generous unemployment benefits discourage job creation, they prolong the adjustment process and ultimately lower social welfare. However, because production is reallocated towards more productive sectors, aggregate productivity rises.

The model application in this paper is motivated by the rapid and persistent relative price changes that began in 2002 (commodity prices and exchange rates), 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. This episode exemplifies a common situation where policymakers face pressure to ease the burden on the individuals and sectors that disproportionately bear the costs of reallocating production.

Existing empirical labour studies provide convincing evidence that individual workers who lose their jobs and/or change sectors can suffer large and persistent earnings losses.[1] However, after sector-specific disturbances, when large numbers of workers endure job turnover, it is unclear exactly how large these costs are for the aggregate economy and how other related sectors of production might be affected.[2] One goal of this paper is to quantify these aggregate adjustment costs in an equilibrium framework, and in particular, to identify the relative contributions of specific labour market frictions to these aggregate costs.

I study these issues using a model that extends Pissarides (2000) to include multisector

[1] 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).

[2] Trefler (2004) 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.

production and search, and skill acquisition through on-the-job training. In the model, adjustment costs arise because of two frictions. The first is the standard search friction, where reallocation requires resources and time for firms and workers to locate appropriate partners before new production can begin. The second obstacle to adjustment is the fact that acquiring skills is costly and its success is uncertain. Furthermore, some skills accumulated in one job may not be fully transferable to new jobs.

Before applying the model, I use micro-level Labour Force Survey data as well as Payroll Survey data to document Canada's adjustment. 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, wage gains were concentrated in the resource sector, and particularly in the upper end of the distribution.

The model quantitatively captures key features of the adjustment, such as the sectoral employment effects and relative wage effects among high and low-skill workers in the resource sector. The model's adjustment mechanism features a *reservation wage effect*. In the resource sector, the relative increase in output per worker raises profits, encourages job creation and increases wages. Because the unemployed search simultaneously in the resource and manufacturing sectors, this increases the value of search, causing workers to raise their reservation wages. This acts as a negative spillover, raising the cost of labour and discouraging job creation in the manufacturing sector. These asymmetric hiring responses are consistent with the data. Over time, sectoral labour reallocation occurs because there are more vacancies in the resource sector and fewer vacancies in the manufacturing sector.

The model estimates that the adjustment costs during this episode are significant, accounting for up to three percent of output. These costs occur mainly in the first three years after the shock. The costs are attributable largely to the non-transferability of skills, rather than search frictions. The respective contributions are roughly 90 percent due to skills lost during labour turnover and 10 percent due to search frictions.

To address these significant labour adjustment costs, a policy response often advocated is to compensate displaced workers with increased unemployment benefits. Using the model to analyze such a response reveals important policy implications. In the model, more generous unemployment benefits lower aggregate employment, output, and social welfare and raise unemployment incidence and duration. These results are standard in a search model and occur because unemployment becomes less costly, so workers raise their reservation (and bargained) wages. This, in turn, discourages job creation and prolongs the adjustment process. This result is consistent with empirical findings from OECD data (Scarpetta, 1996) and computational results by Ljungqvist and Sargent (1998). Ljungqvist and Sargent's results are based on a fall in workers' search intensity as their skills depreciate while unemployed. In my model, workers' search intensity is fixed, highlighting the fact that firms will also reduce their search intensity and post fewer jobs, because higher unemployment benefits decrease the match surplus.

In addition, changes to unemployment benefits in my model affect sectors differently and may have unexpected consequences. For instance, because the job discouraging effect is stronger in less productive sectors, the sectoral composition of the remaining jobs shifts favorably towards more productive sectors and raises aggregate productivity. While unemployment benefits affect productivity in other search models, 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 this paper carries over from recent controversy for the one-sector model.[3] A shock of a given size – in this case an increase in workers' reservation wages – 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.

Finally, it is important to emphasize that in the example considered, even though it is not a calibration target, the model's unemployment rate response to changes in unemployment benefits is consistent with estimates from empirical studies.[4] Matching this feature of the data has been problematic for the baseline one-sector model.[5]

[3]See, among others, Shimer (2005a); Hagedorn and Manovskii (2006); and Mortensen and Nagypál (2007).
[4]See Nickell and Laynard (1999); and Costain and Reiter (2006).
[5]See Hornstein, Krusell, and Violante (2005); Costain and Reiter (2006); Silva and Toledo (2007).

2 Documenting Canada's Labour Market Adjustment

This section presents some empirical facts from the labour adjustment following the recent increase in commodity prices and associated Canadian exchange rate appreciation.

2.1 Energy Price Shock and Associated Exchange Rate Movement

Figure 1 shows 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 2 shows a concurrent, persistent increase in Canada's nominal effective exchange rate.[7]

While several factors undoubtedly contributed to these shocks, 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 more 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.[8] For the purposes of this paper, however, identifying the sources of these shocks are not important. What matters is simply that these changes had different impacts on productivity and profitability in particular sectors, beginning in 2002.

2.2 Asymmetric Sectoral Responses Expected

Commodity and exchange rate movements generally impact sectors of the economy differently. The exogenous increase in commodity demand and energy prices has clear benefits

[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]Author's calculations from *BP Statistical Review of World Energy*, June 2007, available at: www.bp.com.

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

At the same time, the associated exchange rate shock will similarly generate sectoral winners and losers. Table 1 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, it 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 evidence of the impact the appreciation on Canadian firms (Mair, 2005). More than three-quarters of manufacturing firms reported adverse effects from the appreciation, mainly from lower profit margins on foreign sales. Firms reportedly responded to the appreciation by cutting labor and other costs and attempting to increase productivity. Leung and Yuen (2005) provide empirical evidence of significant labour market adjustments in response to real exchange rate movements for Canadian manufacturing industries during 1981–1997. 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 shock.

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. The strongest employment growth was in the resource sector (mining, oil and gas), while the biggest employment losses were in manufacturing. Figure 3 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 reallocation can potentially have aggregate impacts, given the sizeable differences in output per worker observed across sectors prior to the shock (Figure 4). Canada's sectoral reallocation is typical of the general labour adjustment over this period in developed economies in North America, Western Europe and the Pacific.[9] This evidence suggests a broader global reallocation of manufacturing employment to developing Asia.

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 readily observable, how they were achieved is not. 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:

$$\Delta e_{i,t} = f_{i,t} u_{i,t} - s_{i,t} e_{i,t} \tag{1}$$

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* microdata. Given the employment and unemployment series, equation (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 5 shows the results for the resource sector. Both series are expressed in logarithms and identically-scaled so their relative movements are directly comparable.[10] The resource

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

[10] 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.

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 6 shows that in the manufacturing sector, firms did not increase firings, they simply slowed hiring. This 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. Gourinchas (1999) finds similar results using firm-level data on French manufacturers. Following a real appreciation, the job creation margin was much more responsive than the job destruction margin. This result is counter to the prediction of his model, and he suggests, "should shift the focus of future discussions towards the entry margin." (p. 1314). This conclusion leads me to model job separations as exogenous and focus on job creation. 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 are more cyclically sensitive than permanent layoffs over 1978–1993.

Unfortunately, no reliable data are available by sector for vacancies or job training expenditures in Canada.[11] 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. Finally, if workers require training to operate new machinery and

[11] 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 devoted to employment ads is no longer a useful indicator of firms' recruiting efforts.

equipment (M&E), then M&E per worker provides a 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.

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 2 reports the gains in real hourly wages and annual wages between 2001, the year before the shock, and 2006, the latest available data.[12] I report the quartiles to highlight the differences within a given sector along the wage distribution. Since the shock, 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.[13] Also see Figure 7, 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 8 plots the estimated wage distribution.

3 Multisector Search Model with Training

This section briefly describes the model of sectoral labour adjustment.[14] There are two key extensions to a discrete time version of Pissarides' (2000, Ch. 1) baseline search and matching labour model. The first is multisector search which links labour market conditions across sectors and gives rise to sectoral wage and hiring spillovers (inter-sectoral labour reallocation). The second extension is on-the-job training and skill acquisition. This amplifies the model's response to productivity shocks through endogenous shifts in the skill composition of the labour force (intra-sectoral labour reallocation).

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

[13] 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.

[14] See Tapp (2007) for an extended discussion, equilibrium derivations and proofs.

3.1 Environment

Time is discrete with an infinite horizon. To simplify the exposition, there is no aggregate uncertainty to focus on the model's steady-state. There are multiple sectors of the economy indexed by $i \in \{1, 2, \ldots, I\}$ that produce a non-storable good. The model features a measure one continuum of potential workers and a continuum of firms. Each type of agent is *ex ante* identical, infinitely-lived and risk-neutral, discounting future payoffs at rate δ. Agents are either matched and productive, or searching for a partner to begin production.

Workers: Unemployed workers receive benefits, z, each period and search for jobs simultaneously in all sectors at no cost. There is no on-the-job search or quits.[15] Workers maximize the expected present value of their lifetime income subject to the random arrival of job offers when unemployed. There are no savings in the model; workers simply consume their current income.

Firms: Before production can occur, firms must post vacancies to attract unemployed workers. There is free entry and exit of vacancies, which incur recruiting cost, c, each period. When matched with a worker, production begins as a low-skill match. Firms can train low-skill workers on the job. Training costs the firm $\tau(t_i)$ each period and increases the probability the match becomes high-skill, which is $\lambda_i t_i$, where λ_i is the skill arrival rate and t_i is training. Skills are match-specific and therefore are lost when the match terminates, which occurs with probability s_i each period.

Production: Matches produce output using only labour with constant returns to scale, skill-specific technologies. Each period sector i matches produce: $y_i^{SK} = A_i p_i^{SK} l_i^{SK}$, where y is output; $SK \in \{L, H\}$ superscripts low and high-skill matches; A_i is a sector-specific shock, which equals 1 in the steady-state; p is productivity, with $p_i^H > p_i^L$; and l is labour. Each firm employs one worker.

Matching: Matching functions determine the number of pairwise matches per period in each sector. The matching functions have the Cobb-Douglas functional form: $m_i(u, v_i) = \mu_i u^\alpha v_i^{1-\alpha}$, 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

[15] Osberg (1991) finds a significant number of Canadian workers changing sectors experience intervening unemployment. The model abstracts from job-to-job transitions; all transitions occur through unemployment.

i; and α is the elasticity of matches with respect to unemployment. Because the model is set in discrete, rather than continuous time, I need to avoid complications arising from workers receiving multiple offers in a period.[16] To do so, the number of matches in each sector is determined at the start of the matching process. Then pairwise matches are randomly allocated. Once a pair is matched, they exit to bargain. Matching rates are determined in equilibrium and can vary by sector. Let $\theta_i \equiv \frac{v_i}{u}$ denote market tightness in sector i from the firm's perspective; $f_i(\theta_i) = \frac{m_i}{u}$ denotes an unemployed worker's job-finding probability in sector i;[17] and $q_i(\theta_i) = \frac{m_i}{v_i}$ denotes the job-filling probability for a sector i vacancy, where $\sum_{i=1}^{I} f_i(\theta_i), q(\theta_i) \in [0, 1]$. Finally, workers and firms split the surplus from a match by the generalized Nash bargaining solution. Workers' bargaining power is $\beta \in (0, 1)$.

Value Functions: The present value of being unemployed is U. The present value of being a worker in a low-skill sector i match is W_i^L and working in a high-skill match is W_i^H. In the steady-state, the worker's Bellman equations are:

$$U = z + \delta[\sum_{i=1}^{I} f_i(\theta_i)W_i^L + (1 - \sum_{i=1}^{I} f_i(\theta_i))U] \tag{2}$$

$$W_i^L = w_i^L + \delta[s_i U + \lambda_i t_i W_i^H + (1 - s_i - \lambda_i t_i)W_i^L] \tag{3}$$

$$W_i^H = w_i^H + \delta[s_i U + (1 - s_i)W_i^H] \tag{4}$$

The interpretations are standard. In the current period, the unemployed worker receives benefits, z. 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 and begins next period as a worker in a low-skill match — the present value of which is W_i^L. δ discounts next period's payoffs and the summation is over all sectors. With complementary probability the worker does not match and remains unemployed.

For a worker in a low-skill match, 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.

[16]Julien et al. (2006) and Albrecht et al. (2006) among others, address these issues.

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

With probability $\lambda_i t_i$, the match acquires skill and produces next period as high-skill. With complementary probability the worker keeps his current job. The interpretation is analogous for workers in high-skill matches.

For the firm the value functions are the following, where V_i is the present value of posting a sector i vacancy, and that of being in a low-skill and high-skill sector i job is J_i^L and J_i^H:

$$V_i = -c + \delta[q_i(\theta_i)J_i^L + (1 - q_i(\theta_i))V_i] \tag{5}$$

$$J_i^L = A_i p_i^L - w_i^L - \tau(t_i) + \delta[s_i V_i + \lambda_i t_i J_i^H + (1 - s_i - \lambda_i t_i)J_i^L] \tag{6}$$

$$J_i^H = A_i p_i^H - w_i^H + \delta[s_i V_i + (1 - s_i)J_i^H] \tag{7}$$

Using these value functions, the new match surplus, S_i, is what the pair gains from producing less what they give up, $S_i \equiv W_i^L - U + J_i^L - V_i$. Nash Bargaining results in worker's getting their bargaining share β of surplus; the firms gets the remainder, $(1-\beta)S_i$. If the match becomes high-skill, the gain in value, or skill premium, $SP_i \equiv W_i^H - W_i^L + J_i^H - J_i^L$ is similarly split, giving workers βSP_i and firms $(1-\beta)SP_i$.

Equilibrium: An equilibrium solves for training, market tightness, wages, employment and unemployment $\{t_i^*, \theta_i^*, w_i^{L*}, w_i^{H*}, e_i^{L*}, e_i^{H*}, u^*\}_{i=1}^I$. Equilibrium wages are:

$$w_i^{L*} = \overline{w} + \beta(A_i p_i^L - \tau(t_i^*) - \overline{w}) \tag{8}$$

$$w_i^{H*} = \overline{w} + \beta(A_i p_i^H - \overline{w}) \tag{9}$$

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

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 worker's reservation wage is the value of unemployed search each period. When market conditions change in one sector, this impacts the worker's reservation wage, which impacts profits and job creation in the rest of the economy. This *'reservation wage effect'* causes sectoral employment and wage spillovers.

For interior solutions, the linear training cost function gives a closed-form solution, where a threshold skill arrival rate, $\overline{\lambda_i}$, characterizes firms' training decisions. The optimal symmetric training policy in sector i is:

$$t_i^* = \frac{(1-\beta)}{\beta} A_i(p_i^H - p_i^L) - \frac{r+s_i}{\lambda_i \beta} \tag{10}$$

where: $\overline{\lambda_i} = \frac{(r+s_i)}{(1-\beta)A_i(p_i^H - p_i^L)}$. Firms provide training if and only if the skill arrival rate is sufficiently high, $\lambda_i > \overline{\lambda_i}$, otherwise they provide no training. Training is increasing in the sector specific shock, A_i. This is the *'training effect'*. Following a positive shock, the increase in training accelerates skill acquisition and endogenously increases the share of high-skill matches in the sector. This, in turn, raises productivity.

4 Applying the Model to the Canadian Data

This section applies the model to analyze Canada's labour market adjustment. I construct the benchmark model to represent the Canadian economy in steady-state prior to the shocks. This environment corresponds to 'low' commodity prices and a 'weak' Canadian currency. After imposing shocks to the model, the benchmark economy adjusts to a new steady-state, corresponding to 'high' commodity prices and a 'strong' Canadian dollar. I demonstrate that given shocks of a reasonable magnitude, the model's labour adjustment captures the empirical facts identified in Section 2.

4.1 Approach

Section 2 finds that the resource and manufacturing sectors had the largest proportional employment responses following the shocks (Fact 1). Therefore, I focus the analysis by considering a model economy consisting of only these two sectors, which in 2001, accounted for 23 percent of Canada's output. With two sectors, there are 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 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 3.

4.2 Parameter Selection/Calibration

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 rate 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.[18]

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 2.

Productivities (p_i^L, p_i^H): The model distinguishes 'low' and 'high' skill workers in each sector. In the benchmark calibration, low-skill productivity is set to match the 25^{th} 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 2, the lower quartile manufacturing 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, representing 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 scheme (which among other things, distinguishes eligibility by employment histories),

[18] 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.

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.[19] 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 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 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 this choice.

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

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

percent and 89 percent, respectively, and the unemployment rate is 7.7 percent. See Table 4.

Hitting these targets requires $\mu_r = 0.07$ 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 $f_M^* + f_r^* = 0.26$, which is quite close to the 0.289 estimated for Canada by Hobijn and Sahin (2007). 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.[20]

4.3 Comparing the Model to the Data

This section assesses whether the model can generate labour market adjustments quantitatively similar to those observed in the data, given shocks of a reasonable magnitude. I compare the steady-states of the benchmark economy before and after shocks, and consider transition dynamics.

The model is general and stylized. Commodity prices and exchange rates are not explicitly modeled. What matters is simply that these shocks affect productivity differently in the two sectors, as discussed in Section 2. In the quantitative exercises which follow, I assume that for the Canadian economy, these productivity changes were exogenous, unanticipated and permanent. 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

[20] 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.

markets. If agents had expected future increases in commodity prices and exchange rates, they should have been reflected in the 2001 prices and futures contracts, but were not. Finally, these relative price movements have been persistent — holding for six years, so far, and to the extent Asian industrialization is responsible, one could reasonably expect this to be a long-run phenomenon.

I use two proxies to infer the sector-specific productivity impacts of the shocks, $\hat{A}_i$:

Shock 1: (Wage Proxy) In the model's new steady-state, because free entry exhausts economic profits, wage growth is proportional to labour-augmenting productivity changes. Therefore, from the wage data in Table 2, 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 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 a second proxy is: $\hat{A}_r = 1.067; \hat{A}_m = 1.046$.

Table 4 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 2, with the wage proxy, shock 1, performing best. Consistent with Fact 1, labour is reallocated from manufacturing to resources. With the wage proxy, the model exactly predicts the reallocation that occurred, while for the smaller output per worker proxy, the model features considerably less reallocation than in the data (only a 0.8 percentage point reallocation in the model versus 2.9 in the data). Figures 9 and 10 compare the model's dynamics to data from the payroll and labour force surveys. 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 employment adjustment begins in earnest.

Second, resource firms increased hiring, while manufacturing firms reduced hirings, consistent with Fact 2. By construction, separations are exogenous and constant, so the model has no predictions on this adjustment margin.[21]

Third, wage gains are larger for the resource sector and concentrated in the upper end of the wage distribution, see Fact 3 and Table 5. The table compares the *Labour Force Survey* data to an artificial cross-section generated by model simulation. Given 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 4 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.

Furthermore, by extending the basic search and matching model to incorporate heterogeneous jobs and skill acquisitions, the model also 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.[22]

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 5.

The model economy's new steady state following productivity shock 1 (the wage proxy), correctly captures the sectoral labour reallocation of the actual Canadian economy in 2006,

[21] In the data, however, separations fell in both sectors after the shocks. I can address this 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.

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

five years after the shock. Therefore, in the quantitative measurement exercises which follow, I assume that this is the economy's new steady-state after the adjustment to the higher commodity prices and Canadian exchange rate. This allows me to isolate specific frictions and assess the impacts of alternative policies.

5 Quantifying the Impacts of Search Frictions and Skill Non-Transferability

In models with Walrasian labour markets, production can be costlessly reorganized without delay. In such an environment, after a shock or policy change, the economy moves immediately to its new steady-state. In contrast, this model features two frictions that result in a costly and time-consuming adjustment process. First, before new matches can begin producing, agents must search to match with new partners. Second, skills acquired in a match cannot be transferred to new matches. Therefore, when a high-skill worker loses her job, she must undergo training to acquire new skills in her subsequent job to once again become high-skill. This section isolates and quantifies the contribution of each friction to the adjustment process. I first discuss steady-state effects, then analyze the transition between steady-states.

5.1 Steady-State Effects: Amplification Through Skill Accumulation

In the following results, I assess the impacts on the aggregate model economy using the following summary 'welfare' measures and their components:

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

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

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

3) Worker's Expected Income: wages plus unemployment benefits $= \sum_{i=r}^{m} w_i^L e_i^L + w_i^H e_i^H + zu$

Consider first the steady-state impacts of the 'training effect' — *i.e.* the increase in a sector's training and skill accumulation that occurs after a positive sector-specific productivity shock. Isolating this effect is accomplished by comparing the model economy's responses to productivity shocks in environments with, and without, training and skill accumulation. Table 6 reports the results. The first column is the steady-state percent changes after the shocks, in the model without skill accumulation; the second column is the response with skill accumulation, and the last column isolates the steady-state effects of skill accumulation.

The results reveal that extending the basic model to include skill accumulation through on-the-job training amplifies the economy's response to productivity shocks. From the previous section, the data suggest a larger relative productivity increase in the Canadian resource sector since 2002. After imposing these shocks, the composition of production shifts favorably towards more productive matches. Not only does production shift towards the more productive resource sector (inter-sectoral reallocation), but within both sectors, when workers can accumulate skills, production shifts towards high-skill jobs (intra-sectoral reallocation). This result is consistent with Keane and Prasad (1996), who find that employment shifted towards high-skill workers in the U.S. following earlier oil price increases. This intra-sectoral productivity gain in the model appears new to this literature.

The positive productivity shocks impact firms' hiring and training decisions. As resource sector jobs are relatively more profitable, there is more job posting in this sector, so over time its share of employment increases. In addition, the shocks raise the skill premia in both sectors (there is a bigger gain in moving from low-skill to high-skill matches), so all firms offer more training. With more training, matches acquire skills faster, increasing the percentage of high-skill matches in the economy. Overall, training raises productivity, so even without a change in aggregate employment, aggregate output and the welfare measures are over three percent higher, with the training effect. Finally, there are also distributional wage effects with training, as the wages of high-skill workers rise relative to low-skill workers. This relative wage result is also consistent with Keane and Prasad's (1996) empirical findings.

5.2 Transition Costs of Search Frictions and Skill Accumulation

The previous section establishes that firm's job training responds to the incentives to accumulate skills in a match and can, therefore, have long-run steady-state effects. This section investigates the importance of training/skill accumulation and search frictions for the transition process between steady-states. To do so, I compare the benchmark model economy without these frictions which adjusts to its new steady-state in one period, to the same economy which adjusts subject to these search and skill non-transferability frictions. This is the appropriate comparison because society's opportunity cost is what the economy is producing during the adjustment versus what it is capable of producing after sectoral adjustment.

First, some additional information is necessary to characterize the model's transition dynamics between steady-states. This section provides a brief summary, Appendix C has more details. The sector-specific productivity shocks occur at the beginning of the period. The shocks are denoted $\hat{A}_i$ in sector i, where the hat superscript is for updated values after the shock. Prior to production, existing matches renegotiate low and high-skill wages and training policies in the same manner described above, but in light of the new information about the shocks. Prior to recruitment, unmatched firms optimally update their vacancy decisions. Because of free entry and free disposal of vacancies, the value of a vacancy is zero for all sectors at all points in time. In Pissarides' (2000) terminology, wages, training and market tightness (vacancies) are 'jump variables' updating in the period the shock hits. Given the new values of the sector-specific shocks, $\hat{A}_i$, jump variables are given by the solutions to:

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

$$\frac{r+s_i}{q(\hat{\theta_i^*})} + \beta\sum_i \hat{\theta_i^*} = \frac{(1-\beta)}{c}[\hat{A}_i p_i^L - \tau(\hat{t_i^*}) - z + \lambda_i \hat{t_i^*} \cdot \frac{\hat{A}_i(p_i^H - p_i^L) + \tau(\hat{t_i^*})}{r + s_i + \lambda_i \hat{t_i^*}}]$$

$$\hat{w_i}^{L*} = \hat{\overline{w}} + \beta(\hat{A}_i p_i^L - \tau(\hat{t_i^*}) - \hat{\overline{w}}); \qquad \hat{w_i}^{H*} = \hat{\overline{w}} + \beta(\hat{A}_i p_i^H - \hat{\overline{w}})$$

where $\hat{\overline{\lambda_i}} = \frac{(r+s_i)}{(1-\beta)\hat{A}_i(p_i^H - p_i^L)}$ and $\hat{\overline{w}} = z + \delta\sum_i^I f_i(\hat{\theta}_i^*)(\hat{W}_i^L - \hat{U})$

Employment and unemployment adjust more slowly to their new steady-state values according to the following difference equations:

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

$$\hat{e}_{i,t+1}^H = \lambda_i \hat{t}_i^* e_{i,t}^L + (1 - s_i)e_{i,t}^H$$

$$\hat{u}_{t+1} = \sum_{i=1}^I s_i(e_{i,t}^L + e_{i,t}^H) + [1 - \sum_{i=1}^I f_i(\hat{\theta}_i^*)]u_t$$

Output adjusts along with employment changes.

Table 7 reports the adjustment costs attributable to both the search and non-transferable skill 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. Figure 11 demonstrates the intuition for the calculations in a diagram.

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 imped the adjustment, social welfare measures — the social planner's value and social net production — are four percent, and aggregate output nearly three percent, below their new steady-state values in the first year after the shock. Training costs are over seven percent above their eventual steady-state value in the first year, as low-skill (particularly resource) workers are trained more intensely until the stationary distribution of low-to-high skill jobs is obtained. Finally, the full economic adjustment is time-consuming, taking over five years to complete.

Table 8 isolates the adjustment costs attributable to search frictions alone, by computing the transition for the model without skill accumulation. The estimated costs are much smaller, suggesting that search frictions are a minor contributor to the overall adjustment costs. This result 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. Finally, comparing the model with and without skill accumulation re-enforces the point that the training effect is the model's key source of amplification.

My quantitative cost estimates of labour adjustment relate to results by Lee and Wolpin (2006).[23] In their counterfactual experiments, removing inter-sectoral mobility costs raised the average annual growth rate of aggregate U.S. output by 1.2 percent over their sample. Given that I focus on the most affected sectors after a particularly dramatic shock, my estimated cost of 2.8 percent output in the first year after the shock is reasonable. Finally, my results also relate to an empirical literature that uses regression analysis to study employment

[23] A key difference is that my model focuses on search frictions, training and unemployment, while their model features a complex modeling of occupation and education choices.

and wage responses to exchange rate movements.[24] The model here provides a more explicit account of the mechanism by which employment and unemployment adjust following shocks, captures the equilibrium wage and employment interactions between sectors, and permits policy and welfare analysis.

6 Policy Analysis: Unemployment Benefits

The results suggest that these impediments to adjustment were economically significant in Canada during this episode. A natural next step is to analyze whether policy changes might improve the situation. This section investigates how changes in unemployment benefits impact economic allocations, social welfare, and the speed of adjustment.

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. Such policy options are often discussed during particularly acute labour adjustments and argued for on the basis of equity considerations.[25] 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.

Table 9 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 the usual effects in a search model, quantifying the impacts is important. In addition, there are two key results to highlight. First, the policy significantly prolongs the economy's adjustment. Second, the policy encourages sectoral reallocation to the more-productive sector, generating aggregate productivity gains.

The model mechanism driving these results is the reservation wage effect. More generous unemployment benefits make unemployment less costly. Unemployed workers respond by

[24] See for example, Leung and Yuen (2005), Campa and Goldberg (2001) and Burgess and Knetter (1998).

[25] 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.

raising their reservation wage to accept a job. Similarly, currently employed workers have an improved threat point in the wage bargain, so they renegotiate for higher wages. As a result, labour is now more expensive, so given a match's productivity, jobs are less profitable. This, in turn, discourages job creation, so recruiting costs and aggregate employment fall. Fewer workers produce less aggregate output and cost less to train (though training intensity per worker is unchanged). With less job creation, unemployment incidence and duration both rise dramatically, resulting in a significant increase in the total unemployment benefits collected. Further, lower job creation slows the adjustment process by two years. Stated differently, with more generous benefits the adjustment is 23 percent longer. This result is consistent with empirical work for OECD countries by Scarpetta (1996). Ljungqvist and Sargent (1998) also argue that higher unemployment benefits prolong the economy's adjustment to shocks.

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. In the model, because skills are not transferable, unemployed workers are homogeneous regardless of their employment histories. So if 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.[26] 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 small. 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 9 shows, vacancies fall in both sectors with more generous benefits, but they fall more in the manufacturing 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 shift to resources making the economy more productive, with output per worker rising 0.6 percent.

All things considered, does this policy change improve social welfare? The social planner's

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

value is one percent higher, however, this is somewhat misleading because it arises solely from higher unemployment income. In reality, more generous unemployment benefits ultimately require higher taxes, and these considerations are absent in the model. Indeed, once unemployment benefits are removed, the more generous benefits lower social net production by over one percent. As a result, even without the distortionary impacts of taxation, society is ultimately worse off.

Not everyone, however, is worse off from this policy change. Despite less aggregate production and income, workers take a larger share of overall income. So those who are employed are better off and those that are unemployed are receiving higher benefits. 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, because I perform a counterfactual experiment that never occurred, one cannot assess whether the model matches observed data. Nonetheless, 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.[27] 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 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 4 demonstrates that my results are consistent with the sectoral employment data. It is noteworthy then, that my model simultaneously matches sectoral em-

[27] Nickell and Laynard (1999) and Costain and Reiter (2006).

ployment responses to productivity shocks and unemployment's response to unemployment benefits.

7 Robustness of Results to Parameter Selection

This section assesses the sensitivity of the results to different parameter choices for values that were taken from the literature or pre-selected. I find that varying the matching function elasticity (with respect to unemployment) in the range found in Pissarides and Petrongolo's (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 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 parameterization, 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 $\beta = 0.05$.

8 Conclusions and Future Work

This paper 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 paper is to quantitatively demonstrate a logical implication of this fact: During sectoral reallocations, large numbers of workers make sectoral 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 after the increase in commodity prices and associated exchange rate appreciation, which began in 2002. Popular discussions of this episode typically emphasize job losses from layoffs in the manufacturing sector. However, my analysis suggests the reason manufacturing employment fell so dramatically was not because of an unusually high rate of job loss (i.e., separations). Instead, the cause for concern is the weak job creation, which was entirely responsible for the fall in employment.

I used a multisector 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. Finally, increasing unemployment benefits in model were shown to reduce employment, output and social welfare. However, such a policy would likely increase the composition of high-productivity jobs in the economy and raise output per worker.

Several extensions are possible in future work. One is to repeat the quantitative analysis with a third sector to capture movements to the rest of the economy. Another is to add physical capital to the model. This may be important because in the data, the resource sector experienced not only a large increase in labour, but also a large increase in capital per worker following the commodity price shock. I would also like to consider the impacts of policies that increase the incentives for training displaced workers. Another potential 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. In future research, I plan to study regional labour market responses and migration after shocks. With suitable modifications, the basic framework in this paper 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 (real estate) when workers move. The interaction of capital and labour markets in this environment may provide some interesting new insights into the labour adjustment process.

Appendix

A Tables

Table 1: **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 2: **Distribution of Real Wage Gains, 2006 vs. 2001**

	Annualized Wage Gain	Hourly Wage 2001	Hourly Wage 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 25^{th}, 50^{th} and 75^{th} 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 3: **Parameter Values for the Benchmark Model**

Variable	Parameter	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 4: **Comparing Model to Data, Target Variables in the Benchmark and New Steady-State**

	Benchmark 2001		New Steady-State		
	Data	Model	2006 Data	Shock 1 Model	Shock 2 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 are 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 state using the output per worker proxy for the productivity shocks: $A_r = 1.067; A_m = 1.046$.

Table 5: **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 2 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 6: **Isolating and Quantifying the Steady-State Skill Effect**

Aggregate Impacts	**No Skill Accumulation**	**Skill Accumulation**	**Skill Effect**
Social Planners Value (a+b-c-d)	5.4	8.7	3.2
Social Net Production (a-c-d)	5.7	9.1	3.4
Workers Expected Income	5.4	8.7	3.3
a) Output	5.9	9.3	3.4
b) Unemployment Benefits	-0.4	0.4	0.8
c) Training Costs	0.0	8.1	8.1
d) Recruiting Costs	11.9	25.2	13.3
Employment	0.0	0.0	0.0
% High-Skill	0.0	4.0	4.0
Output per Worker	5.9	9.4	3.5
Reservation Wage	5.4	8.7	3.3
Unemployment	-0.4	0.4	0.8
Unemployment Duration (months)	-0.1	-0.1	0.0
Sectoral Impacts			
Output - Resources	30.7	44.5	13.8
Manufacturing	2.5	4.4	2.0
Employment - Resources	19.1	26.2	7.1
Manufacturing	-2.3	-3.3	-0.9
% High Skill - Resources	0.0	7.0	7.0
Manufacturing	0.0	4.0	4.0
Profits - Resources	30.8	41.0	10.2
Manufacturing	-2.9	-5.4	-2.5
Market Tightness - Resources	56.4	77.3	20.9
Manufacturing	-4.8	-8.9	-4.1
Distributional Impacts			
Low-Skill Wages - Resources	7.8	5.4	-2.3
Manufacturing	5.2	5.2	0.1
High-Skill Wages - Resources	8.1	9.4	1.3
Manufacturing	5.1	6.3	1.2

Note: The first two columns report the percentage change in the variables relative to their benchmark models. The last column subtracts the results without skills from the model with skills to isolate the steady-state effects. The first column without skills is: (2) - (1), where (2) is the new steady-state with no skills $\lambda_i = 0; p_i = \frac{p_i^L + p_i^H}{2}; A_r = 1.097, A_m = 1.049$; and (1) is the benchmark with no skills $\lambda_i = 0; p_i = \frac{p_i^L + p_i^H}{2}; A_i = 1$; The second column with skills is: (4) - (3), where (4) the new steady-state with skills $\lambda_r = 0.09; \lambda_m = 0.05; A_r = 1.097, A_m = 1.049$; and (3) is the benchmark with skills $\lambda_r = 0.09; \lambda_m = 0.05; A_i = 1$.

Table 7: **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 8: **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.

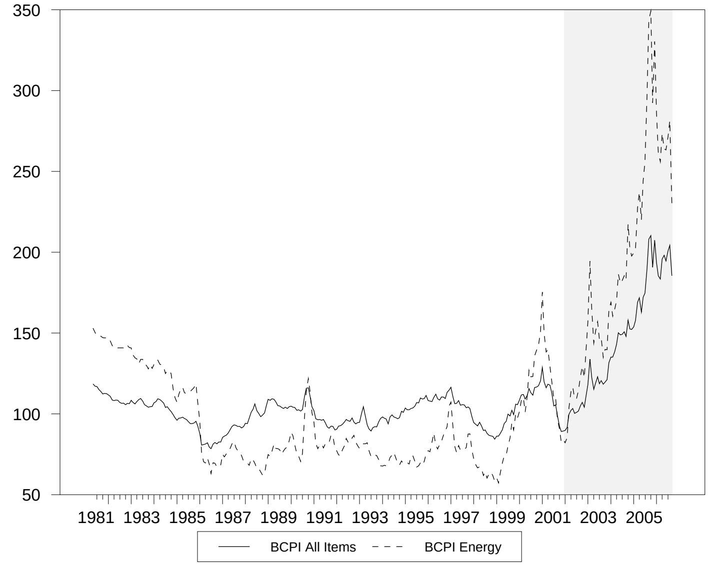
Table 9: **Steady-State Impacts of Increased Unemployment Insurance**

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).

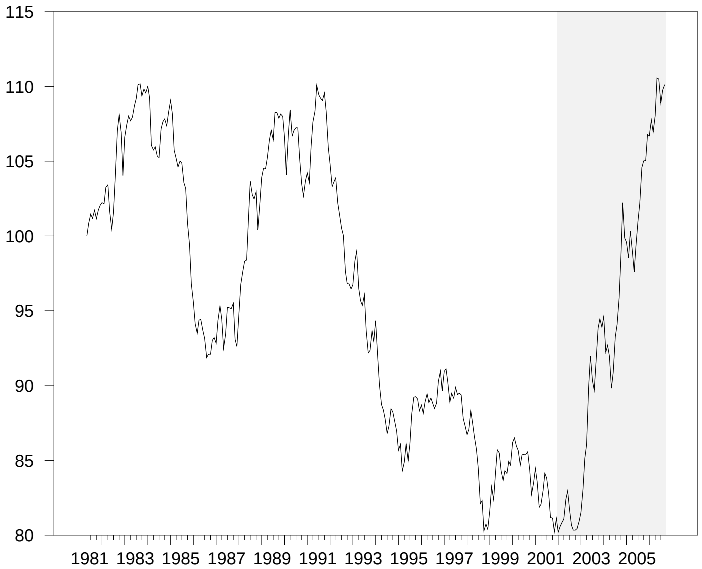
B Figures

Figure 1: **Bank of Canada Commodity Price Index and Energy Subindex, 1981–2006**



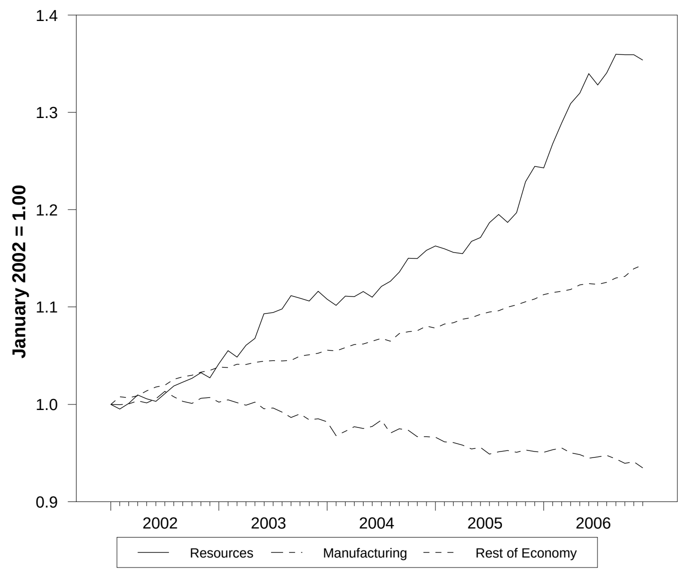
Source: Bank of Canada. The Bank of Canada Commodity Price Index is a fixed-weight index of the spot or transaction prices of 23 commodities produced in Canada and sold in world markets. Each commodity's index weight is based on the average value of its Canadian production over the 1988-1999 period.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

Figure 2: **Canadian Nominal Effective Exchange Rate, 1981–2006**



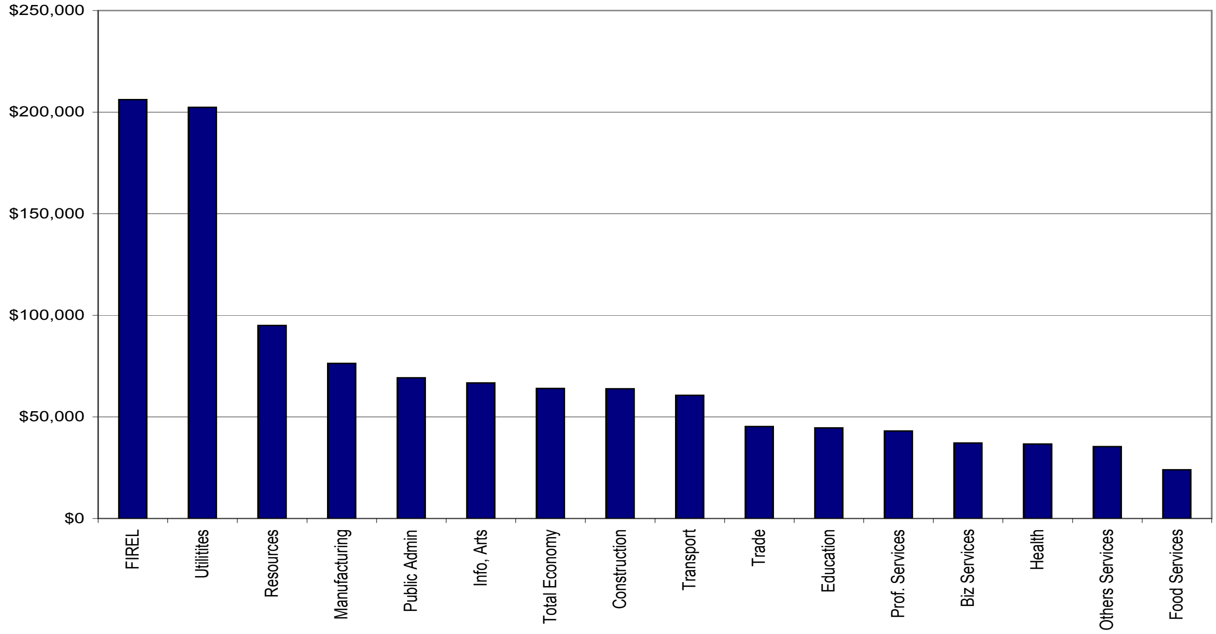
Source: Bank of Canada. The nominal effective exchange rate uses multilateral trade weights for the six currencies of countries or economic zones with the largest share of Canada's international trade. For more information on its construction see Ong (2006). The average value of the index is 100 in 1992.

Figure 3: **Relative Employment Changes, Canada 2002–2006**, SEPH Payroll Survey



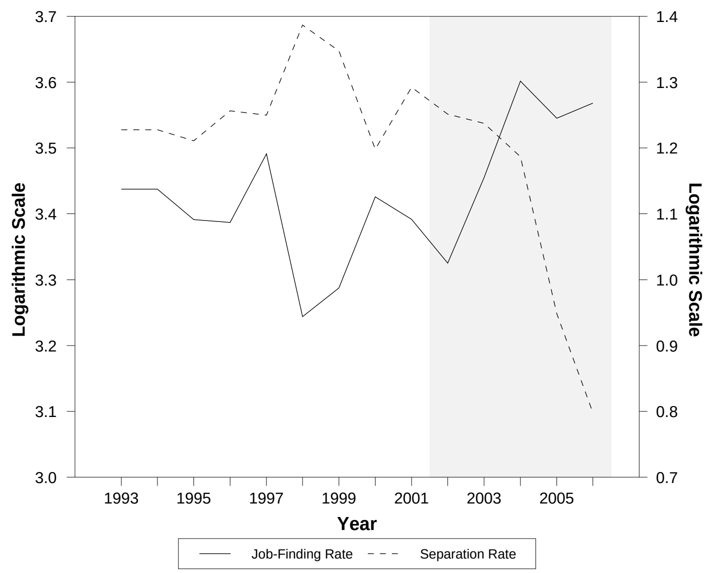
Source: Cansim, Survey of Employment, Payrolls and Hours (SEPH), seasonally adjusted employment. Manufacturing v1596771. Mining and oil and gas extraction v1596768. Rest of Economy = Industrial aggregate excluding unclassified, v1596764, less manufacturing and mining, oil and gas employment.

Figure 4: **Sectoral Output per Worker, Canada 2001**



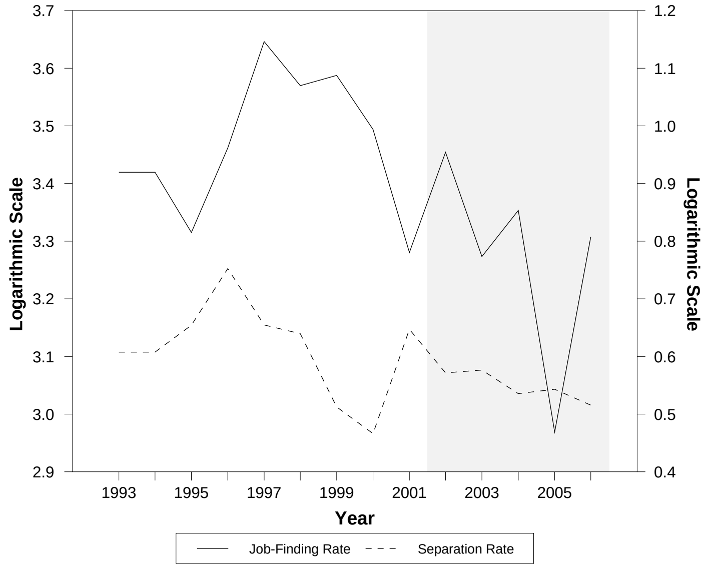
Data Source: Cansim. Output is GDP at basic prices, Table 3790019; Employment is from the Labour force survey, Table 2820094

Figure 5: **Resource Sector Job-Finding and Separation Rates, 1993–2006**



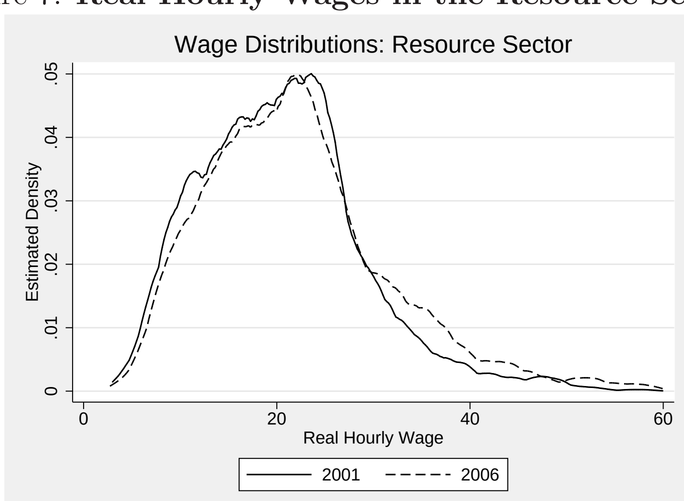
Data Source: *Labour Force Survey* Public Use Microdata files. I estimate total employment outflows in each sector by aggregating individuals' (frequency-weighted) employment-to-unemployment transitions. Given the employment and unemployment series, equation (1) gives the job-finding and separation rate 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 6: **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 (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 7: **Real Hourly Wages in the 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 8: **Real Hourly Wages in the 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 9: **Employment Dynamics Model vs. Data, 2002–2006**, SEPH Payroll Survey

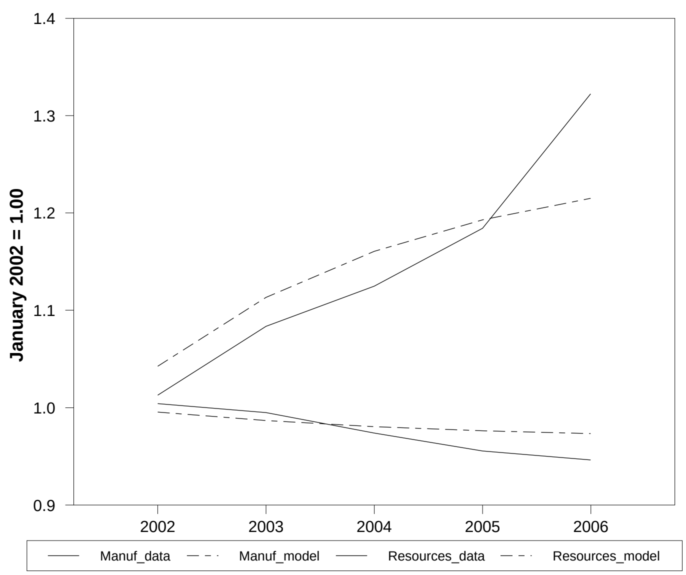


Figure 10: **Employment Dynamics Model vs. Data, 2002–2006**, LFS Data

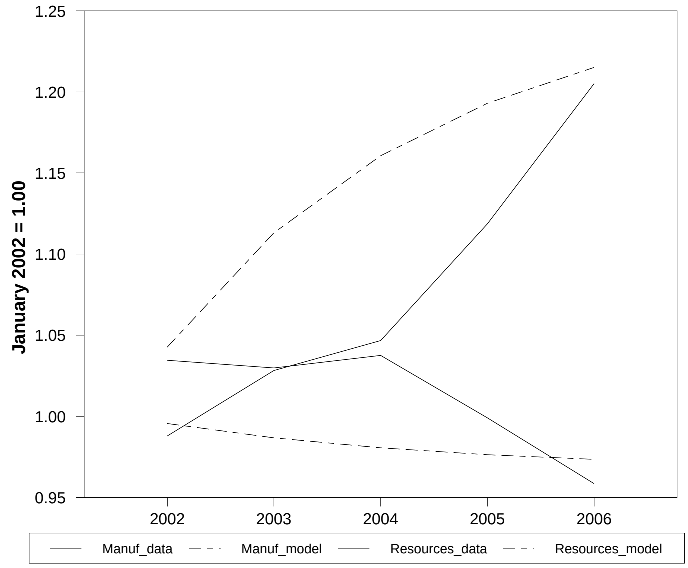
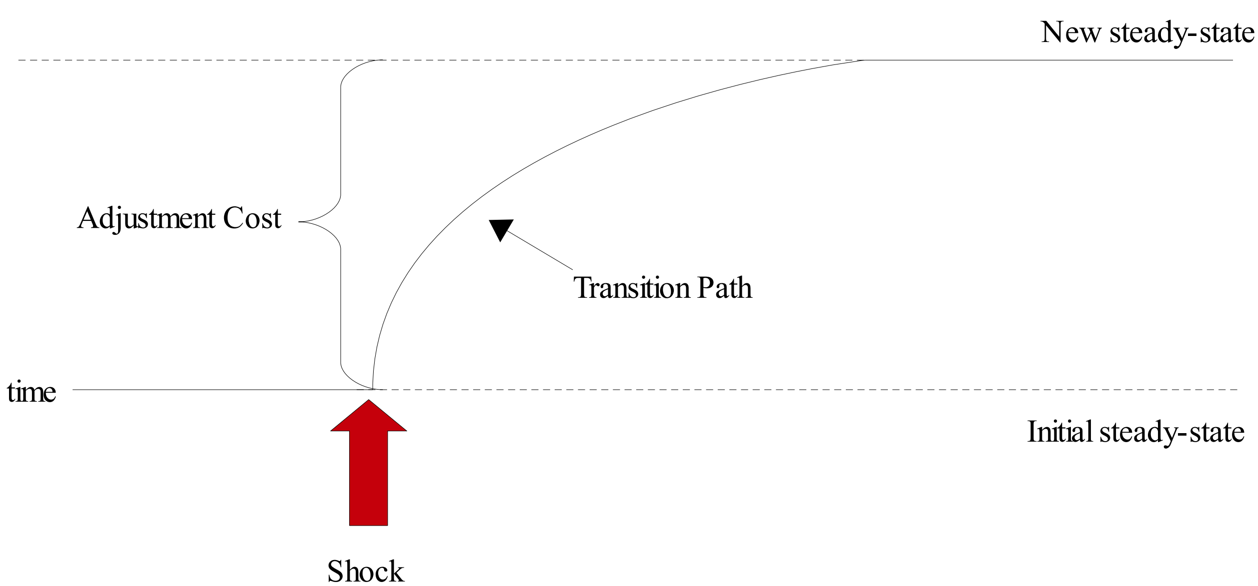


Figure 11: **Calculating Adjustment Costs During the Model's Transition**



C Transition Dynamics

The shock, denoted $\hat{A}_{i,t}$, hits at the beginning of period t, where the hat superscript denotes an updated value. With free entry and exit of vacancies and costless renegotiation of labour contracts conditional on the new sector-specific state, training, market tightness and wages update immediately in period t, prior to production and search. Their new values are:

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

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

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

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

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 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:

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

And similarly for the other value functions which are now:

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

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

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

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

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

Free entry and exit of vacancies implies $\hat{V}_{i,t} = \hat{V}_{i,t+1} = 0$. 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 $\hat{S}_{i,t} = \frac{c}{(1-\beta)\delta q_i(\hat{\theta}^*_{i,t})}$ or equivalently:

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

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

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

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

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

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 $\theta_{i,t} \equiv \frac{v_{i,t}}{u_t}$, vacancies overshoot their steady-state level and move in the same direction as unemployment so that market tightness remains constant at its new value during the transition. See Pissarides (1985) or (2000, Ch. 1.7).

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