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Abstract

What are the effects of financial market imperfections on unemployment and vacancies in Canada? The author estimates the model of Zhang (2011) – a standard monetary dynamic stochastic general-equilibrium model augmented with explicit financial and labour market frictions – with Canadian data for the period 1984Q2–2010Q4, and uses it to examine the importance of financial shocks on labour market fluctuations in Canada. She finds that the estimated value of the elasticity of external finance, the key parameter capturing financial frictions, is much higher than the value suggested in the literature. This gives rise to a larger amplification effect from the financial accelerator mechanism, which helps the model generate a more volatile labour market. The author finds that the model accounts well for the cyclical behaviour of unemployment and vacancies observed in the data. She also finds that financial shocks are one of the main sources of fluctuations in the Canadian labour market. Overall, financial shocks contribute about 30 per cent of the fluctuations in unemployment and vacancies for the Canadian economy.

JEL classification: E32, E44, J6
Bank classification: Economic models; Financial markets; Labour markets

Résumé

Quels effets les imperfections des marchés financiers ont-elles sur le chômage et l'offre d'emplois au Canada? À l'aide de données canadiennes allant du deuxième trimestre de 1984 au quatrième trimestre de 2010, l'auteure estime un modèle monétaire d'équilibre général dynamique et stochastique intégrant des frictions financières et un marché du travail soumis à des frictions – tiré de Zhang (2011) – afin d'examiner le rôle des chocs financiers dans les fluctuations du marché canadien du travail. La valeur qu'elle obtient pour l'élasticité du financement extérieur, le principal paramètre qui rend compte des frictions financières, est beaucoup plus élevée que celle avancée dans la littérature. Cette forte élasticité accentue l'effet d'accélérateur financier, le modèle générant ainsi plus de volatilité sur le marché du travail. L'auteure constate que le modèle reproduit bien le comportement cyclique du chômage et de l'offre d'emplois observé dans les données. D'après ses résultats, les chocs financiers sont l'une des grandes sources des variations sur le marché canadien du travail. Au total, ils expliquent environ 30 % des fluctuations du chômage et de l'offre d'emplois dans l'économie.

Classification JEL : E32, E44, J6
Classification de la Banque : Modèles économiques; Marchés financiers; Marchés du travail

1 Introduction

The recent financial crisis has been associated with a significant rise in the unemployment rates in both the United States and Canada. In the United States, the unemployment rate more than doubled from 4.8 per cent at the beginning of the recession to peak around 10 per cent in the last quarter of 2009. In Canada, the unemployment rate rose from 6 per cent in the last quarter of 2007 to peak at 8.5 per cent in the third quarter of 2009. A recent paper by Zhang (2011) develops and estimates a quantitative macroeconomic model that incorporates both labour and financial market frictions using U.S. time-series data from 1964Q1 to 2010Q3. She finds that the financial accelerator mechanism plays an important role in amplifying the effects of the financial shock on unemployment. Overall, the financial shock contributes around 37 per cent of the fluctuations in unemployment and vacancies in the U.S. economy.

This paper considers the Canadian case and asks: How much of the fluctuations in unemployment and vacancies in the Canadian economy can be attributed to financial factors; i.e., financial frictions and shocks? Although the recent literature has shown an increasing interest in the role of financial factors in business cycle fluctuations in medium-scale dynamic stochastic general equilibrium (DSGE) models (e.g., Bernanke, Gertler and Gilchrist 1999; Christiano, Motto and Rostagno 2007), it has largely abstracted from modelling unemployment in models where financial factors play an important role. Zhang (2011) and Christiano, Trabandt and Walentin (2007) are two recent exceptions.[1] Both papers model financial market frictions as in Bernanke, Gertler and Gilchrist (1999), and use a search and matching framework to model labour market frictions. In particular, both papers use the staggered wage contracting in Gertler and Trigari (2009) to model wage-setting frictions.[2] The key difference between Zhang (2011) and Christiano, Trabandt and Walentin (2007) is that Zhang (2011) focuses on the transmission mechanism of financial shocks to labour market activities. In particular, Zhang (2011) highlights the important role of the financial accelerator mechanism in amplifying the responses in unemployment and vacancies to financial shocks.

I start the analysis by reviewing some stylized facts about the Canadian labour market. I show that the dynamics of the Canadian labour market are similar to those observed in the United States. That is, over the cycle, while real wages are relatively rigid, both unemployment and vacancies are more volatile relative to output: unemployment is 5 times more volatile than output, and vacancies are 8 times more. To determine the extent to which financial market frictions may have contributed to fluctuations in the Canadian labour market, I estimate the model in Zhang (2011) using Canadian data from 1984Q2 to 2010Q4.[3] In the model, unemployment rises after a negative financial shock.

[1] A number of studies have incorporated labour market frictions into the standard New Keynesian models; however, financial market frictions have not been considered in these models. For examples of the representative studies, see Walsh (2005); Trigari (2009); Blanchard and Galí (2007). For examples of the most recent developments in this research area, see Gertler, Sala and Trigari (2008); Galí, Smets and Wouters (2010); Ravenna and Walsh (2011).

[2] Since the staggered wage contracting in Gertler and Trigari (2009) does not have a direct impact on ongoing worker-employer relations, it is not vulnerable to the Barro (1977) critique of sticky wages.

[3] Zhang (2011) uses a closed-economy model. Although Canada is a small open economy, using a closed-economy framework is still a useful exercise to generate implications for issues that do not particularly require an open-economy

The intuition is as follows: a negative financial shock reduces the entrepreneurs' net worth and worsens their balance-sheet position. Given the financial frictions in the model, the entrepreneurs will face a higher risk premium on their external finance due to the deterioration of their balance-sheet position. Since external financing becomes more costly, the demand for capital declines. It is optimal for entrepreneurs to keep a constant capital labour ratio given the constant-return-to-scale aggregate production function. Thus, the demand for labour declines as well, leading firms to post fewer vacancies. The labour market becomes less tight and the likelihood of a worker finding a job decreases, leading to a rise in unemployment. Furthermore, the financial accelerator mechanism in the model amplifies the financial shock, leading to even larger fluctuations in unemployment and vacancies in the labour market.

As in Zhang (2011), I find that the estimated value for the elasticity of external finance, the key parameter capturing financial frictions, is much higher than the value suggested in the literature. This results in a larger amplification effect from the financial accelerator mechanism, which helps the model generate a more volatile labour market. Similar to the results in Zhang (2011) for the U.S. economy, I find that the model matches the aggregate volatility in the data for the Canadian economy reasonably well. In particular, the model is able to generate highly volatile unemployment and vacancies, and a relatively rigid real wage. The results suggest that financial shock is one of the main sources of fluctuations in the Canadian labour market: approximately 30 per cent of the variability in unemployment and vacancies can be attributed to financial shock. To further identify the role of financial factors (financial frictions and shocks) in the labour market fluctuations, I exclude the financial shock and re-estimate the model without using any financial data. I find that the estimated degree of financial market frictions is much lower, and the model accounts poorly for the dynamics of unemployment and vacancies.

The paper is organized as follows. In the next section, I document the cyclical features of the Canadian labour market. In section 3, I describe the model, and in section 4 I discuss the data and estimation strategy. In section 5, I present the estimation results and discuss the effects of financial shocks and frictions on the Canadian labour market. In section 6, I conduct robustness checks. In section 7 I offer some concluding remarks.

2 Cyclical Behaviour of Unemployment and Vacancies in Canada

In this section, I briefly document the movements of the main variables in the Canadian labour market: unemployment, job vacancies and real wages. Most of the data are taken from Statistics Canada. The unemployment rate is defined as the fraction of the population in the labour force who are able to work, actively seeking jobs, and yet not working. For vacancies, the conventional measure is the help-wanted index from ads in major newspapers. Statistics Canada's help-wanted index covers the period from 1981 to 2003. However, firms rely increasingly on the Internet to

structure. For example, Clarida, Galí and Gertler (2001) argue that, under certain conditions, the optimal monetary policy design problem for a small open economy is isomorphic to that for a closed economy. For recent examples of using a closed-economy DSGE model for the Canadian economy, see Dib (2003), and Covas and Zhang (2010).

post their vacancies, and Statistics Canada stopped compiling the help-wanted index in 2003 as it became less useful. Currently, the only available data for the help-wanted index are from the Conference Board of Canada. Their help-wanted index is based on the seasonally adjusted number of new, unduplicated jobs posted online during the month across 79 Canadian job-posting websites. Therefore, in this paper, the vacancy data from 1984Q2 to 2003Q1 are from Statistics Canada, and the data from 2005Q4 to 2010Q3 are from the Conference Board of Canada.[4] For real wages, I use hourly total compensation for the business sector. All the series are logged and detrended using a Hodrick-Prescott (HP) filter with the smoothing parameter set to 1600.

Figure 1 shows the cyclical components of unemployment, vacancies and real wages. Output is added for comparison.[5] Compared to output, unemployment and vacancies are much more volatile, while real wages are relatively rigid. Unemployment and vacancies are negatively correlated: unemployment is countercyclical, while vacancies are procyclical. Table 1 quantifies what is evident in Figure 1. The first row of Table 1 reports the relative standard deviations (compared to output) of the key labour market variables. Unemployment is 5 times more volatile than output, vacancies are 8 times more, and the volatility of real wages is slightly less than that of output. The lower panel in Table 1 provides the correlation matrix. Vacancies are procyclical with a correlation coefficient of 0.87, while unemployment is countercyclical with a correlation coefficient of -0.85. The correlation coefficient for real wages and output is 0.03, suggesting that wages are acyclical. The data also show that unemployment and vacancies are negatively correlated with a correlation coefficient of -0.85.[6]

Table 1: Summary Statistics: Quarterly Data, Canada, 1984–2010

		y	w	v	u
Standard deviation		1	0.88	9.65	5.59
Correlation matrix	y	1	0.03	0.87	-0.85
	w	-	1	-0.27	0.03
	v	-	-	1	-0.85
	u	-	-	-	1

3 The Model

Since the model is taken from Zhang (2011), in this section I provide only an overview of the model. Zhang (2011) considers an economy populated by a representative household, retailers, entrepreneurs, capital producers and employment agencies. In addition, there is a government in

[4]Note that there are no vacancy data available between 2003Q2 and 2005Q3.

[5]Output is measured by real GDP, which is also logged and detrended using an HP filter with the smoothing parameter set to 1600.

[6]Table 1 is based on the data from 1984 to 2010. However, the values related to vacancies (the standard deviation of vacancies, the correlation coefficient of vacancy and output, vacancy and unemployment, and vacancy and real wages) are computed using data from 1984–2003.

the model that balances the budget, and a central bank that implements a simple interest rate rule. In what follows, I briefly describe the role of each agent in the model.

3.1 Household

Each member in the household consumes, holds nominal bonds B_t, receives dividends from retailers Π_t, and pays taxes T_t. At time t, a fraction of household members are employed (n_t), and a fraction of household members are unemployed ($u_t = 1 - n_t$). The employed family members earn nominal wages w_t^n. The unemployed members receive unemployment benefits $\bar{b}_t$. Following Andolfatto (1996) and Merz (1995), family members are assumed to be perfectly insured against the risk of being unemployed, and thus consumption is the same for each family member. The budget constraint for the representative household is

$$c_t \leq \frac{w_t^n}{p_t} n_t + \bar{b}_t(1 - n_t) + \Pi_t - T_t + \frac{B_t - r_{t-1}^n B_{t-1}}{p_t}, \tag{1}$$

where w_t^n is determined by Nash bargaining between employment agencies and workers, and the labour supply n_t is determined by a search and match process.

The representative household maximizes lifetime utility subject to equation (1),

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t).$$

The first-order condition for consumption is

$$\frac{e_t}{c_t} \frac{1}{r_t^n} = \beta E_t \left[\frac{e_{t+1}}{c_{t+1}} \frac{p_t}{p_{t+1}} \right],$$

where e_t is a preference shock that follows

$$\log\, e_t = \rho_e \log\, e_{t-1} + \epsilon_t^e, \quad \epsilon_t^e \sim i.i.d.\, N(0, \sigma_{\epsilon^e}^2).$$

3.2 Entrepreneurs

Following Bernanke, Gertler and Gilchrist (1999), entrepreneurs are risk-neutral and have a finite life. At each period t, entrepreneurs use capital and labour services to produce wholesale goods by using a Cobb-Douglas technology. Entrepreneurs purchase capital at price q_t from capital producers, using both the entrepreneurs' own net worth and bank loans. Entrepreneurs experience idiosyncratic shocks, which can lead them to default; however, only entrepreneurs observe the realization of the idiosyncratic shocks. Given this asymmetric information problem between entrepreneurs and banks, the optimal loan contract in Bernanke, Gertler and Gilchrist (1999) is such that entrepreneurs pay a risk premium on loans. This external finance premium, $s(.)$, depends on an entrepreneur's balance-sheet position, and at the aggregate level it can be characterized by

$$s_t = s\left(\frac{q_t k_{t+1}}{N_{t+1}}\right), \tag{2}$$

where $s^{'}(.) > 0$ and $s(1) = 1$, k_{t+1} is capital demand for the entrepreneur sector, and N_{t+1} is its net worth. Equation (2) expresses that the external finance premium increases with leverage, or decreases with the share of an entrepreneur's capital investment that is financed by the entrepreneur's own net worth.

Given the financial market imperfections, the aggregate capital is determined by the aggregate demand curve for capital,

$$E_t r_{t+1}^k = \frac{E_t[p_{t+1}^w \alpha \frac{y_{t+1}}{k_{t+1}} + q_{t+1}(1-\delta)]}{q_t},$$

and the aggregate capital supply curve $E_t r_{t+1}^k = s_t r_t^n E_t\left[\frac{p_t}{p_{t+1}}\right]$. The aggregate net worth is given by

$$N_{t+1} = \eta^e \gamma_t (r_t^k q_{t-1} k_t - \frac{r_{t-1}^n s_{t-1}}{1+\pi_t} b_{t-1}),$$

where η^e is the survival rate of entrepreneurs. The aggregate net worth of entrepreneurs at the end of period t, N_{t+1}, is the sum of equity held by entrepreneurs surviving from period $t-1$. γ_t is a financial wealth shock, an exogenous shock to the survival probability of entrepreneurs, which follows an AR(1) process:

$$\log\, \gamma_t = \rho_\gamma \log\, \gamma_{t-1} + \epsilon_t^\gamma, \quad \epsilon_t^\gamma \sim i.i.d.\, N(0, \sigma_{\epsilon^z}^2).$$

The aggregate demand for labour services is relatively simple. Given that the aggregate production function is constant returns to scale,

$$y_t = {k_t}^\alpha (z_t l_t)^{1-\alpha},$$

the aggregate labour demand equation can be written as

$$p_t^w (1-\alpha)\frac{y_t}{l_t} = p_t^l,$$

where l_t is the labour services supplied by employment agencies, $(1-\alpha)\frac{y_t}{l_t}$ is the marginal product of labour services, p_t^w is the relative price for wholesale goods and p_t^l is the relative price for labour services.

3.3 Employment agencies

Employment agencies act as intermediaries between the representative household (who supply labour) and entrepreneurs (who demand labour). The labour market is modelled using a standard search model. On the one hand, the employment agencies post vacancies, bargaining wages with workers; on the other hand, these agencies combine labour supplied by households into homogeneous labour services $n_t = \int n_t(i)di$ and supply them to entrepreneurs at a competitive price p_t^l. This leaves the equilibrium conditions associated with the production of wholesale goods unaffected, even though the labour market is frictional.

The basic model features of the employment agencies are as follows. At the beginning of period t, each employment agency i posts $v_t(i)$ vacancies to attract new workers, and employs $n_t(i)$ workers. The total number of vacancies and the number of employed workers are $v_t = \int v_t(i)di$ and $n_t = \int n_t(i)di$. The number of unemployed workers at the beginning of period t is

$$u_t = 1 - n_t.$$

The number of new hires m_t is governed by a standard Cobb-Douglas aggregate matching technology:

$$m_t = \mu_m u_t^{\sigma_m} v_t^{1-\sigma_m}.$$

For an employment agency, the value of adding another worker at time t is the price of selling one unit of labour service p_t^l, minus the wage cost $\frac{w_t^n(i)}{p_t}$ and vacancy costs $\frac{\kappa}{2}x_t(i)^2$, plus the continuation value of the filled vacancy:

$$J_t(i) = p_t^l - \frac{w_t^n(i)}{p_t} - \frac{\kappa}{2}x_t(i)^2 + (\rho + x_t(i))\beta E_t \Lambda_{t,t+1} J_{t+1}(i),$$

where $x_t(i)$ is the hiring rate for employment agency i, and ρ is the probability of a match that survives to the next period. The value of employment for a new worker at employment agency i at time t, $V_t(i)$, is

$$V_t(i) = w_t(i) + \beta E_t \Lambda_{t,t+1}[\rho V_{t+1}(i) + (1-\rho)U_{t+1}],$$

where $w_t(i)$ is the real wage. The value of unemployment, U_t is

$$U_t = \bar{b} + \beta E_t \Lambda_{t,t+1}[s_{t+1}^l V_{t+1} + (1 - s_{t+1}^l)U_{t+1}],$$

where $\bar{b}$ is the unemployment benefit, s_{t+1}^l is the probability of being employed versus unemployed next period, and V_t is the average value of employment for a new worker at time t.[7] The workers' surplus for having a job at employment agency i, $H_t(i)$, is

$$H_t(i) = V_t(i) - U_t.$$

[7] See Gertler and Trigari (2009) for details about the average value of employment.

Employment agencies and workers negotiate a nominal wage $w_t^n(i)$ to maximize the joint product of the workers' surplus $H_t(i)$ and the employment agencies' surplus $J_t(i)$. However, every period, each employment agency has only a fixed probability $1-\lambda$ to negotiate with workers. Thus, the Nash bargaining problem between employment agencies and workers is

$$\max H_t(i)^\eta J_t(i)^{1-\eta},$$

s.t.

$$\begin{aligned} w_t^n(i) &= w_t^{n*} \text{ with probability } 1-\lambda \\ &= w_{t-1}^n \pi \text{ with probability } \lambda, \end{aligned}$$

where π is the steady-state inflation rate. The equation for the real wage w_t^* derived from this staggered contracting is

$$\begin{aligned} \Delta_t w_t^* &= \eta(p_t^l + \frac{\kappa}{2} x_t^2(i)) + (1-\eta)(\bar{b} + s_{t+1}\beta\Lambda_{t,t+1}H_{t+s+1}) \\ &\quad + \lambda\rho\beta E_t \Lambda_{t,t+1}\Delta_{t+1}w_{t+1}^*. \end{aligned} \tag{3}$$

The first term of equation (3) is the worker's contribution to the match, and the second is the worker's opportunity cost. These are conventional components for Nash bargaining solutions for wages. The third term is from the staggered multi-period contracting. Finally, the aggregate real wage w_t can be expressed as

$$w_t = (1-\lambda)w_t^* + \lambda\pi\frac{1}{\pi_t}w_{t-1}.$$

3.4 Capital producers

Capital production is assumed to be subject to an investment-specific shock, τ_t. Capital producers purchase the final goods from retailers as investment goods, i_t, and produce efficient investment goods, $\tau_t i_t$, where τ_t follows

$$\log \tau_t = \rho_x \log \tau_{t-1} + \epsilon_t^\tau, \epsilon_t^\tau \sim i.i.d.N(0, \sigma_{\epsilon^\tau}^2).$$

Capital producers are also subject to a quadratic capital adjustment cost, $\frac{\xi}{2}(\frac{i_t}{k_t} - \delta)^2 k_t$. The profit of capital producers is thus given by

$$\Pi_t^k = E_t\left[q_t\tau_t i_t - i_t - \frac{\xi}{2}\left(\frac{i_t}{k_t} - \delta\right)^2 k_t\right].$$

3.5 Retailers

Retailers buy wholesale goods from entrepreneurs and produce a good of variety j. Let $y_t(j)$ be the retail good sold by retailer j to households and let $p_t(j)$ be its nominal price. The final good, y_t, is the composite of individual retail goods,

$$y_t = \left[\int_0^1 y_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}}.$$

The price index that minimizes the household's expenditure is

$$p_t = \left[\int_0^1 p_t(j)^{1-\varepsilon} dj \right]^{\frac{1}{1-\varepsilon}}.$$

Following Calvo (1983), in each period, only a fraction $1-\nu$ of retailers reset their prices, while the remaining retailers keep their prices unchanged. The retailer chooses $p_t(j)$ to maximize its expected real total profit over the periods during which its prices remain fixed:

$$E_t \Sigma_{i=0}^{\infty} \nu \Delta_{i,t+i}^p \left[\left(\frac{p_t(j)}{p_{t+i}} \right) y_{t+i}(j) - mc_{t+i} y_{t+i}(j) \right],$$

where mc_t is the real marginal cost, which is the price of wholesale goods relative to the price of final goods $(p_{w,t}/p_t)$, and $\Delta_{t,i}^p \equiv \beta^i c_{t+i}/c_t$ is the stochastic discount factor. Let p_t^* be the optimal price chosen by all firms adjusting at time t. The first-order condition is:

$$p_t^* = \left(\frac{\varepsilon}{\varepsilon - 1} \right) \frac{E_t \sum_{i=0}^{\infty} \nu^i \Delta_{i,t+i}^p mc_{t+1} y_{t+i} (\frac{1}{p_{t+i}})^{-\varepsilon}}{E_t \sum_{i=0}^{\infty} \nu^i \Delta_{i,t+i}^p y_{t+i} (\frac{1}{p_{t+i}})^{1-\varepsilon}}.$$

The aggregate price evolves according to:

$$p_t = [\nu p_{t-1}^{1-\varepsilon} + (1-\nu)(p_t^*)^{1-\varepsilon}]^{\frac{1}{1-\varepsilon}}.$$

3.6 Government

The government is assumed to balance its budget,

$$g_t = T_t,$$

where g_t follows an AR(1) process,

$$\log g_t = (1-\rho_x) \log g_{ss} + \rho_x \log g_{t-1} + \epsilon_t^g, \epsilon_t^g \sim i.i.d.N(0, \sigma_{\epsilon^g}^2).$$

3.7 Monetary policy rules

The central bank adjusts the nominal interest rate r_t^n according to a simple interest rate rule:

$$\frac{r_t^n}{r^n} = (\frac{r_{t-1}^n}{r^n})^{\rho_r} ((\frac{\pi_t}{\pi})^{\rho_\pi} (\frac{y_t}{y})^{\rho_y})^{1-\rho_r} e^{\epsilon_t^m},$$

where r^n, π and y are the steady-state values of r^n_t, π_t and y_t, and ε^m_t is a monetary policy shock that follows

$$\varepsilon^m_t \sim i.i.d.\, N(0, \sigma_{\varepsilon^m}).$$

ρ_π, ρ_y and ρ_r are policy coefficients chosen by the central bank.

3.8 Aggregation and equilibrium

The resource constraint is

$$z_t k_t^\alpha {l_t}^{1-\alpha} = c_t + i_t + g_t + \frac{\xi}{2}\left(\frac{i_t}{k_t} - \delta\right)^2 k_t + \frac{\kappa}{2} x_t^2 n_t.$$

Furthermore, for the labour market,

$$l_t = n_t.$$

4 Estimation

4.1 Calibrated values

As in Zhang (2011), I use a Bayesian approach to estimate the model. However, before using the model with the data, some parameters need to be calibrated to match the salient features of the Canadian economy. Table 2 reports these parameters and their calibrated values. Among the 13 parameters listed in Table 2, six relate to the labour market, two relate to the financial market, and the rest are "conventional" preference and technology parameters. As in Zhang (2011), I use standard values in the literature for the conventional parameters. The discount factor β is set to 0.99, which corresponds to an annual real interest rate in the steady state at 4 per cent. The curvature parameter in the utility function, σ, is set to 2, implying an elasticity of intertemporal substitution of 0.5. The steady-state depreciation rate, δ, is set to 0.025, which implies an annual rate of depreciation of 10 per cent. The parameter of the Cobb-Douglas function, α, is set to $1/3$. The steady-state price markup $\varepsilon/(\varepsilon - 1)$ is set to 1.1 by setting $\varepsilon = 11$.

For the labour market parameters, following Zhang (2011), the bargaining power parameter, η, is set to 0.5, which is commonly used in the literature. The elasticity of matches to unemployment, σ_m, is set to 0.5, the midpoint of values typically used. Following the suggestion of Zhang (2008), the job-separation rate, $1 - \rho$, is set to 0.09, matching the average job duration of 2.8 years in Canada; the job-finding rate s^l is set to 0.927, matching the fact that one-third of the unemployed workers find jobs within one month. Following Zhang (2008), the mean of market tightness is normalized to 1, which implies that the value of μ_m in the matching function equals the quarterly job-finding rate. Following Gertler, Sala and Trigari (2008), I express $\bar{b}$, the steady-state flow value of unemployment, as

$$\bar{b} = \tilde{b}(p^l + \frac{\kappa}{2}x^2), \tag{4}$$

where $\tilde{b}$ is the fraction of the worker's contribution to the job. Following Shimer (2005), I set $\tilde{b}$ to

0.4.

The survival rate of entrepreneurs, η^e, and the steady-state ratio of the net worth to capital N/k, are two financial market parameters. I set $\eta^e = 0.9865$ so that the steady-state external risk premium is 138 basis points, which is the sample average spread between the prime lending rate and overnight rate in Canada. I also set N/k to 0.6, which is suggested by Covas and Zhang (2010). In calibration, the following functional form is used for the external finance premium:

$$s_t = \left(\frac{q_t k_{t+1}}{N_{t+1}}\right)^{\chi}, \tag{5}$$

where χ is the elasticity of the external risk premium with respect to leverage and $\chi > 0$. χ can be viewed as a "reduced-form" parameter capturing financial market frictions.

Table 2: Calibrated Values

Conventional parameters		
β	discount factor	0.99
σ	inverse of intertemporal substitution of consumption	2
α	capital share	0.33
δ	capital depreciation rate	0.025
ε	intermediate-good elasticity of substitution	11
Financial market parameters		
N/k	steady-state ratio of net worth to capital	0.6
η^e	survivor rate of entrepreneurs	0.987
Labour market parameters		
ρ	survival rate of firms	0.91
s^l	job-finding rate	0.927
q^l	job-filling rate	0.927
η	bargaining power of workers	0.5
$\tilde{b}$	parameter for unemployment flow value	0.4
σ_m	elasticity in matches to unemployment	0.5

4.2 Data and priors

I use Bayesian techniques to estimate the remaining parameters. There are seven behavioural parameters: the elasticity of the external risk premium χ; the capital adjustment cost parameter ξ; the Calvo price and wage parameters ν and λ; and the Taylor rule parameters ρ_π, ρ_y and ρ_r. I also estimate the first-order autocorrelations of all the exogenous shocks and their respective standard deviations. I follow Zhang (2011) when choosing priors, which are reported in Tables 3 and 4.[8]

The data sample spans from 1984Q2 to 2010Q4, and includes six series of quarterly Canadian data: output, consumption, investment, nominal interest rate, inflation and external finance cost.

[8]For a detailed discussion of prior distributions, see Zhang (2011).

Output is measured by real GDP. Consumption is measured by real expenditures of non-durable goods. Investment is measured by the sum of business gross fixed capital formation, investment in inventories and real expenditure of durable goods. Data on these real variables are expressed in per capita terms using the civilian population aged 15 and up. The nominal interest rate is measured by the overnight rate in quarterly terms. Inflation is the quarter-to-quarter growth rate of the core CPI. External finance costs are measured by business prime lending rates in real terms. All the series are detrended using an HP filter with the smoothing parameter set to 1600.

Table 3: Prior and Posterior Distribution of Structural Parameters: Baseline

		Prior	Posterior distribution			
		distribution	Mode	Mean	5%	95%
Risk premium elasticity	χ	gamma (0.05,0.02)	0.188	0.195	0.156	0.228
Calvo wage parameter	λ	beta (0.67, 0.05)	0.850	0.847	0.819	0.873
Calvo price parameter	ν	beta (0.67, 0.05)	0.571	0.569	0.497	0.639
Capital adj. cost parameter	ξ	norm (0.25, 0.05)	0.222	0.224	0.142	0.300
Taylor rule inertia	ρ_r	beta (0.75, 0.1)	0.424	0.425	0.315	0.523
Taylor rule inflation	ρ_π	gamma (1.5, 0.1)	1.72	1.75	1.602	1.886
Taylor rule output gap	ρ_y	norm (0.125, 0.15)	0.001	0.004	-0.022	0.028

Table 4: Prior and Posterior Distribution of Shock Parameters: Baseline

		Prior	Posterior distribution			
		distribution	Mode	Mean	5%	95%
Panel A: Autoregressive parameters						
Technology	ρ_z	beta (0.6,0.2)	0.869	0.864	0.818	0.911
Preference	ρ_e	beta (0.6,0.2)	0.484	0.497	0.377	0.639
Investment	ρ_τ	beta (0.6,0.2)	0.884	0.877	0.847	0.913
Government	ρ_g	beta (0.6,0.2)	0.589	0.602	0.500	0.704
Financial	ρ_γ	beta (0.6,0.2)	0.422	0.397	0.146	0.598
Panel B: Standard deviations						
Technology	σ_{ϵ^z}	invg (0.005,2)	0.57	0.58	0.52	0.64
Monetary	σ_{ϵ^m}	invg (0.005,2)	0.26	0.27	0.22	0.32
Investment	σ_{ϵ^τ}	invg (0.005,2)	2.16	2.13	1.58	2.70
Preference	σ_{ϵ^e}	invg (0.005,2)	1.22	1.26	1.09	1.44
Government	σ_{ϵ^g}	invg (0.005,2)	1.44	1.45	1.31	1.60
Financial	σ_{ϵ^γ}	invg (0.005,2)	0.34	0.36	0.27	0.46

5 Results

5.1 Estimates

Table 3 reports the mode, the mean and the 5 and 95 percentiles of the posterior distribution of the behavioural parameters. The risk premium elasticity parameter, χ, is estimated to be around 0.19 (mean 0.195, mode 0.188). This value is lower than 0.24, the estimated value for χ for the U.S. economy in Zhang (2011),[9] but much higher than 0.05 – the value that is typically calibrated in the literature – or the estimates in other related studies.[10] As suggested in Zhang (2011), the high value of χ might be due to the inclusion of the financial data and financial shock. In other words, the non-financial variables used in the estimation in the other studies contain very limited information on financial frictions, and therefore they underestimate χ. The Calvo wage contract parameter, λ, is estimated to be around 0.85, suggesting a mean of six-and-a-half quarters between wage contracting periods. This value is higher than the estimate of the same parameter in Zhang (2011), suggesting a higher wage rigidity in Canada compared to the United States. The degree of price stickiness, ν, is estimated to be 0.57, which implies an average price-adjustment duration of 2.3 quarters. This value is also higher than its counterpart for the U.S. economy, suggesting that the price rigidity is slightly higher in Canada. The capital adjustment cost parameter, ξ, is estimated to be around 0.22. For the monetary policy reaction function parameters, ρ_π (the Taylor rule inflation parameter) is estimated to be 1.75, and the reaction coefficient to the output gap, ρ_y, is estimated to be 0.004, suggesting that policy responds very little to the output gap. There is a relatively low degree of interest rate smoothing, since the coefficient on the lagged interest rate is estimated to be 0.42. Compared to the estimated rule for the U.S.economy in Zhang (2011), this estimated Taylor rule suggests that, in Canada, the degree of inertia in the policy rate is higher, and the policy rate responds to inflation slightly more aggressively.[11]

Table 4 reports the estimates of the shock processes. The results are consistent with the findings in Zhang (2011), although the exact magnitude of the persistence and volatility of the shocks differs for these two countries: the new shock, a financial wealth shock, appears to be the least persistent shock, with an AR(1) coefficient of 0.39. The technology and investment shocks are estimated to be most persistent, with a coefficient of 0.86 and 0.88, respectively. The mean of the standard error of the shock to investment is 2.13, suggesting that it is the most volatile shock. In contrast, the standard deviation of the financial shock is relatively low at 0.36.

[9]See Tables D1 and D2 in Appendix D for Zhang's (2011) estimation results for the United States.

[10]For example: for the U.S. economy, Bernanke, Gertler and Gilchrist (1999) and Bernanke and Gertler (2000) calibrate χ at 0.05; Christensen and Dib (2008) and Queijo von Heideken (2009) estimate χ at 0.04; and De Graeve (2008) estimates χ at 0.1. For the Canadian economy, Covas and Zhang (2010) estimate χ at 0.04.

[11]Since the sample period in Zhang (2011) is from 1964Q1 to 2010Q3, a portion of the differences in estimates between Canada and the United States could be the result of different sample periods. Indeed, Zhang (2011) also estimates the model for the United States for the period from 1984Q1 to 2010Q3. The estimates from this later period are closer to the Canadian counterpart, although the differences remain.

5.2 Fit of the model

Table 5 compares the standard deviations of the key variables in the model against the data. Overall, the model does a good job of matching the Canadian economy. The model performs particularly well in matching the volatility in investment, real wages and inflation. Moreover, the model is able to capture some stylized facts of the Canadian labour market: real wages are rigid, but both unemployment and vacancies are highly volatile. For financial variables, the model is able to capture 50 per cent of the relative volatility in the external finance cost fc.

Table 5: Relative Standard Deviations: Model vs. Data

	y	c	i	w	v	u	r_n	π	fc
Data	1	0.53	3.93	0.88	9.65	5.59	0.18	0.17	0.29
Baseline	1	0.72	4.28	0.84	16.02	13.25	0.29	0.19	0.16

Given that studying the Canadian labour market is the focus of this paper, I also report the correlation matrix of the key labour market variables generated by the model in Table 6. The model does very well in matching the correlation between output and unemployment: -0.84 in the model and -0.85 in the data. The model also does relatively well in matching the correlations between output and vacancies: 0.76 in the model and 0.87 in the data. Moreover, the model is able to capture the strong negative relationship between unemployment and vacancies observed in the data, although the predicted value of the correlation coefficient, -0.97, is higher than that in the data. However, the model has some difficulties in matching the correlations between wages and the other variables.

Table 6: Correlation Coefficients of the Key Labour Market Variables: Model

	y	w	v	u
y	1	-0.27	0.76	-0.84
		(0.03)	(0.87)	(-0.85)
w	-	1	-0.82	0.73
			(-0.27)	(0.03)
v	-	-	1	-0.97
				(-0.85)
u	-	-	-	1

5.3 Sources of Canadian labour market fluctuations

Zhang (2011) shows that financial shocks are the most important shocks determining the variations in unemployment and vacancies for the U.S. economy. They account for 37 per cent of the variations in these two variables. To assess the contribution of financial shocks to the variations in the key labour market variables for the Canadian economy, I conduct a similar exercise. Given the estimation results of the shock processes, I simulate the model to examine the contribution of each shock to the variations in these variables. Table 7 shows the results. The investment-specific shock appears to be the most important shock, accounting for 50 per cent of the variations in unemployment and vacancies, and 41 per cent of the variations in real wages. The financial shock is next in importance, accounting for roughly 30 per cent of the variations in unemployment and vacancies, and 29 per cent in real wages. The technology shock is in third place, explaining 14 per cent of the fluctuations in unemployment and vacancies, and 22 per cent in real wages.

Table 7: Variance Decomposition of the Key Labour Market Variables

	Technology	Monetary	Financial	Investment	Preference	Government
u	13.9	2.1	30.5	50.1	0.4	3.1
v	13.9	2.2	30.7	49.7	0.4	3.1
w	22.6	3.3	29.6	41.4	0.4	2.7
y	15.7	1.7	30.4	49.9	0.3	2.0
π	11.8	15.7	30.2	38.3	0.5	3.5

To assess the contribution of financial shocks to the overall economy, I also report the variance decomposition of output and inflation in the last two rows of Table 7. Overall, the financial shock accounts for 30 per cent of the variations in both output and inflation.

5.4 Effects of the financial accelerator mechanism on the Canadian labour market

5.4.1 *Model dynamics after a financial shock*

Estimation results show that the financial shock is the least persistent among the six shocks, and has a low standard deviation; however, variance decomposition suggests that 30 per cent of the variation in unemployment and vacancies can be accounted for by the financial shock. This implies that the financial accelerator mechanism might have played an important role in amplifying the shock. In this section, I first show the responses of the key labour market variables to the financial shock, and then I simulate the model to show how the financial accelerator mechanism amplifies the shock.

Figure 2 shows the model dynamics after a negative financial shock. After the shock, the number of vacancies declines and the unemployment rate rises. This is because a negative financial wealth shock reduces the survivor rate of entrepreneurs, leading the aggregate net worth to fall. This pushes up the external finance premium, forcing entrepreneurs to reduce their demand for capital by reducing investment. The fall in demand for capital is accompanied by a fall in demand for labour. The asset price falls with the reduced demand for capital, and this further decreases entrepreneurs' net worth (the financial accelerator effect). Employment agencies post fewer vacancies due to the fall in the aggregate demand for labour. As a result, the probability of a worker finding a job decreases and the unemployment rate rises.

5.4.2 *Financial accelerator mechanism*

Figure 3 shows how the financial accelerator mechanism amplifies the financial shock. For the purpose of illustration, I consider two cases: one is the baseline economy ($\chi = 0.19$), and the other an economy in which the financial market is less frictional ($\chi = 0.05$).

After the shock, the initial responses of net worth and leverage ratio are similar for both cases; however, given the higher value of χ, the response of the risk premium is significantly larger in the baseline economy than in the alternative economy. The risk premium rises more in the baseline model, leading to a larger decline in demand for capital. The asset price declines further, driving net worth further down. The amplification effect of the financial accelerator is more significant in the baseline economy, leading to stronger responses by the other variables to the financial shock.

This is not necessarily the case for a shock that is not from the financial sector. For example, Figure 4 shows that a negative technology shock has a similar impact on unemployment and vacancies as a negative financial shock: after the shock, unemployment rises and vacancies fall. However, rather than amplifying the effect of the shock, as is seen with a financial shock, the financial accelerator mechanism dampens the responses of the key variables. Compared to the alternative economy, in the baseline economy ($\chi = 0.19$), in which external finance costs are more elastic with respect to entrepreneurs' balance-sheet positions, unemployment rises by less and vacancies decline by less. This is because, after a negative technology shock, risk premium falls, reducing the external finance costs that firms face. With the reduced cost, the responses of firms' demand for capital and labour are dampened. The higher the χ, the more significant the dampening effect. Thus, although the technology shock is more persistent and volatile than the financial shock, its impact on unemployment and vacancies is less persistent and less significant due to the dampening effect of the financial accelerator mechanism.

6 Robustness

As suggested in Zhang (2011), for the model to capture the labour market dynamics, the following two features are essential: (i) a financial shock is included in the model and financial data are included in the estimation; and (ii) a staggered wage contract. In what follows, I examine whether this is the case for the Canadian economy.

6.1 Financial shock and financial data

In this section I re-estimate the model, but without the financial shock and without using the financial time series. Table 8 compares the results of this alternative model (the no financial shock, or NoFS, model) with the baseline model. Similar to Zhang (2011), although estimates of the behavioural parameters and the shock processes do not change much, there is a significant decline in the estimated value of the elasticity of external financing: χ falls to 0.024 from 0.19. As suggested in Zhang (2011), this significant reduction might reflect the fact that it is important to include financial time series to identify financial frictions.

Table 8: Comparison of Estimation Results: NoFS vs. Baseline

	Structural parameters			Shock process	
	NoFS	Baseline		NoFS	Baseline
χ	0.024	0.195	ρ_z	0.851	0.864
λ	0.697	0.847	ρ_e	0.539	0.497
ν	0.651	0.569	ρ_τ	0.793	0.877
ξ	0.236	0.224	ρ_g	0.684	0.602
ρ_r	0.368	0.425	ρ_γ	–	0.397
ρ_π	1.776	1.75	σ_{ϵ^z}	0.57	0.58
ρ_y	0.025	0.004	σ_{ϵ^m}	0.29	0.27
			σ_{ϵ^τ}	0.39	2.13
			σ_{ϵ^e}	1.20	1.26
			σ_{ϵ^g}	1.45	1.45
			σ_{ϵ^γ}	–	0.36

I further explore how well the NoFS model is able to account for the overall volatility in the data compared to the baseline model. Table 9 reports the results. Similar to the findings in Zhang (2011), the NoFS model matches the data poorly. In particular, the NoFS model has difficulties capturing the fact that unemployment and vacancies are highly volatile in the Canadian labour market. Without the financial shock, the technology shock becomes the most important shock: it explains around 63 per cent of the variance of unemployment and vacancies, and 86 per cent of the variance of real wages (Table 10).

Table 9: Relative Standard Deviations: Model vs. Data

	y	c	i	w	v	u	r_n	π	fc
Data	1	0.53	3.93	0.88	9.65	5.59	0.18	0.17	0.29
NoFS	1	1.33	4.17	0.81	3.24	2.54	0.21	0.22	0.11
Baseline	1	0.72	4.28	0.84	16.02	13.25	0.29	0.19	0.16

6.2 Staggered wage contracting

Zhang (2011) suggests that the interaction of the financial accelerator mechanism with wage-setting frictions is the key for the model to match the data; in this section I conduct a similar exercise. I first study a NoFS case but replace $\tilde{b}$ and η with the unconventional values used in Gertler, Sala

Table 10: Variance Decomposition for Labour Market Variables

	NoFS			Baseline		
Shocks	Unemployment	Vacancy	Real wage	Unemployment	Vacancy	Real wage
Technology	62.3	63.9	86.2	13.9	13.9	22.6
Monetary	8.7	8.8	3.4	2.1	2.2	3.3
Investment	22.4	21.5	3.8	50.1	49.7	41.4
Preference	0.5	0.5	0.6	0.4	0.4	0.4
Government	6.1	5.4	6.1	3.1	3.1	2.7
Financial	-	-	-	30.5	30.7	29.6

Table 11: Relative Standard Deviations: Model Comparison

	y	c	i	w	v	u	r_n	π	fc
Data	1	0.53	3.93	0.88	9.65	5.59	0.18	0.17	0.29
Baseline	1	0.72	4.28	0.84	16.02	13.25	0.29	0.19	0.16
NoFS	1	1.33	4.17	0.81	3.24	2.54	0.21	0.22	0.11
NoFS with high $\tilde{b}$ and η	1	0.37	4.83	0.69	17.05	13.79	0.14	0.12	0.07
Baseline w/ flexible wages	1	2.28	4.63	0.90	1.73	1.43	0.51	0.34	0.36

and Trigari (2008) ($\tilde{b} = 0.73$, and $\eta = 0.9$). I then examine a model that is essentially the baseline model, but replace staggered wage contracting with period-by-period Nash bargaining ($\lambda = 0$).

Table 11 shows that with $\tilde{b} = 0.73$, and $\eta = 0.9$, the NoFS model generates a similar variability in unemployment and vacancies as the baseline model. As suggested in Zhang (2011), these unconventional values might serve the same role in amplifying the responses in unemployment and vacancies to shocks as the financial accelerator mechanism serves in the baseline model.

The last row of Table 11 shows that, although the external finance premium stays very elastic ($\chi = 0.19$), the flexible wage case is not able to generate enough variability in unemployment and vacancies, confirming the findings of recent studies that the conventional search models cannot account for the key cyclical movements of unemployment and vacancies in the labour market.

7 Conclusions

In this paper, I employ a model from Zhang (2011), in which both labour market and financial market frictions are explicitly modelled. I estimate this model using Canadian data from 1984Q2 to 2010Q4, and use the estimated model to assess the importance of financial frictions and shocks in driving movements in the labour market. As in Zhang (2011), I find that, although the financial shock is neither persistent nor volatile, the financial accelerator mechanism amplifies this financial shock and generates large fluctuations in the labour market. Overall, around 30 per cent of the variations in unemployment and vacancies in the Canadian labour market are explained by financial shocks. I also find that ignoring financial shocks and financial data reduces the model's explanatory power. In particular, the model without these financial factors has difficulties matching the observed volatilities of unemployment and vacancies for the Canadian economy.

Despite the similarities in results between this paper and Zhang (2011),[12] this paper suggests that there is a gap between Canada and the United States in terms of the magnitude of the effects financial shocks have on unemployment and vacancies: the impact of domestic financial shocks in Canada is somewhat smaller, at 30 per cent versus 37 per cent for the United States. Indeed, this gap might even be larger if the model allows for a small open-economy structure, because financial conditions in other countries, especially the United States, are likely to contribute to the fluctuations in the Canadian labour market. If this is the case, part of the fluctuations in the labour market accounted for by the domestic financial shocks might be due to the shocks that originate in the international financial market.[13]

It would be interesting for future research to extend the current model to a small open economy and examine the impact on the Canadian labour market of shocks originating from the financial sector in the United States. Another interesting extension would be to study optimal monetary policy design, since the model in this paper features both labour and financial frictions. One possible question could be whether and how policy-makers should take into account fluctuations in financial (e.g., asset price) and labour (e.g., unemployment) markets when conducting monetary policy.

[12]This is largely because the model used in both papers is the same and the Canadian labour market has a similar volatility to that in the United States.

[13]Dib, Mendicino and Zhang (2008) estimate a DSGE model with both international and domestic financial shocks using Canadian data. They show that international financial shocks account for about 11 per cent of the fluctuations in GDP for the Canadian economy, and that other foreign shocks account for about 10 per cent.

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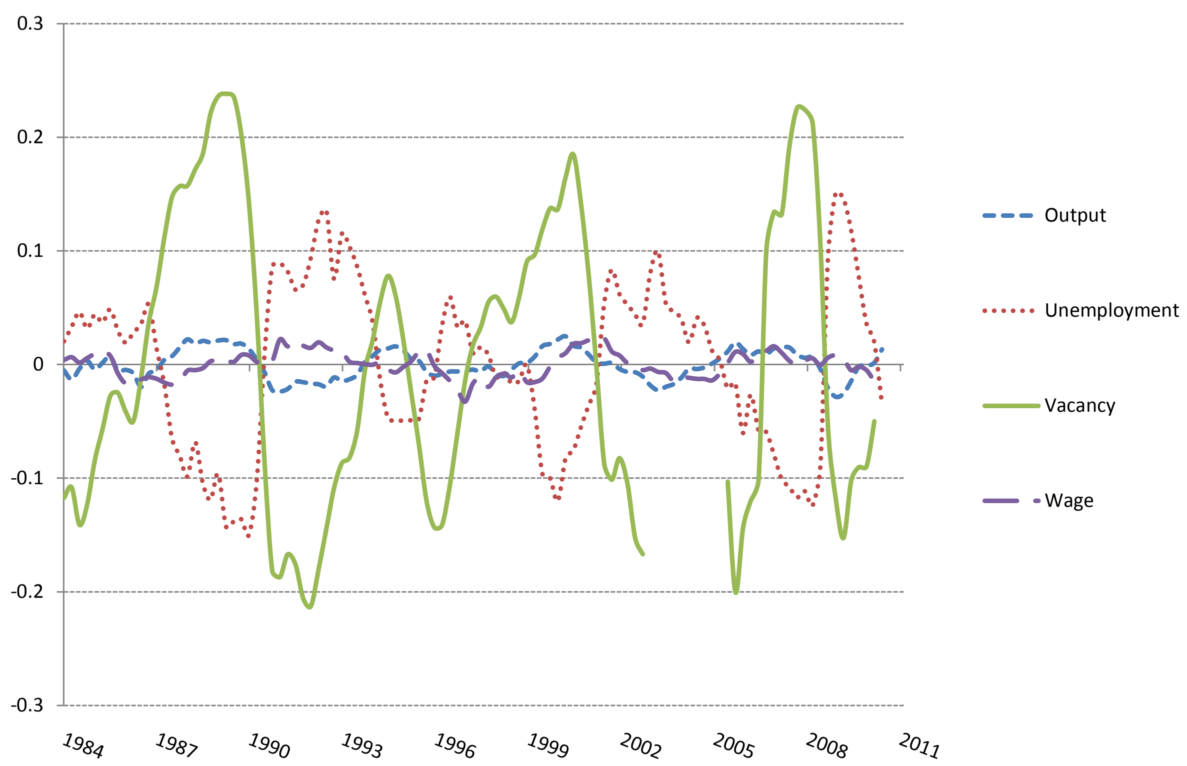

Figure 1: Comparison of Cyclical Components of Unemployment, Vacancies, Real Wages and Output, Canada, 1984–2010
Note: All the variables in Figure 1 are expressed in logs as deviations from the HP trend with the smoothing parameter set to 1600.

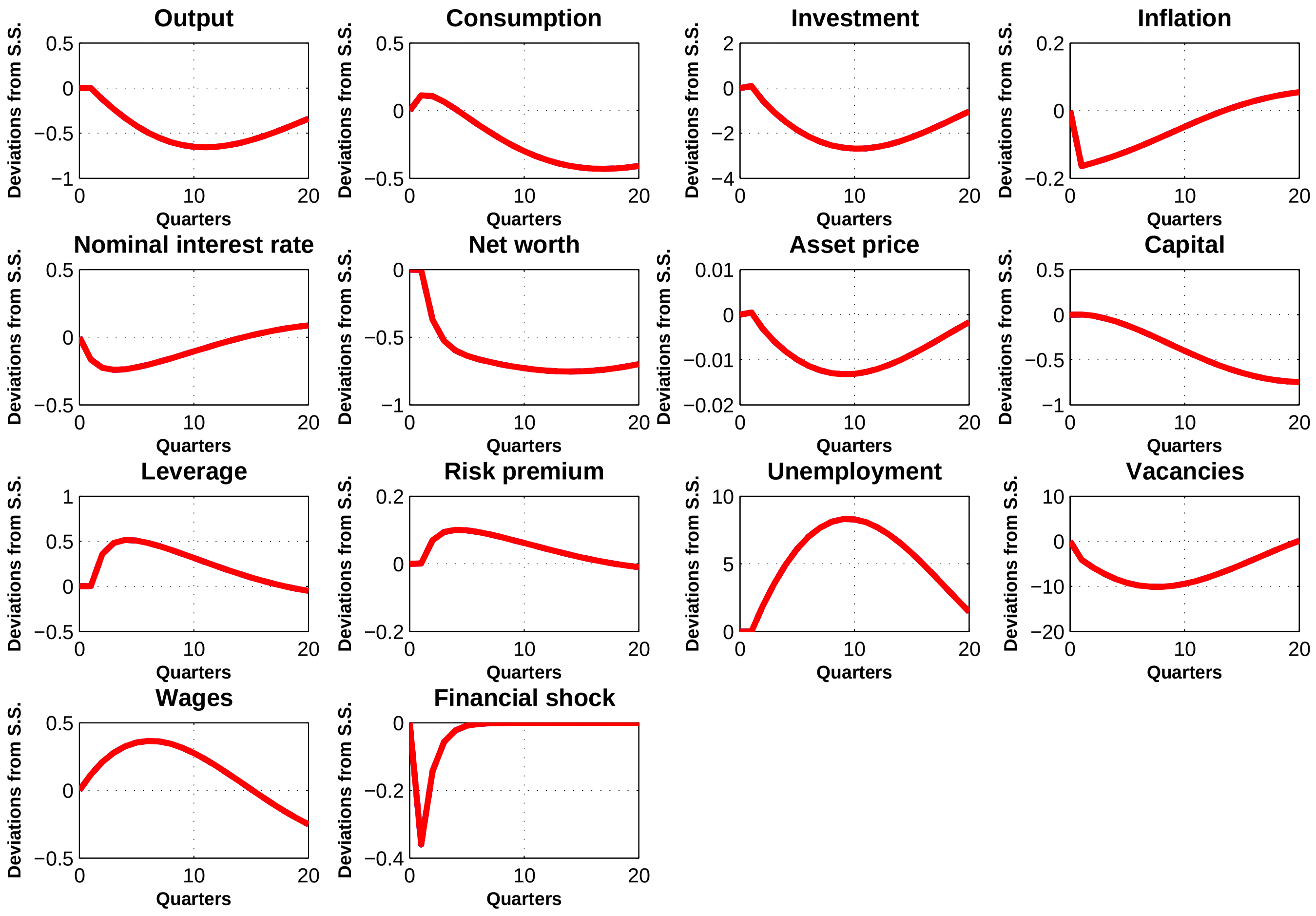

Figure 2: Effects of a Negative Financial Shock

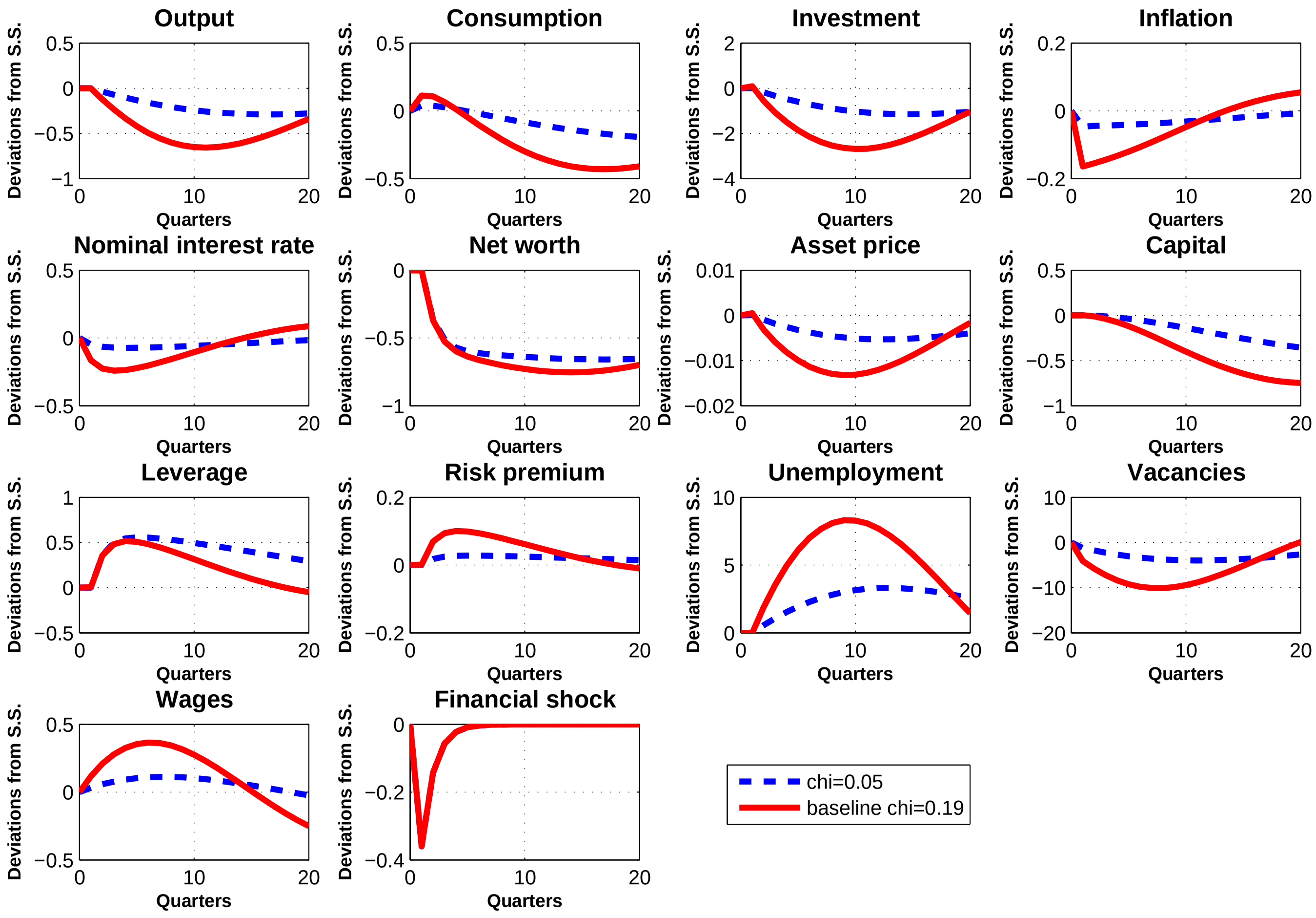

Figure 3: Effects of a Negative Financial Shock under Different Degrees of Financial Frictions

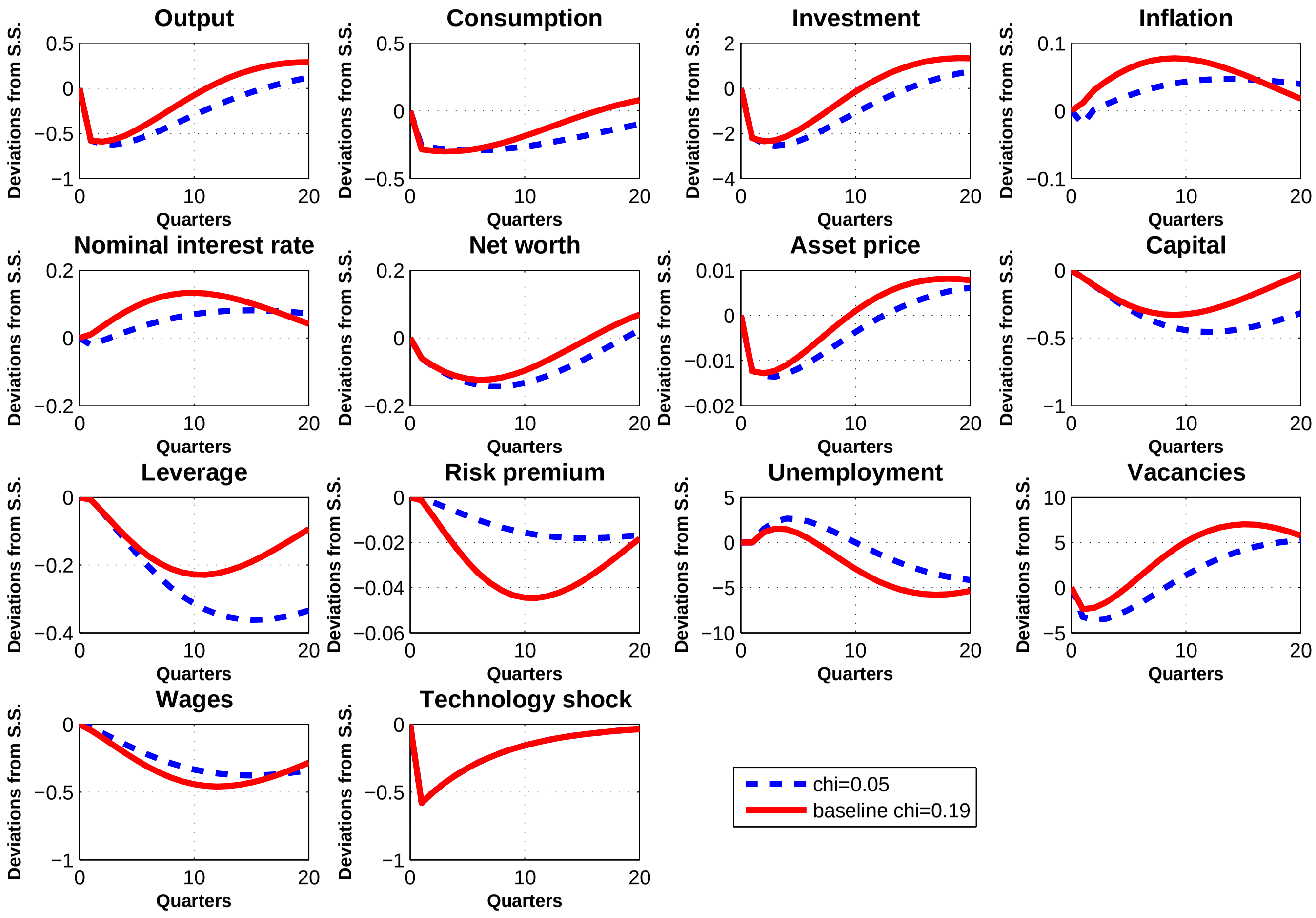

Figure 4: Effects of a Negative Technology Shock under Different Degrees of Financial Frictions

Appendix A: System of Equations

$$\frac{u'(e_t c_t)}{p_t} = \beta r_t^n \frac{u'(e_{t+1} c_{t+1})}{p_{t+1}}$$

$$E_t r_{t+1}^k = \frac{E_t[p_{t+1}^w \alpha \frac{y_{t+1}}{k_{t+1}} + q_{t+1}(1-\delta)]}{q_t}$$

$$E_t r_{t+1}^k = E_t \frac{r_t^n s_t}{1+\pi_{t+1}}$$

$$N_{t+1} = \eta^e \gamma_t [r_t^k q_{t-1} k_t - \frac{r_{t-1}^n s_{t-1}}{1+\pi_t}(q_{t-1} k_t - N_t)]$$

$$s_t = (\frac{q_t k_{t+1}}{N_{t+1}})^\chi$$

$$k_{t+1} = (1-\delta) k_t + \tau_t i_t$$

$$q_t \tau_t = 1 + \xi(\frac{i_t}{k_t} - \delta)$$

$$m_t = u_t^\sigma v_t^{1-\sigma}$$

$$n_{t+1} = \rho n_t + m_t$$

$$u_t = 1 - n_t$$

$$x_t = \frac{q_t^l v_t}{n_t}$$

$$\kappa x_t(i) = \beta E_t \Lambda_{t,t+1} [p_{t+1}^l a - \frac{w_{t+1}^n(i)}{p_{t+1}} + \frac{\kappa}{2} x_{t+1}(i)^2 + \rho \kappa x_{t+1}(i)]$$

$$w_t^{flex} = \eta(p_t^l + \frac{\kappa}{2} x_t^2 + \kappa s_{t+1}^l x_t) + (1-\eta)\bar{b}$$

$$\begin{aligned} w_t^{tar}(i) \quad &= \quad w_t^{flex} + \eta[\frac{\kappa}{2}(x_t^2(i) - x_t^2) + \kappa s_{t+1}^l (x_t(i) - x_t)] \\ &\quad +(1-\eta) s_{t+1}^l \beta \Lambda_{t,t+1} \lambda \pi \frac{p_t}{p_{t+1}} \Delta_{t+1}(w_t - w_t^*) \end{aligned}$$

$$\Delta_t w_t^* = w_t^{tar}(i) + \lambda \rho \beta E_t \Lambda_{t,t+1} \Delta_{t+1} w_{t+1}^*$$

$$\Delta_t = 1 + E_t \Lambda_{t,t+1} (\rho \lambda \beta) \frac{p_t}{p_{t+1}} \pi \Delta_{t+1}$$

$$w_t^n = (1-\lambda) w_t^{n*} + \lambda \pi w_{t-1}^n$$

$$p_t^w (1-\alpha) \frac{y_t}{l_t} = p_t^l$$

$$y_t = c_t + c_t^e + i_t + g_t + \frac{\kappa}{2} x_t^2 n_t + \frac{\xi}{2}(\frac{i_t}{k_t} - \delta)^2 k_t$$

$$y_t = z_t k_t^\alpha l_t^{1-\alpha}$$

$$p_t^* = \left(\frac{\varepsilon}{\varepsilon - 1}\right)\frac{E_t\sum_{i=0}^{\infty}\nu^i\Delta_{i,t+i}mc_{t+1}y_{t+i}(\frac{1}{p_{t+i}})^{-\varepsilon}}{E_t\sum_{i=0}^{\infty}\nu^i\Delta_{i,t+i}y_{t+i}(\frac{1}{p_{t+i}})^{1-\varepsilon}}$$

$$p_t = [\nu p_{t-1}^{1-\varepsilon} + (1-\nu)(p_t^*)^{1-\varepsilon}]^{\frac{1}{1-\varepsilon}}.$$

$$\frac{r_t^n}{r^n} = (\frac{r_{t-1}^n}{r^n})^{\rho_r}((\frac{\pi_t}{\pi})^{\rho_\pi}(\frac{y_t}{y})^{\rho_y})^{1-\rho_r}e^{\epsilon_t^m},$$

Appendix B: Log-Linearized System of Equations

$$\hat{\lambda}_t = \hat{r}_t + \hat{\lambda}_{t+1} - E_t\hat{\pi}_{t+1}$$

$$\hat{\lambda}_t = \hat{u}_c + \hat{e}_t$$

$$E_t\hat{R}_{t+1}^k = \frac{mc\alpha\frac{y}{k}}{mc\alpha\frac{y}{k} + q(1-\delta)}(m\hat{c}_{t+1} + \hat{y}_{t+1} - \hat{k}_{t+1}) + \frac{(1-\delta)}{mc\alpha\frac{y}{k} + q(1-\delta)}\hat{q}_{t+1} - \hat{q}_t$$

$$E_t\hat{R}_{t+1}^k = \hat{r}_t + \hat{s}_t - E_t\hat{\pi}_{t+1}$$

$$\hat{n}w_{t+1} = \frac{k}{N}\hat{R}_t^k - (\frac{k}{N} - 1)(\hat{r}_{t-1} + \hat{s}_{t-1} - \hat{\pi}_t) + n\hat{w}_t + \hat{\gamma}_t$$

$$\hat{s}_t = \chi(\hat{q}_t + \hat{k}_{t+1} - \hat{n}_{t+1})$$

$$\hat{k}_{t+1} = (1-\delta)\hat{k}_t + \delta\hat{\imath}_t + \delta\hat{\tau}_t$$

$$\hat{q}_t = \xi\delta(\hat{\imath}_t - \hat{k}_t) - \hat{\tau}_t$$

$$\hat{m}_t = \hat{\sigma}\hat{u}_t + (1-\sigma)\hat{v}_t$$

$$\hat{n}_t = \rho\hat{n}_t + (1-\rho)\hat{m}_t$$

$$\hat{u}_t = -\frac{n}{u}\hat{n}_t$$

$$\hat{x}_t = \hat{q}_t^l + \hat{v}_t - \hat{n}w_t$$

$$\hat{x}_t = E_t\hat{\Lambda}_{t,t+1} + (\frac{\beta}{\kappa x})(pE_t\hat{p}_{t+1}^l - wE_t\hat{w}_{t+1}) + \beta(x+\rho)E_t\hat{x}_{t+1}$$

$$\hat{w}_t^{flex} = \frac{\eta p^l}{w}\hat{p}_t^l + \frac{\eta\kappa x(x+s)}{w}\hat{x}_t + \frac{\eta\kappa xs}{w}\hat{s}_t^l$$

$$\hat{w}_t^{tar} = \hat{w}_t^{flex} + (\tau_1 + \tau_2)(\hat{w}_t - \hat{w}_t^*)$$

$$\hat{w}_t^* = (1-\rho\beta\lambda)\hat{w}_t^{flex} + \rho\beta\lambda E_t\hat{w}_{t+1}^* + (1-\rho\beta\lambda)(\tau_1 + \tau_2)(\hat{w}_t - \hat{w}_t^*) + \frac{\rho\beta\lambda}{1-\rho\beta\lambda}E_t\hat{\pi}_{t+1}$$

where $\tau_1 = \eta(x + s^l)\lambda\beta\frac{1}{1-(x+\rho)\lambda\beta}$ and $\tau_2 = (1-\eta)s^l\beta\frac{\lambda}{1-\rho\beta\lambda}$

$$\hat{w}_t = (1-\lambda)\hat{w}_t^* + \lambda(\hat{w}_{t-1} - \hat{\pi}_t)$$

$$\hat{p}_t^l = m\hat{c}_t + \hat{y}_t - \hat{l}_t$$

$$\hat{y}_t = \frac{c}{y}\hat{c}_t + \frac{i}{y}\hat{\imath}_t + \frac{g}{y}\hat{g}_t + \frac{\kappa x^2 n}{y}(\hat{x}_t + \frac{\hat{n}_t}{2})$$
$$\hat{y}_t = \hat{z}_t + \alpha\hat{k}_t + (1-\alpha)\hat{l}_t$$
$$\hat{r}^n_t = \rho_r \hat{r}^n_{t-1} + (1-\rho_r)(\rho_\pi \hat{\pi}_t + \rho_y \hat{y}_t) + \hat{\varepsilon}^r_t$$

Appendix C: Steady States

$$\pi = 1$$
$$mc = \frac{\epsilon - 1}{\epsilon}$$
$$r^n = \frac{\pi}{\beta}$$
$$r^k = \frac{1}{\eta^e}$$
$$s = \frac{r^k}{r^n/\pi}$$
$$q = 1$$
$$i = \delta k$$
$$\frac{y}{k} = \frac{r^k - (1-\delta)}{\alpha mc}$$
$$\frac{l}{k} = (\frac{y}{k})^{-(1/1-\alpha)}$$
$$\frac{y}{l} = \frac{y}{k}/\frac{l}{k}$$
$$p^l = (1-\alpha)mc\frac{y}{l}$$
$$n = \frac{s^l}{1-\rho+s^l}$$
$$u = 1-n$$
$$x = s^l u/n$$
$$x(i) = x$$
$$m = s^l u$$
$$v = \frac{m}{q^l}$$
$$\sigma^m = \frac{m}{u^\sigma v^{1-\sigma}}$$

κ and w are solved from the following two steady-state conditions:

$$\kappa x = \beta(p^l - w + \frac{\kappa}{2}x^2 + \rho\kappa x)$$

$$w = \eta(p^l + \frac{\kappa}{2}x^2 + s^l\kappa x) + (1-\eta)\bar{b}$$

where

$$\tilde{b} = \bar{b}/(p^l + \frac{\kappa}{2}x^2)$$

$$w^{flex} = w^{tar} = w^* = w$$

$$l = n$$

$$y = \frac{y}{l}l$$

$$k = l/(l/k)$$

$$N = k(N/k)$$

$$i = (i/k)k$$

$$c = y - i - (\frac{\kappa}{2})x^2 n$$

$$\lambda = 1/c$$

$$X = \frac{\lambda mcy}{1 - \nu_p\beta\pi^{\epsilon}}$$

$$Y = \frac{\lambda y}{1 - \nu_p\beta\pi^{\epsilon-1}}$$

$$p^* = (\frac{1 - \nu_p p^{\epsilon-1}}{1-\nu_p})^{1/(1-\epsilon)}$$

Appendix D: Tables from Zhang (2011)

Table D1: Prior and Posterior Distribution of Structural Parameters: United States (Zhang 2011)

		Prior distribution	Posterior distribution			
			Mode	Mean	5%	95%
Risk premium elasticity	χ	gamma (0.05,0.02)	0.230	0.240	0.203	0.288
Calvo wage parameter	λ	beta (0.67, 0.05)	0.810	0.806	0.777	0.833
Calvo price parameter	ν	beta (0.67, 0.05)	0.538	0.530	0.470	0.590
Capital adj. cost parameter	ξ	norm (0.25, 0.05)	0.217	0.216	0.144	0.292
Taylor rule inertia	ρ_r	beta (0.75, 0.1)	0.275	0.292	0.213	0.372
Taylor rule inflation	ρ_π	gamma (1.5, 0.1)	1.675	1.685	1.562	1.782
Taylor rule output gap	ρ_y	norm (0.125, 0.15)	-0.006	-0.007	-0.022	0.008

Table D2: Prior and Posterior Distribution of Shock Parameters: United States (Zhang 2011)

		Prior distribution	Posterior distribution			
			Mode	Mean	5%	95%
Panel A: Autoregressive parameters						
Technology	ρ_z	beta (0.6,0.2)	0.896	0.891	0.867	0.914
Preference	ρ_e	beta (0.6,0.2)	0.598	0.591	0.471	0.709
Investment	ρ_τ	beta (0.6,0.2)	0.834	0.813	0.741	0.882
Government	ρ_g	beta (0.6,0.2)	0.692	0.687	0.623	0.759
Financial	ρ_γ	beta (0.6,0.2)	0.242	0.270	0.095	0.444
Panel B: Standard deviations						
Technology	σ_{ϵ^z}	invg (0.005,2)	0.83	0.83	0.76	0.90
Monetary	σ_{ϵ^m}	invg (0.005,2)	0.34	0.34	0.30	0.38
Investment	σ_{ϵ^τ}	invg (0.005,2)	1.66	1.57	0.98	1.99
Preference	σ_{ϵ^e}	invg (0.005,2)	1.03	1.06	0.96	1.15
Government	σ_{ϵ^g}	invg (0.005,2)	1.02	1.02	0.95	1.11
Financial	σ_{ϵ^γ}	invg (0.005,2)	0.55	0.54	0.41	0.67