The Effects of Shocks in a Monetary Business Cycle Model with Unemployment

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Introduction

Limited-participation models generally require agents to have high labour-supply elasticities to reproduce the high variation of employment and low variation of real wages over the business cycle.[1] This assumption, however, is at odds with microeconomic evidence indicating that labour-supply elasticities for workers are usually low.[2] Many researchers have suggested that incorporating labour market frictions into this type of model may help the model account for the behaviour of wages and employment without having to rely on assumptions that are at odds with the microeconomic estimates. This paper examines whether embedding imperfectly observed effort into a standard limited-participation model can help the model reproduce the behaviour of wages and employment over the business cycle. This friction is chosen in part because of the empirical evidence in support of the shirking efficiency wage theory in the United States and Canada.[3]

1. See, for example, Christiano, Eichenbaum, and Evans (1997); Gust (1997); and Rotemberg and Woodford (1996).
2. According to studies such as MaCurdy (1981), Card (1991), and Pencavel (1986), the labour-supply elasticity of males is near zero in the United States.
3. For example, see Gera and Grenier (1994), Blanchflower and Oswald (1994), and Campbell (1989) for the Canadian evidence, and Alexopoulos (2000) and Katz (1986) for an overview of the U.S. evidence.

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The monetary business cycle model examined in this paper has three main features: (i) households make nominal savings decisions before seeing the values of the period's shocks; (ii) firms only imperfectly observe their workers' effort levels; and (iii) detected shirkers forgo a bonus. The first two features are common in limited-participation models and Shapiro-Stiglitz (1984) style shirking efficiency wage models, respectively. However, the assumption that detected shirkers forgo a bonus is a departure from the standard Shapiro-Stiglitz efficiency wage model.

Papers such as Alexopoulos (2000, 2002), Felices (2001), and Burnside, Eichenbaum, and Fisher (2000) have explored how this type of model fits the facts in the U.S. economy. This paper focuses on determining whether this model has the ability to explain the presence of involuntary unemployment and the behaviour of wages and employment in the Canadian economy.

The findings suggest that the estimated versions of the model with imperfectly observed effort generally produce smaller variations in wages alongside large variations in employment than the standard limited-participation model. Moreover, in contrast to the standard limited-participation model, the new model's ability to produce large employment variation alongside small wage variation does not depend on high levels of markups or large labour-supply elasticities. The model with partial income insurance produces lower wage variation and larger employment variation than the model with full income insurance. However, both versions of the efficiency wage model can reproduce the wage and employment variation in Canada better than the standard limited-participation model once capital adjustment costs are introduced.

In addition to being able to reproduce the wage and employment behaviour, the model's responses to technology shocks, as well as monetary and fiscal policy shocks, are qualitatively consistent with empirical evidence in the United States and Canada.[4] Following a contractionary monetary policy shock, real output, employment, consumption, investment, profits, and real wages fall, and interest rates rise. Moreover, following an expansionary fiscal policy shock, output, employment, and investment increase, while real wages, consumption, and prices fall. These qualitative responses do not depend on the nature of risk-sharing arrangements between workers. However, the amount of risk-sharing available to agents affects the magnitudes of the responses. For example, in response to a monetary policy

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4. See Christiano, Eichenbaum, and Vigfusson (2002); Ramey and Shapiro (1998); Edelberg, Eichenbaum, and Fisher (1998); Christiano, Eichenbaum, and Evans (1997, 1998); and Sims and Zha (1996) for the U.S. evidence, and papers such as Cushman and Zha (1997) and Fung and Gupta (1997) for Canadian evidence.

shock, the model with partial income insurance produces a much larger employment response and a smaller real-wage response than the model with full income insurance.

All efficiency wage models start with the premise that wages affect a worker's productivity. However, the reason for the link between wages and productivity differs across the various types of efficiency wage models. In my model, and in models following the Shapiro and Stiglitz (1984) tradition, the link between a worker's wage and a worker's productivity emerges because the firm can only imperfectly observe employee effort.[5] Therefore, when making decisions about effort, wages, and employment, firms take into account their workers' incentive-compatibility (IC) constraints. In equilibrium, firms will offer workers wages and effort levels that ensure that the workers voluntarily provide the optimal effort level.

Shirking efficiency wage models have a number of attractive features. First, they are compatible with positive levels of unemployment, since the optimal wage chosen by firms may not induce them to hire all workers in equilibrium. Second, employment fluctuations represent changes in the number of people working, as opposed to changes in the number of hours worked per person when there is equilibrium unemployment.[6] Third, employment and wages are determined by the labour-demand curve and the individuals' IC constraints when there is unemployment. Therefore, the behaviour of wages and employment does not depend on the elasticity of the labour-supply curve. Fourth, the model is consistent with evidence suggesting that the prevailing wage rate is inversely related to the level of unemployment.[7]

The model's features give rise to the possibility that introducing a shirking efficiency wage friction into a standard business cycle model may help the model reproduce the behaviour of wages and employment without relying on a high labour-supply elasticity. For example, in a simple efficiency wage model, such as the one presented in Solow (1979), firms choose to offer workers a real wage that is rigid across periods, and unemployment is involuntary. If firms want to increase the size of their workforce in this model, they can simply hire additional employees at the prevailing wage from the pool of unemployed workers. Since employment responds to market conditions while wages are unaffected, this simple model produces

5. In this environment, it is assumed that the monitoring technology is imperfect. This may occur because no perfect monitoring system exists or because the cost associated with implementing a perfect monitoring system is too high for its adoption to be profitable.

6. Lilien and Hall (1986) report that most of the variation in employment hours is accounted for by changes in the number of people employed.

7. See Blanchflower and Oswald (1994).

the same responses as a simple neo-classical model with divisible labour and individuals who have infinite labour-supply elasticity.

Encouraged by the predictions of Solow's simple efficiency wage model, papers such as Danthine and Donaldson (1995), Gomme (1999), and Kimball (1994) have examined the predictions of general-equilibrium Shapiro-Stiglitz shirking efficiency wage models. Following in the tradition of Shapiro and Stiglitz (1984), their models assume that individuals are fired if they are detected shirking on the job. In general, these authors find that their models are unable to generate high employment variation and low real-wage variability. These results are attributable to the assumption that firms fire detected shirkers.[8] Therefore, this paper incorporates imperfectly observable effort into a monetary model where individuals who are found shirking on the job forgo a portion of their possible pay for the period (i.e., a bonus or a raise), instead of being dismissed.[9]

There are two main reasons why this alternative "monetary punishment" is of interest. First, the evidence presented in Agell and Lundborg (1995), Malcomson (1998), Hall (1993), and Weiss (1990) suggests that firms more commonly rely on this type of "monetary punishment" to discipline workers than on outright dismissal. Second, if firms punish detected shirkers by withholding a bonus, firms can punish shirking workers even when there is full employment in the economy. Consequently, a model with this monetary punishment does not embed the same powerful forces leading to strongly procyclical wages and weakly procyclical employment at low levels of unemployment as do models with the traditional Shapiro and Stiglitz dismissal punishment.

In section 1, I describe the limited-participation model with imperfectly observed effort and a monetary punishment. In section 2, I outline the results for the estimated versions of the model and the empirical implications for the model's second-moment properties of wages and employment for Canada. I present the estimated model's responses to technology, monetary and fiscal policy shocks, and compare them with the existing evidence on

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8. In the model where firms fire detected shirkers at the end of the period, firms must increase the wage paid to workers as the economy moves towards full employment. This occurs because the decrease in the expected duration of unemployment causes the punishment associated with being dismissed to approach zero. This implies that the IC constraint becomes infinitely steep in the model as the unemployment rate approaches zero. Since wages are determined by the intersection of labour demand and the individual's IC constraint, changes in labour demand lead to large changes in the number of people employed and small changes in real wages at low rates of unemployment. Consequently, the model predicts that wages are highly procyclical.

9. This environment is similar to those seen in Alexopoulos (2000); Burnside, Eichenbaum, and Fisher (2000); and Felices (2001).

the economy's responses to these shocks. I then compare the results for the model with imperfectly observed effort with results obtained from a standard limited-participation model with divisible labour. Finally, I conclude and suggest areas for future research.

1 The Model

The description of the model in this section closely follows the model outlined in Alexopoulos (2002).[10] The economy has six sectors: the monetary authority, the financial intermediaries, the government, families and individuals, the final good firms, and the intermediate goods firms.

1.1 The monetary authority

Each period, the monetary authority increases the economy's money supply by transferring X_t units of money to the financial intermediaries. The growth rate of money, x_t, is defined by

$$x_t = \frac{X_t}{M_t} = \frac{M_{t+1} - M_t}{M_t},$$

where M_t is the nominal stock of money at the beginning of period t, and X_t is the amount of the monetary injection. Here, the money stock is assumed to be measured by M2, and x_t is the realization of an AR(1) process:[11]

$$x_t - \mu_x = \rho_x(x_{t-1} - \mu_x) + \varepsilon_{xt},$$

where μ_x is the mean growth rate of money, and ε_{xt} is a serially uncorrelated process with mean zero and standard deviation σ_x.[12]

1.2 Financial intermediaries

At the beginning of each period, the continuum of perfectly competitive financial intermediaries receives nominal deposits, D_t, from families to

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10. Alexopoulos (2002) explores whether a monetary shirking efficiency wage model can explain the observed behaviour of real wages and employment in the U.S. economy.
11. See Christiano, Eichenbaum, and Evans (1998) for a discussion of how a model that uses this exogenous policy is related to a model where monetary policy follows an endogenous policy such as the Taylor rule.
12. This assumption is consistent with the findings of Christiano, Eichenbaum, and Evans (1998), who indicate that x_t follows an AR(1) process if the money stock is measured by M2.

invest for the duration of the period. After D_t is deposited, the financial intermediaries receive the lump-sum monetary injection, X_t, from the monetary authority.

I assume that intermediate goods firms borrow funds from the financial intermediaries to finance their wage bill at a gross interest rate, R_t, as in the standard limited-participation model. It follows that the economy's loan-market clearing condition is:

$$L_t = D_t + X_t, \tag{1}$$

where L_t is the total amount of funds demanded by firms in time period t, and $D_t + X_t$ is the supply of loans available. At the end of each period, the intermediate goods firms repay their loans with interest, and the financial intermediaries distribute $R_t + D_t$ to the households in return for their deposits and $R_t + X_t$ in the form of profits.

1.3 The government

Each period, the government purchases G_t units of the final good. The government finances its purchases by levying lump-sum taxes on families. This implies that the government's period t budget constraint is:

$$G_t \leq Tax_t,$$

where Tax_t is the amount of lump-sum taxes collected. Since all families are identical in the model, each family is assumed to pay the same amount of taxes.

1.4 Families and individuals

In models with unemployment, when individuals' incomes are not fully insured, their incomes are heterogeneous. If an agent can transfer wealth across time periods, his savings decision then becomes dependent on his entire work history. To isolate the role of the imperfect observability of effort and to facilitate a comparison of my model to the standard limited-participation model, I make assumptions that guarantee that the workers' problems will be homogeneous. Specifically, I assume that workers belong to families.[13]

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13. Past research has presented two other approaches that ensure that agents' problems are homogeneous. The first method fully insures workers' incomes against unemployment. The second method introduces entrepreneurs into the model. In this case, it is assumed that entrepreneurs are allowed to save and accumulate capital, but workers are not. Versions of my shirking limited-participation model that use these different structures do not yield significantly different results from the model with the family structure.

The economy is populated by a large number of families, each of which contains a [0,1]-continuum of infinitely lived individuals. Individuals do not directly own assets in this model. Instead, it is assumed that each individual's family owns an equal portion of the capital stock, as well as equal shares in the intermediate goods firms and the financial intermediaries. The funds a family receives from its assets are used to pay taxes, invest in capital goods, and purchase some consumption goods for family members.

1.4.1 A representative family

Each period, the family chooses how much to invest in capital, I_t, how much family consumption to purchase, c_t^f, how much cash to deposit in financial intermediaries, D_t, and how much money to carry into the next period, M_{t+1}. Consistent with the limited-participation constraint, the family chooses the level of nominal deposits before the values of the period's shocks are revealed.

After the shocks are revealed, the family pays taxes, Tax_t, and purchases I_t and c_t^f, using their beginning-of-period money holdings, M_t/P_t, and their return on capital, $r_t K_t$. Since profits and the return on deposits are distributed to the family at the end of the period, these funds are unavailable for purchasing period t goods. This implies that the family's cash-in-advance constraint and money holdings are given by:

$$P_t c_t^f \leq M_t - D_t - P_t Tax_t + P_t r_t K_t - P_t I_t, \tag{2}$$

$$\begin{aligned} M_{t+1} = & \left[M_t - D_t - P_t c_t^f - P_t Tax_t + P_t r_t K_t - P_t I_t\right] \\ & + R_t[D_t + X_t] + PR_t. \end{aligned} \tag{3}$$

Here, PR_t and $R_t X_t$ denote the profits from intermediate goods firms and financial intermediaries in period t, respectively. Since the family distributes c_t^f among the members before firms hire employees, each family member is provided with an equal amount.

As in the standard limited-participation model, it is assumed that the family faces adjustment costs whenever they alter their stock of capital or their flow of funds to the goods market. These adjustment costs are similar to those used in Christiano and Eichenbaum (1992a) and Christiano and Fisher (1998), and cause the effects of monetary policy shocks to be persistent. In particular, it is assumed that each individual spends a portion of his or her leisure time reorganizing the family's purchases, if the flow of funds to the goods market changes. Moreover, the capital-adjustment costs imply that the end-of-period capital stock, K_{t+1}, is determined by the following technology:

$$K_{t+1} = \left[\gamma_1 I_t^{\upsilon} + \gamma_2 K_t^{\upsilon}\right]^{\frac{1}{\upsilon}}. \tag{4}$$

Here, I_t is the amount of period t investment, $\upsilon \leq 1$ determines the cost of adjusting the capital stock, and γ_1 and γ_2 are positive constants. Similar to the adjustment costs in Christiano and Fisher (1998), γ_1 and γ_2 are chosen so that the steady-state values of the rental rate of capital and investment are invariant to the level of υ. This implies:

$$\gamma_1 = \delta^{1-\upsilon} \text{ and } \gamma_2 = (1-\delta),$$

where δ is the depreciation rate of capital. When $\upsilon = 1$, equation (4) reduces to the conventional linear capital-accumulation equation.

1.4.2 Family members

Although individual family members do not have direct access to financial or capital markets, they receive some consumption that is financed by their family's return on financial and capital investments through c_t^f. Family members can increase their consumption levels above c_t^f by seeking employment from the intermediate goods firms. All intermediate goods firms are assumed to have identical production technology. As a result, all firms will offer workers the same wage and require the same level of effort. Since effort is imperfectly observed by the firms, if a worker is hired, that worker must decide whether to provide the level of effort specified in the contract.

Each worker who is hired by an intermediate goods firm receives a one-period contract. This contract specifies the real-wage rate the worker can earn, w_t, the number of hours an employee must work, f, and the effort level the firm requires from the worker, e_t.[14] All workers receive a fraction, s, of their wage bill up front. However, the final payment of $(1-s)w_t f$ is paid only to workers not disciplined for shirking. Workers all know that if they shirk, firms will detect them with probability $d < 1$.

In addition to the level of c_t^f provided by the family, unemployed family members can purchase extra consumption using the transfer they receive

14. To reduce the amount of notation, the subscript that identifies the different firms is omitted here, since all firms are identical and will choose the same values.

from their family's employment insurance fund, provided that they do not reject a job offer. To finance this family-run insurance program, each employed family member is required to transfer a lump sum, F_t, to their family's employment insurance fund. The total amount collected is then distributed among the unemployed family members during the period. The existence of the employment insurance ensures that individuals who are unemployed will not suffer a large drop in consumption. In this paper, I examine two different risk-sharing arrangements, partial income insurance and full income insurance, to determine the sensitivity of my results to the amount of insurance provided to individuals.

1.4.3 The worker's problem

Employed workers' consumption levels are determined by the level of their family's consumption benefits, c_t^f, and their after-transfer wage income, $w_t - F_t$, while the consumption of the unemployed workers is determined by the level of their families' consumption benefits, c_t^f, and their transfer from the family insurance fund. This implies that c_t, the consumption of non-shirking workers and shirkers who are not detected, c_t^s, the consumption of the detected shirkers, and c_t^u, the consumption of the unemployed are:

$$c_t = c_t^f + w_t f - F_t, \tag{5}$$

$$c_t^s = c_t^f + s w_t f - F_t, \tag{6}$$

$$c_t^u = \begin{cases} c_t^f + \dfrac{N_t}{1 - N_t} F_t & \text{if the individual had no job offer,} \\ c_t^f & \text{if the individual rejects a job offer,} \end{cases} \tag{7}$$

where N_t represents the total number of family members employed in period t. Individuals' utility levels are then described by the function:

$$u(\tilde{c}_t, \hat{e}_t) = \ln(\tilde{c}_t) + \theta \ln(T - \vartheta(\hat{e}_t > 0)(f\hat{e}_t + \xi)) - \theta \ln(1 + H(Q_t, Q_{t-1})), \tag{8}$$

where $\tilde{c}_t$ is the realized value of the individual's consumption, $\hat{e}_t$ is the level of effort provided to an employer, T is the individual's time endowment, ξ is the disutility associated with providing any effort, and $\vartheta(\cdot)$ is an indicator function that equals 1 when $\hat{e}_t > 0$, and equals 0 otherwise.[15] The term $-\theta\ln(1 + H(\cdot,\cdot))$ reflects the assumption that each individual spends a portion of his leisure time,

$$\frac{H(\cdot,\cdot)}{1 + H(\cdot,\cdot)},$$

involved in reorganizing the household's flow of funds to the goods market. This assumption guarantees that unemployed family members will spend more time reorganizing the flow of funds to the goods market than their working counterparts in equilibrium. Here, it is assumed that:

$$H(Q_t, Q_{t-1}) = a_0\left\{\exp\left[a_1\left(\frac{Q_t}{Q_{t-1}} - 1 - x^s\right)\right] + \exp\left[-a_1\left(\frac{Q_t}{Q_{t-1}} - 1 - x^s\right)\right] - 2\right\},$$

where $Q_t = M_t - D_t$. (9)

Therefore, when there are no changes in the flow of funds to the goods market, no adjustment costs are incurred.

After the shocks are realized, all family members attempt to find employment. In the case where firms set wages above the market-clearing level, only a portion of the workers will receive offers of employment and there will be unemployment in equilibrium. Family members who are offered jobs must determine: (i) if they will accept the job; and (ii) whether they will abide by the terms of the contract. Since workers who reject job offers are ineligible for the employment insurance transfer, workers will always accept job offers in this economy. Moreover, the level of effort supplied by a worker is:

$$\hat{e}_t = \begin{cases} e_t \text{ if } e_t \le \frac{T}{f}\left(1 - \left(\frac{c_t}{c_t^s}\right)^{-\frac{d}{\theta}}\right) - \frac{\xi}{f} \\ 0 \text{ if } e_t \ge \frac{T}{f}\left(1 - \left(\frac{c_t}{c_t^s}\right)^{-\frac{d}{\theta}}\right) - \frac{\xi}{f} \end{cases}.$$

15. Since firms do not perfectly observe effort, they also do not observe whether individuals incur the cost ξ.

Therefore, an individual will provide the required effort if his IC constraint is satisfied, i.e., if

$$u(c_t, e_t) \geq du(c_t^s, 0) + (1-d)u(c_t, 0) \ (IC) .$$

1.4.4 The family's problem

Each period, firms hire N_t family members. Of these workers, N_t^s are shirkers who exert no effort on the job, and $N_t - N_t^s$ are non-shirkers who each exert an effort level of $\hat{e}_t$. Given the utility function of each of the family members, the form of the adjustment costs, and the definitions of c_t, c_t^s, and c_t^u, the family's problem can be expressed as:

$$\max_{\{c_t^f, K_{t+1}, M_{t+1}, D_t\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \begin{array}{l} (N_t - dN_t^s)\ln(c_t) + dN_t^s \ln(c_t^s) + (1-N_t)\ln(c_t^u) \\ + (N_t - N_t^s)\theta \ln(T - f\hat{e}_t - \xi) + (1 - (N_t - N_t^s))\theta \ln(T) \\ - \theta \ln(1 + H(Q_t, Q_{t-1})) \end{array} \right\}$$

subject to equations (2) through (4), where:

$$F_t = \left\{ \begin{array}{c} (1-N_t)sw_t f \text{ under partial income insurance} \\ (1-N_t)w_t f \text{ under full income insurance} \end{array} \right. .$$

In equilibrium, the cash-in-advance constraint holds with equality and firms offer workers wages that induce no one to shirk (i.e., $N_t^s = 0$). Therefore, the family's Euler equations for deposits and capital can be written as:[16]

$$E_{t-1} \left\{ \begin{array}{l} \left(\dfrac{U_{c_t^f}}{P_t}\right) - \theta \dfrac{H_1(Q_t, Q_{t-1})}{1 + H(Q_t, Q_{t-1})} - \beta\theta \dfrac{H_2(Q_{t+1}, Q_t)}{1 + H(Q_{t+1}, Q_t)} \\ -\beta R_t \left[\left(\dfrac{U_{c_{t+1}^f}}{P_{t+1}}\right) - \theta \dfrac{H_1(Q_{t+1}, Q_t)}{1 + H(Q_{t+1}, Q_t)} - \beta\theta \dfrac{H_2(Q_{t+2}, Q_{t+1})}{1 + H(Q_{t+2}, Q_{t+1})} \right] \end{array} \right\} = 0$$

and

16. It is assumed that families do not believe that their choices can affect the employment probability of their members. This assumption is made for simplicity. See Alexopoulos (2001) for a more complex model that yields the same allocations.

$$E_t\left\{U_{c_t^f}\frac{\partial I_t}{\partial K_{t+1}} - \beta U_{c_{t+1}^f}\left(r_{t+1} - \frac{\partial I_{t+1}}{\partial K_{t+1}}\right)\right\} = 0,$$

where

$$U_{c_t^f} = \frac{N_t}{c_t} + \frac{1-N_t}{c_t^u}$$

$$H_1(Q_t, Q_{t-1}) = \frac{a_0 a_1}{Q_{t-1}}\left\{\begin{array}{c} \exp\left[a_1\left(\frac{Q_t}{Q_{t-1}} - 1 - x^s\right)\right] \\ -\exp\left[-a_1\left(\frac{Q_t}{Q_{t-1}}\right) - 1 - x^s\right] \end{array}\right\}$$

$$H_2(Q_t, Q_{t-1}) = -H_1(Q_t, Q_{t-1})\frac{Q_t}{Q_{t-1}}$$

$$\frac{\partial I}{\partial K_{t+1}} = \delta^{\frac{\upsilon-1}{\upsilon}}(K_{t+1}^{\upsilon} - (1-\delta)K_t^{\upsilon})^{\frac{1}{\upsilon}-1}K_{t+1}^{\upsilon-1}$$

$$\frac{\partial I_{t+1}}{\partial K_{t+1}} = \delta^{\frac{\upsilon-1}{\upsilon}}(K_{t+2}^{\upsilon} - (1-\delta)K_{t+1}^{\upsilon})^{\frac{1}{\upsilon}-1}(\delta-1)K_{t+1}^{\upsilon-1}.$$

1.5 Final good firms

In the economy, the final good, Y_t, is produced and sold to agents by perfectly competitive final good firms. These firms produce Y_t by combining the output of the continuum of intermediate firms according to the following production function:

$$Y_t = \left[\int_0^1 Y_{it}^{\frac{1}{\mu}}\,di\right]^{\mu}.$$

Here, Y_{it} represents the input from the i^{th} intermediate firm in period t, and $1 \le \mu < \infty$ is a measure of substitutability between inputs. This implies that a representative final good firm faces the following problem in period t:

$$\max_{Y_t,\, \{Y_{it}\}_0^1} P_t Y_t - \int_0^1 P_{it} Y_{it}\, di \text{ s.t. } Y_t = \left[\int_0^1 Y_{it}^{\frac{1}{\mu}}\, di\right]^{\mu},$$

where P_t is the price of the final good, and P_{it} is the price of the i^{th} intermediate good at time t. The Euler equations from this problem define the demand functions for the output of the intermediate goods firm:

$$Y_{it} = Y_t \left(\frac{P_{it}}{P_t}\right)^{\frac{\mu}{1-\mu}}.$$

This implies that the demand for firm i's product is increasing in the level of aggregate output, Y_t, and decreasing in the price of its intermediate good, P_{it}. From the demand equations and the zero-profit condition, it follows that the price of the final good is:

$$P_t = \left[\int_0^1 P_{it}^{\frac{1}{1-\mu}}\, di\right]^{(1-\mu)}.$$

1.6 Intermediate goods firms

The intermediate goods are produced by a [0,1]-continuum of monopolistic competitors, where the i^{th} intermediate good is produced according to the following production function:[17]

$$Y_{it} = A_t K_{it}^{\alpha}((N_{it} - N_{it}^{s}) f \hat{e}_{it})^{1-\alpha}.$$

Here, $0 < \alpha < 1$, N_{it}, N_{it}^{s}, and K_{it} denote the number of workers hired, the number of shirkers hired, and the amount of capital rented in period t by firm i, respectively, and A_t is the level of technology, where $\ln A_t = (1-\rho_A)\ln A + p_A \ln A_{t-1} + \varepsilon_{A,t}, -1 < \rho_A < 1$, and $\varepsilon_{A,t}$ is a serially uncorrelated process with mean zero and standard deviation σ_A. This function implies that a firm must receive a positive level of effective labour from its workers for production to occur. Each labourer hired by a firm works a fixed shift, f, and provides an effective labour unit input of $f\hat{e}_{it}$, provided the worker does not shirk. The firms rent capital in a perfectly competitive factor market after the values of the shocks are realized, and entry and exit into the production of intermediate good i are ruled out.

17. This form of the production function takes into account that non-shirking workers will provide an effort level of $\hat{e}_{it}$, while shirking workers provide zero effort.

After the shocks are observed, firms publicly advertise how many workers they want to hire, as well as the wage they are willing to pay hired workers and the required effort level from each worker. According to the contract, workers know that they are guaranteed a base salary of $sw_{it}f$ if they accept employment.[18] Furthermore, they know that they will receive an additional payment of $(1-s)w_{it}f$ if they are not detected shirking on the job, and detected shirkers are detected with probability $d < 1$.[19, 20]

Once the employees are hired, each firm borrows its nominal-wage bill, $P_t w_{it} f N_{it} = W_{it} f N_{it}$, from the bank at the gross interest rate, R_t. Although the firm possesses the funds to pay its entire wage bill before the workers begin production, the firm chooses to withhold a fraction, $(1-s)$, of the funds. This shows the firm's intention to pay the workers while making the punishment for shirking credible.

After production takes place, the output is sold to the final good firms. The firms then pay households for the rental of capital and repay their bank loans with interest. Any remaining funds are then distributed in the form of profits to the families at the end of the period.

A representative intermediate goods firm, hiring identical workers, faces the following problem in period t:

$$\max_{\{P_{it}, w_{it}, N_{it}, K_{it}, e_{it}\}} \{P_{it}(A_t K_{it}^{\alpha}(f e_{it} N_{it})^{1-\alpha}) - R_t P_t w_{it} f N_{it} - P_t r_t K_{it}\},$$

subject to the period-by-period demand functions:

$$P_{it}^{\frac{\mu}{\mu-1}}(A_t K_{it}^{\alpha}(f e_{it} N_{it})^{1-\alpha}) - P_t^{\frac{\mu}{\mu-1}} Y_t = 0,$$

18. In this model, s is assumed to be an exogenous parameter. However, the model delivers the same results as a model where: (i) there is a restriction on the minimum value of s, (e.g., a legal restriction or an industry norm); and (ii) s is chosen endogenously by firms. Since firms in this case would set s to its lowest possible level, the exogenous parameter s in the model presented in the paper can be considered this minimum value.
19. In this case, $[1-s]w_{it}$ can be interpreted as a bonus that is paid only to non-disciplined workers.
20. Firms are assumed to never "cheat" by withholding a bonus from a non-shirking worker. This assumption is made for simplicity. The results in this paper are unaffected if the model instead assumes: (i) there are continuing matches between workers and firms that break up with an exogenous probability; (ii) firms get a reputation as bad employers if they do not pay the bonus to non-detected shirkers; (iii) workers will not provide effort to bad employers because they believe that bad employers will fail to provide them with their bonus; and (iv) there are reasonable levels of markups in the economy.

and the period-by-period IC constraints and individual rationality (IR) constraints:

$$u(c_{it}, e_{it}) \geq du(c_{it}^{s}, 0) + (1-d)u(c_{it}, 0) \text{ (IC)},$$

$$u(c_{it}, e_{it}) \geq u(c_{t}^{u}, 0) \text{ (IR)}.$$

Here, $u(\cdot,\cdot)$ denotes the representative worker's utility for the period, e_{it} is the effort level specified in the contract, and c_{it}, c_{it}^{s}, and c_{t}^{u} are the levels of consumption for a non-disciplined worker, a detected shirker, and an unemployed individual, respectively. Furthermore, w_{it} denotes the real-wage rate offered by the firm, and r_t is the real rate of return on capital.

The IC constraint defines the relationship between effort and wages, since the form of the family's employment insurance implies that the IR constraint does not bind in equilibrium. Using the definitions of c_{it} and c_{it}^{s} in equilibrium (i.e., equations (5) and (6)), the IC constraint implies that effort is a function of the real wage, the price level, and the intrafamily transfers:

$$e_{it}(w_{it}) = \frac{T}{f}\left(1 - \left(\frac{c_{it}}{c_{it}^{s}}\right)^{-\frac{d}{\theta}}\right) - \frac{\xi}{f}.$$

The Euler equations from the firm's problem imply:

$$\frac{e'_{it}(w_{it})w_{it}}{e_{it}(w_{it})} = 1 \text{ (the Solow condition)}$$

$$\frac{Y_{it}}{N_{it}}\frac{(1-\alpha)}{\mu} = \frac{P_t}{P_{it}} f w_{it} R_t$$

$$\frac{Y_{it}}{K_{it}}\frac{\alpha}{\mu} = \frac{P_t}{P_{it}} r_t$$

$$P_{it}^{\frac{-\mu}{1-\mu}} Y_{it} = P_{t}^{\frac{-\mu}{1-\mu}} Y_t.$$

The Solow condition demonstrates that the firm's choices will minimize the cost per unit of effort. Given the individuals' utility function, the Solow condition implies that, in equilibrium, wages will be chosen by firms to ensure that:

$$\frac{c_{it}}{c_{it}^s} = const \Rightarrow e_{it} = \frac{T}{f}\left(1-(const)^{-\frac{d}{\theta}}\right) - \frac{\xi}{f} = e.$$

Since all of the intermediate goods firms have identical technologies and all workers are identical, all firms choose to offer the same wages and required effort levels to workers. The Euler equations also imply that the firm chooses to set its time t price equal to a constant markup over the period's marginal costs:

$$P_{it} = \mu MC_{it}.$$

Finally, the equilibrium demand for funds can be expressed as:

$$L_t = \int_0^1 W_{it} f N_{it} di,$$

since firms borrow funds from the financial intermediaries to finance their wage bills, $L_t = D_t + X_t$, and no one shirks in equilibrium.

2 The Empirical Results

To estimate the model, growth is introduced by adding an exogenous labour-augmenting technology to the production function as follows:

$$Y_{it} = A_t K_{it}^{\alpha}(\gamma^t N_{it} f \hat{e}_{it})^{1-\alpha},$$

where $\gamma \geq 1$. In addition, government expenditures are assumed to evolve according to $G_t = \gamma^t \exp(g_t)$, where $g_t = (1-\rho_g)\mu_g + \rho_g g_{t-1} + \varepsilon_{g,t}, -1 < \rho_g < 1$, and $\varepsilon_{g,t}$ is a serially uncorrelated process with mean zero and standard deviation σ_g.[21]

To diagnose the performance of the model, I use a generalized method of moments (GMM) procedure similar to the one described in Christiano and Eichenbaum (1992b). The Canadian data are obtained from the OECD quarterly national accounts, the OECD International Sectoral Database, and Statistics Canada.[22]

21. When the process for g_t is estimated, I also include a term, $\tau_g \times t$, to capture the time trend seen in the post-war data.

22. A detailed description of the data is found in Appendix 1, followed by an outline of the exactly identified GMM procedure, based on the Euler equations from the model with technological growth, in Appendix 2.

After the parameters and second moments are estimated, the model is tested by: (i) comparing the estimated second moments from the data to those computed from the model using a Wald test; and (ii) determining whether the model's predictions about how the economy responds to shocks are qualitatively consistent with the empirical evidence.[23, 24]

Not all of the model's parameters are estimated using the Euler equations. The values for $\beta, T, f, \xi, \theta, \upsilon, a_1$, and a_2, are chosen to coincide with values commonly seen in the literature:[25]

β	T	f	ξ	θ	υ	a_1	a_2
$\left(\frac{1}{1.03}\right)^{0.25}$	1,369	1	16	1.5	1	2	2

An additional assumption about the ratio $\frac{c_t}{c_t^s}$ is made to help identify the ratio $\frac{d}{\theta}$, and the parameter s, in the IC constraint. Here, this ratio is assumed to be equal to 1.0526. This value is chosen to ensure that, given the estimated value of $\frac{d}{\theta}$, the percentage of compensation that is given as bonus is approximately 5 per cent.[26] The GMM procedure and the data are used to estimate the remaining parameters:

23. This Wald test formally explores the hypothesis that the two sets of estimates are the same in population and is discussed in detail in Christiano and Eichenbaum (1992b).
24. Only single hypotheses are tested given the problems associated with small sample properties of GMM-based Wald statistics. See Burnside and Eichenbaum (1996b) for a discussion of these problems.
25. Since f only affects the scale of effort, it is normalized to 1, T is chosen to coincide with a time endowment of 15 hours per day per quarter, ξ represents a fixed cost of 10 minutes a day, $\upsilon = 1$ implies there are no capital-adjustment costs, a_1 and a_2 are set equal to the values in Christiano, Eichenbaum, and Evans (1997), and θ and β are chosen so that they fall in the range commonly seen in the literature. The main findings are robust to small changes in the parameters $\xi, \theta, \upsilon, a_1$, and a_2.
26. The model's sensitivity was assessed by varying the value of $\frac{c_t}{c_t^s}$, since this value is never observed in equilibrium. In general, the findings indicate that small movements in $\frac{c_t}{c_t^s}$ have little effect on the model's second moments and responses to shocks. The value of (1 – s) is consistent with values reported for average bonus in surveys such as ICSA (2001), which included Canadian companies.

$$\left\{\frac{d}{\theta}, \delta, \tau_g, \mu_g, \rho_g, \sigma_g, \ln(A), \rho_A, \sigma_A, A_y, \ln(\gamma), \alpha, \ln\left(\frac{g}{y}\right), \mu_x, \mu, \rho_x, \sigma_x\right\},$$

in the model, along with the second moments,

$$\left\{\frac{\sigma_c}{\sigma_y}, \frac{\sigma_i}{\sigma_y}, \frac{\sigma_g}{\sigma_y}, \sigma_w, \sigma_n, \sigma_y\right\},$$

for the detrended data.[27] The resulting parameter estimates for each case of the limited-participation model with imperfectly observed effort (herein referred to as the efficiency wage model) are reported in Tables 1 through 3 alongside estimates for a standard limited-participation model with divisible labour for the cases where there are adjustment costs on capital.[28] An examination of these estimates reveals that the majority of the predicted values are similar to those commonly seen in the literature.[29] The one exception is found in the standard limited-participation model when $\upsilon = 0.8$. For this case, the value of the markup and the estimate of α are outside the range usually seen in the literature. However, the finding that a large markup helps the standard model reproduce the wage and employment behaviour in the United States is discussed in Christiano, Eichenbaum, and Evans (1998).

The estimated parameters for the efficiency wage models are virtually identical to those in the limited-participation model, with the exception of the values for θ and $\frac{d}{\theta}$.[30] Thus, the differences between the models'

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27. A_y is estimated using the condition: $E(\ln(Y_t) - A_y - t \times \ln(\gamma)) = 0$, and $\frac{g}{y}$ is estimated using the condition: $E\left(\ln(G_t) - \ln(Y_t) - \ln\left(\frac{g}{y}\right)\right) = 0$.

The data for the second moments are detrended using a Hodrick and Prescott (HP) filter with $\lambda = 1{,}600$.

28. The standard limited-participation model with divisible labour is based on Christiano, Eichenbaum, and Evans (1997). See Appendix 3 for details.

29. For example, the estimated markup for the efficiency wage model, μ, is similar to the value of 1.2 reported by Hornstein (1993) and lower than the value assumed in models such as Chistiano, Eichenbaum, and Evans (1997) (i.e., $\mu = 1.4$). In addition, the value of α falls within the range [0.25,0.43] reported in Greenwood, Rogerson, and Wright (1995).

30. For the limited-participation model, the following parameters are estimated:

$$\left\{\theta, \delta, \tau_g, \mu_g, \rho_g, \sigma_g, \ln(A), \rho_A, \sigma_A, A_y, \ln(\gamma_y), \alpha, \ln\left(\frac{g}{y}\right), \mu_x, \mu, \rho_x, \sigma_x\right\},$$

where θ is the coefficient on leisure in the individual's utility function.

Table 1
Parameter estimates for the models

	$v = 1$		
Parameter	**Estimates Efficiency wage model**		**Estimates Standard limited-participation model**
	(P.I.I. Case)	**(F.I.I. Case)**	
μ	1.2342 (0.0842)	1.2690 (0.0164)	1.2964 (0.0825)
$\ln A$	0.0534 (0.0148)	0.0500 (0.0106)	0.0025 (0.0106)
ρ_A	0.9264 (0.0153)	0.9268 (0.0147)	0.9272 (0.0148)
σ_A	0.0078 (0.0006)	0.0078 (0.0005)	0.0077 (0.0006)
A_y	0.0869 (0.0143)	0.0869 (0.0143)	0.0869 (0.0143)
$\ln(\gamma)$	0.0026 (0.0001)	0.0026 (0.0001)	0.0026 (0.0001)
δ	0.0151 (0.0008)	0.0151 (0.0008)	0.0151 (0.0008)
α	0.3272 (0.0460)	0.3082 (0.0101)	0.2933 (0.0449)
$\ln\left(\frac{g}{y}\right)$	1.4575 (0.0084)	1.4575 (0.0084)	1.4575 (0.0084)
$\frac{d}{\theta}$	0.2338 (0.0160)	0.2393 (0.0047)	n/a
θ	n/a	n/a	1.6060 (0.0922)
ρ_g	0.9717 (0.0148)	0.9717 (0.0148)	0.9717 (0.0148)
τ_g	0.0003 (0.0002)	0.0003 (0.0002)	0.0003 (0.0002)
σ_g	0.0136 (0.0011)	0.0136 (0.0011)	0.0136 (0.0011)
μ_g	1.5219 (0.0279)	1.5219 (0.0279)	1.5219 (0.0279)
ρ_x	0.5529 (0.1121)	0.5529 (0.1121)	0.5529 (0.0761)
μ_x	0.0240 (0.0026)	0.0240 (0.0026)	0.0240 (0.0026)
σ_x	0.0131 (0.0023)	0.0131 (0.0023)	0.0131 (0.0023)

Notes: Standard errors in parentheses.
P.I.I. = partial income insurance; F.I.I. = full income insurance.

Table 2
Parameter estimates for the models

	$v = 0.9$		
Parameter	**Estimates Efficiency wage model**		**Estimates Standard limited-participation model**
	(P.I.I. Case)	**(F.I.I. Case)**	
μ	1.2524 (0.0915)	1.2699 (0.0487)	1.2716 (0.0825)
$\ln A$	0.0516 (0.0164)	0.0499 (0.0118)	0.0007 (0.0053)
ρ_A	0.9266 (0.0154)	0.9268 (0.0147)	0.9269 (0.0147)
σ_A	0.0078 (0.0006)	0.0078 (0.0006)	0.0078 (0.0006)
A_y	0.0869 (0.0143)	0.0869 (0.0143)	0.0869 (0.0143)
$\ln(\gamma)$	0.0026 (0.0001)	0.0026 (0.0001)	0.0026 (0.0001)
δ	0.0150 (0.0009)	0.0150 (0.0009)	0.0150 (0.0009)
α	0.3173 (0.0498)	0.3077 (0.0266)	0.3068 (0.0219)
$\ln\left(\frac{g}{y}\right)$	1.4575 (0.0084)	1.4575 (0.0084)	1.4575 (0.0084)
$\frac{d}{\theta}$	0.2377 (0.0168)	0.2400 (0.0095)	n/a
θ	n/a	n/a	1.6315 (0.0517)
ρ_g	0.9717 (0.0148)	0.9717 (0.0148)	0.9717 (0.0148)
τ_g	0.0003 (0.0002)	0.0003 (0.0002)	0.0003 (0.0002)
σ_g	0.0136 (0.0011)	0.0136 (0.0011)	0.0136 (0.0011)
μ_g	1.5219 (0.0279)	1.5219 (0.0279)	1.5219 (0.0279)
ρ_x	0.5529 (0.1121)	0.5529 (0.1121)	0.5529 (0.01121)
μ_x	0.0240 (0.0026)	0.0240 (0.0026)	0.0240 (0.0026)
σ_x	0.0131 (0.0023)	0.0131 (0.0023)	0.0131 (0.0023)

Notes: Standard errors in parentheses.
P.I.I. = partial income insurance; F.I.I. = full income insurance.

Table 3
Parameter estimates for the models

$v = 0.8$			
Parameter	**Estimates Efficiency wage model**		**Estimates Standard limited-participation model**
	(P.I.I. Case)	**(F.I.I. Case)**	
μ	1.2734	1.2695	1.5041
	(0.0990)	(0.0487)	(0.1515)
$\ln A$	0.0496	0.0500	0.0274
	(0.0165)	(0.0136)	(0.0174)
ρ_A	0.9269	0.9268	0.9310
	(0.0151)	(0.0147)	(0.0129)
σ_A	0.0078	0.0078	0.0075
	(0.0006)	(0.0006)	(0.0006)
A_y	0.0869	0.0869	0.0869
	(0.0143)	(0.0143)	(0.0143)
$\ln(\gamma)$	0.0026	0.0026	0.0026
	(0.0001)	(0.0001)	(0.0001)
δ	0.0148	0.0148	0.0148
	(0.0009)	(0.0009)	(0.0009)
α	0.3058	0.3080	0.1800
	(0.0538)	(0.0426)	(0.0825)
$\ln\left(\frac{g}{y}\right)$	1.4575	1.4575	1.4575
	(0.0084)	(0.0084)	(0.0084)
$\frac{d}{\theta}$	0.2420	0.2404	n/a
	(0.0176)	(0.0145)	
θ	n/a	n/a	1.4274
			(0.0991)
ρ_g	0.9717	0.9717	0.9717
	(0.0148)	(0.0148)	(0.0148)
τ_g	0.0003	0.0003	0.0003
	(0.0002)	(0.0002)	(0.0002)
σ_g	0.0136	0.0136	0.0136
	(0.0011)	(0.0011)	(0.0011)
μ_g	1.5219	1.5219	1.5219
	(0.0279)	(0.0279)	(0.0279)
ρ_x	0.5529	0.5529	0.5529
	(0.1121)	(0.1121)	(0.1121)
μ_x	0.0240	0.0240	0.0240
	(0.0026)	(0.0026)	(0.0026)
σ_x	0.0131	0.0131	0.0131
	(0.0023)	(0.0023)	(0.0023)

Notes: Standard errors in parentheses.
P.I.I. = partial income insurance; F.I.I. = full income insurance.

predictions can, in large part, be attributed to the equations and parameters that affect the labour market and adjustment costs.

Next, the models are solved using the estimated parameter values and the linearization technique described in Christiano (1998), and the impulse-response functions are computed for fiscal policy shocks, technology shocks, and monetary policy shocks.

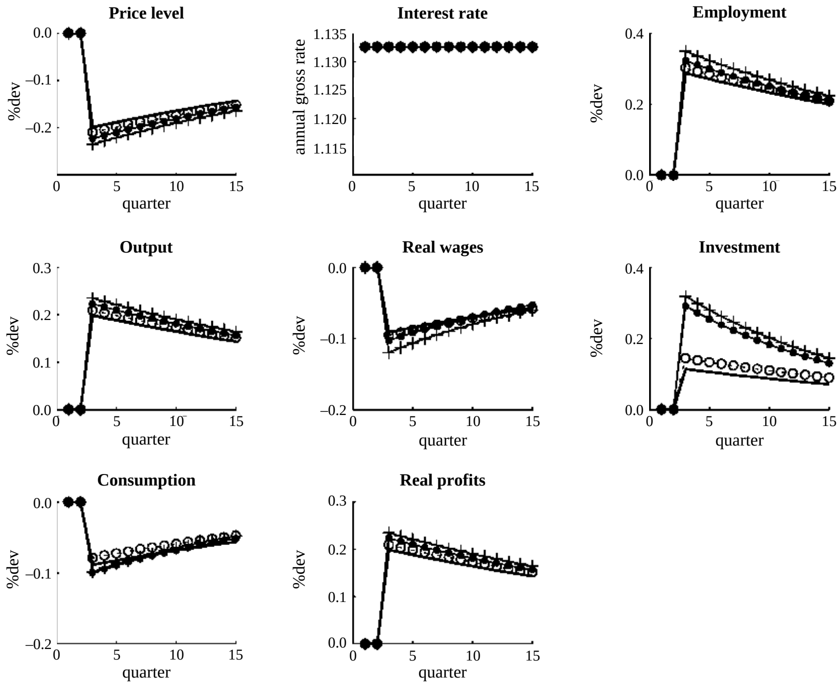
2.1 Fiscal policy shocks

Figure 1 depicts the shirking models' responses to an exogenous increase in government expenditures. Figure 2 illustrates the corresponding responses for the standard limited-participation model. A comparison of these two figures demonstrates that both of the models have the same qualitative predictions for a positive government expenditure shock. In particular, output, employment, investment, and interest rates all increase, while consumption and real wages both decrease. However, neither of the models can account for the observation, seen in Edelberg, Eichenbaum, and Fisher (1998), that prices increase following an exogenous increase in government expenditure.

Figure 1 also demonstrates that the form of the intrafamily transfer and the adjustment cost on capital affect the size of the shirking model's responses to an exogenous fiscal policy shock. In particular, the full income insurance case (—— and • – • lines) produces smaller movements than the partial income insurance case (– + – and – o – lines) in all variables except consumption. Furthermore, comparing the model's responses when $\upsilon = 1$ with the responses of the model when $\upsilon = 0.8$, shows that an increase in the capital-adjustment costs decreases the shock's effect on all variables. The largest difference can be seen in the efficiency wage model with partial income insurance. When one compares Figures 1 and 2, it is evident that the greatest increase in employment, output, and investment, and the greatest decrease in wages and prices occur in the efficiency wage model with partial income insurance.

The intuition behind these responses is straightforward. In the efficiency wage model, an unexpected exogenous increase in government expenditures initially decreases the amount of money spent on investment and family purchased consumption, holding everything else constant. The fall in c_t^f translates into an increase in the relative consumption of a non-disciplined worker to a disciplined worker, $\frac{c_t}{c_t^s}$.

Figure 1
The efficiency wage model's responses to a positive fiscal policy shock



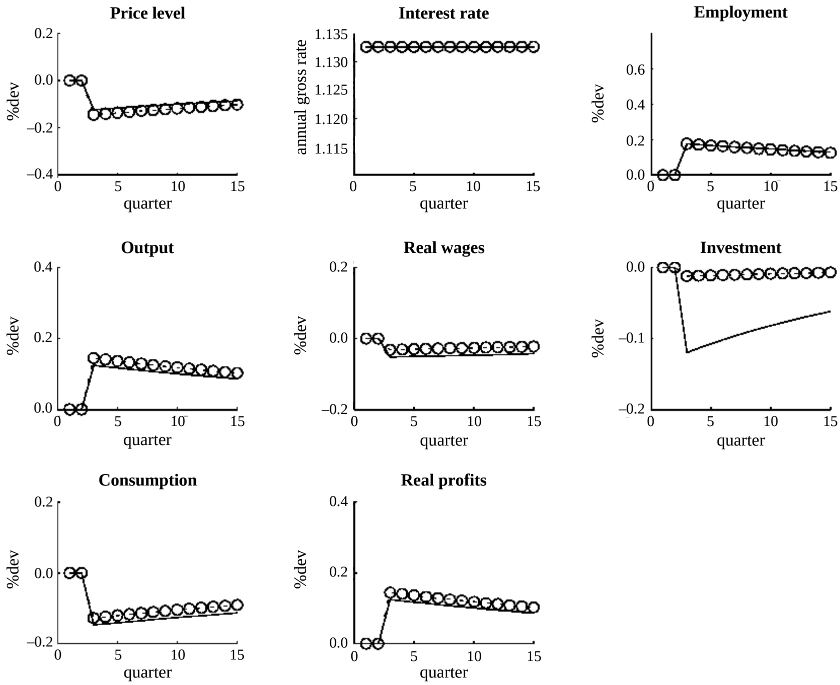
Notes: Partial income insurance, v = 1.0: –+–+
Partial income insurance, v = 0.8: –o–o–
Full income insurance, v = 1.0: ●–●–
Full income insurance, v = 0.8: ———
%dev = percent deviation from steady state.

Therefore, at the previously given real-wage rate and effort level, the utility of a non-shirker is strictly higher than the expected utility of a shirker at this new level of c_t^f. To prevent workers from shirking, firms lower the real wage offered to workers to the point where workers are once again indifferent between providing effort and shirking, i.e., to the point where

$$\frac{c_t}{c_t^s} = const.$$

At this new lower wage, the marginal product of labour exceeds the marginal cost, so firms optimally increase the number of workers they hire.

Figure 2
The standard limited-participation model's responses to a positive fiscal policy shock



Notes: Limited participation, v = 1.0: ———
Limited participation, v = 0.8: –o–o–
%dev = percent deviation from steady state.

Since the equilibrium effort level remains the same and the number of effective labour hours increases, output rises.[31]

The increase in output has two effects. First, it causes the price of the final good to decline. Second, it causes both the current and expected return on capital to rise. The decrease in prices and the increase in the return on capital allow each family to increase the amount of goods they purchase. However, the precise effect of these changes on c_t^f depends on how investment responds to the shock. For example, when the rise in government expenditures is persistent, families invest more in capital goods because of the large increase in the expected future return on capital. In this case, most

31. This is feasible as long as the economy initially contains enough unemployed workers to meet the firms' extra demand.

of the increase in the family's purchasing power is devoted to investment, and the change in c_t^f is small.

In practice, c_t^f decreases in the model because of the size of the increase in investment and taxes. As a result, real wages decline and firms hire more workers in response to the shock. This causes output to increase and prices to decline. Finally, interest rates do not initially respond to the shock because the level of nominal deposits is determined in advance of the shock and there is no increase in the stock of money.

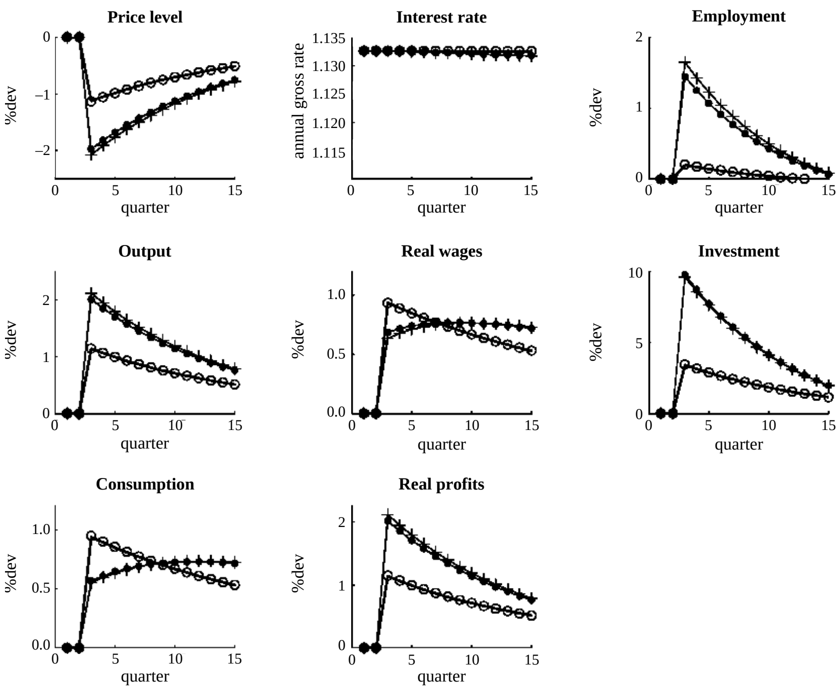
2.2 Technology shocks

Figure 3 displays the efficiency wage model's responses to a shock that increases the level of technology by 1 per cent, and Figure 4 displays the same responses for the standard limited-participation model. These figures show that, in both models, a positive technology shock causes prices to decrease and all other variables to increase.[32] Figure 3 demonstrates that: (i) limiting the amount of income insurance available to agents will increase the employment and output responses; and (ii) increasing the costs of adjustment on capital dampens the positive effect of the shock on output, employment, and investment, and increases the effect of the shock on wages and consumption. A comparison of Figures 3 and 4 highlights the differences in the magnitudes of the models' responses. I find that in the efficiency wage model, the price decrease is larger, real wages increase slightly less, and the employment, output, investment, and consumption responses are generally larger.

These responses follow from the fact that a positive technology shock increases both output and the marginal product of labour for firms in the efficiency wage model. The increase in current output has two effects. First, it decreases the price of the final good, which causes an increase in the purchasing power of the family's cash balances, ceteris paribus. Second, the increase in production causes the real return on capital to rise. Both of these effects allow the family to purchase more consumption and investment goods. The induced change in c_t^f then alters the punishment associated with being detected shirking through its effect on $\frac{c_t}{c_t^s}$, since:

32. These responses are common in the literature and have been supported by evidence in Christiano, Eichenbaum, and Vigfusson (2002). However, papers such as Basu, Fernald, and Kimball (1999) and Galí (1999) have suggested that technology improvements may, in fact, be contractionary in the short run and expansionary only in the long run.

Figure 3
The efficiency wage model's responses to a positive technology shock



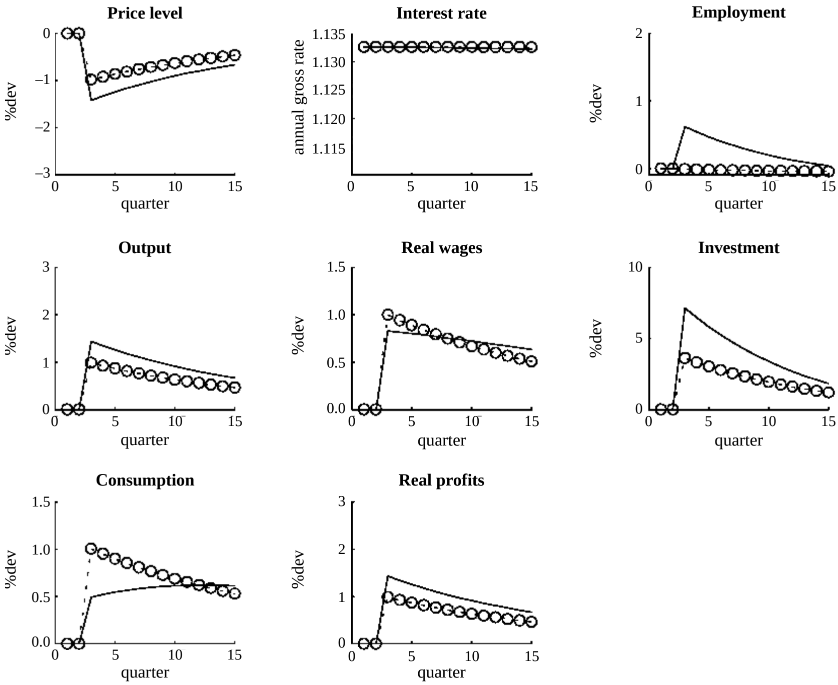
Notes: Partial income insurance, v = 1.0: –+–+
Partial income insurance, v = 0.8: –o–o–
Full income insurance, v = 1.0: ●–●–
Full income insurance, v = 0.8: ———
%dev = percent deviation from steady state.

$$\frac{c_t}{c_t^s} = \frac{w_t f - F_t + c_t^f}{s w_t f - F_t + c_t^f}.$$

In addition to the change in c_t^f caused by the change in output, a positive technology shock also increases the expected future return on capital since the shock is persistent. This induces the family to increase their investment in capital goods, thereby dampening the effects of the increase in $r_t K_t$ and the decrease in P_t on c_t^f. However, the results suggest that c_t^f increases in response to a technology shock.

Firms respond to the rise in the level of family consumption purchased by increasing wages to dissuade workers from shirking. This, in turn, increases

Figure 4
The standard limited-participation model's responses to a positive technology shock



Notes: Limited participation, v = 1.0: ———
Limited participation, v = 0.8: –o–o–
%dev = percent deviation from steady state.

the marginal cost of labour. In practice, however, the increase in the marginal product of labour is larger than the increase in the marginal cost of labour. Therefore, the models predict that, following a positive technology shock, output, employment, consumption, investment, and wages increase, while prices decrease. Finally, the model also predicts that the interest rate is initially unaffected, because the money stock is unaffected by the shock and the level of deposits is initially fixed because of the limited-participation assumption.

2.3 Monetary policy shocks

Figures 5 and 6 display the impulse-response functions of the efficiency wage and limited-participation models for an expansionary monetary policy shock. Despite the fact that both models are consistent with the qualitative results outlined in Christiano, Eichenbaum, and Evans (1997) and Sims and Zha (1996), they differ with respect to their quantitative responses. Figure 5 demonstrates that the magnitude of the efficiency wage model's responses depends on the form of the intrafamily transfer, and a comparison of Figures 5 and 6 highlights the differences between the responses in the efficiency wage model and the standard limited-participation model. The partial income insurance case produces the least inflation, the smallest real-wage response, and the largest output, consumption, employment, and investment responses, compared with the full income insurance case and the standard limited-participation model. Moreover, these figures show that increasing the costs of capital adjustment lessens the increase in employment, output, and investment in response to a positive monetary shock, and increases the real-wage response.

In the monetary efficiency wage models, an unexpected increase in the stock of money initially has two effects. First, financial intermediaries have more funds to lend to firms. In response, the financial intermediaries lower the interest rate on loans to induce firms to borrow the excess funds. Everything else held equal, this decrease in the interest rate lowers the firms' marginal cost of labour. Since profit-maximizing firms choose employment to equate the marginal product of labour to the marginal cost of labour, the decrease in the marginal cost of labour causes firms to expand the size of their labour force. In turn, this increases the economy's output and the return on capital.

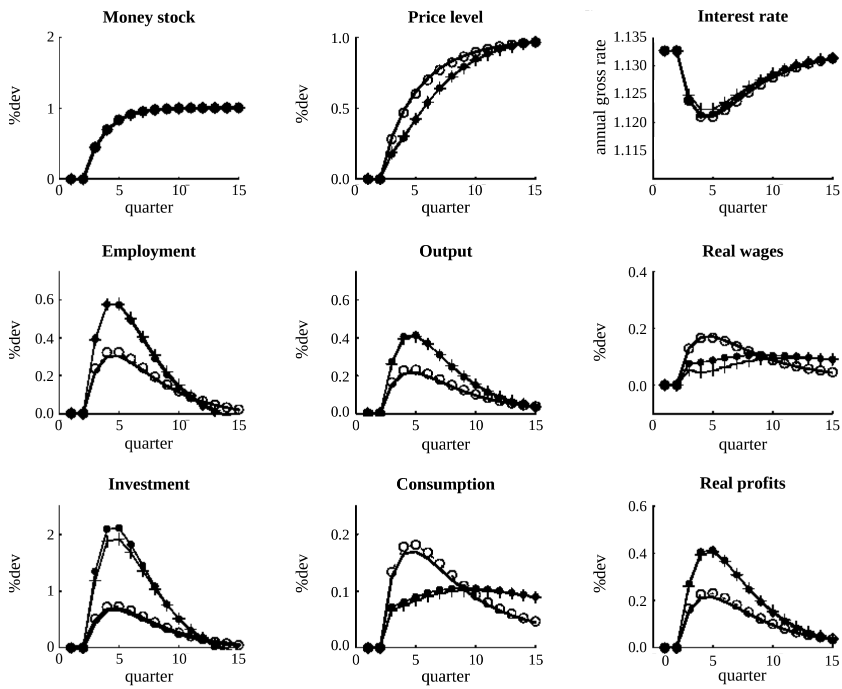
Second, the increase in the stock of money puts upward pressure on prices, if the response of output is small. This is seen clearly from the goods market clearing condition where:

$$P_t Y_t = \frac{1}{\left(1 - \frac{\alpha}{\mu}\right)}(M_t + X_t).$$

It follows that an increase in the price level causes the family's purchasing power to decrease since their cash balances can now buy less. Moreover, this decrease in purchasing power affects both family consumption and investment.

The effect of an expansionary monetary policy shock on c_t^f is generally uncertain. For example, if families choose to reduce capital investment enough in response to the shock, c_t^f may increase overall, despite the decrease in purchasing power. If this occurs, the punishment associated with being detected shirking decreases, and firms must raise wages in order to maintain the same effort level in equilibrium. The increase in wages raises the marginal cost of labour for a given interest rate and causes firms to

Figure 5
The efficiency wage model's responses to a positive monetary policy shock



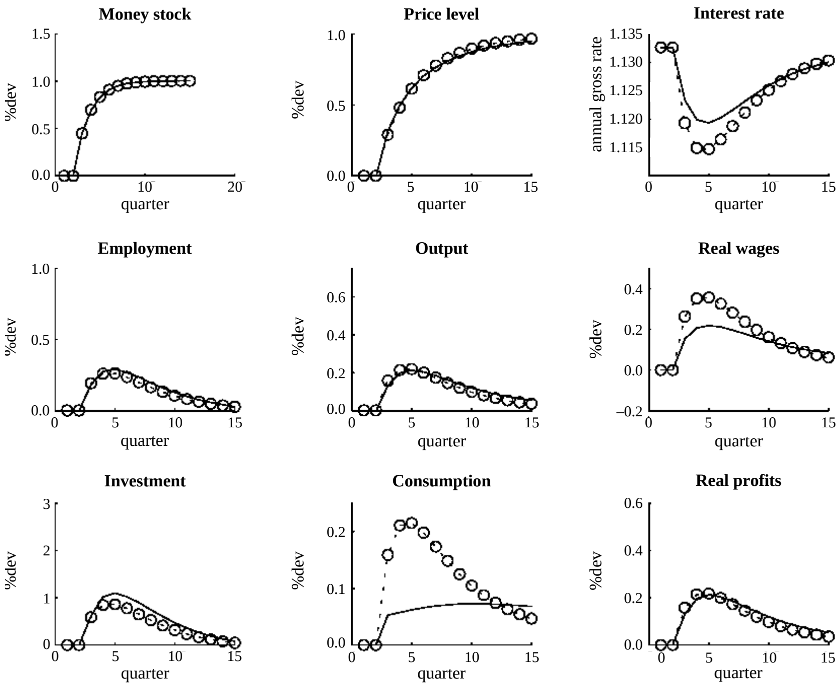
Notes: Partial income insurance, v = 1.0: –+–+
Partial income insurance, v = 0.8: –o–o–
Full income insurance, v = 1.0: ●–●–
Full income insurance, v = 0.8: ———
%dev = percent deviation from steady state.

decrease the number of workers hired, all else being equal. Depending on the magnitude of the increase in c_t^f, the real wage could increase enough to offset the effect of the decreasing interest rates on the marginal cost of labour. However, in the estimated versions of the model, it is clear that employment rises following the positive monetary policy shock.

2.4 The *J*-test

Tables 4 to 6 present the Wald tests that formally explore the hypothesis that the second moments from the estimated models are the same in population as the second moments estimated from the data. The results clearly indicate that the efficiency wage model is better able to produce low real-wage

Figure 6
The standard limited-participation model's responses to a positive monetary policy shock



Notes: Limited participation, v = 1.0 : ———
Partial income insurance, v = 0.8: –o–o–
%dev = percent deviation from steady state.

variation and high employment variation. The lowest real-wage variation and highest employment variation are obtained from the efficiency wage model with partial income insurance. Increasing the cost of adjustment on capital decreases the employment variation and increases the wage variation in both models. The results also show that the standard limited-participation model also needs a higher adjustment cost on capital to capture the second moments of interest. Both models have the best fit for $\upsilon = 0.8$. However, unlike a standard model, the efficiency wage model does not require a high markup or a high labour-supply elasticity when $\upsilon = 0.8$.

Conclusions

This paper develops a monetary business cycle model where: (i) individuals make nominal savings decisions before observing the period's shocks;

Table 4
Second moments

	$v = 1.0$					
Moment	$\frac{\sigma_c}{\sigma_y}$	$\frac{\sigma_i}{\sigma_y}$	$\frac{\sigma_g}{\sigma_y}$	σ_n	σ_w	σ_y
Canadian data	0.8674 (0.0501)	2.9587 (0.3916)	0.9445 (0.1265)	0.0085 (0.0011)	0.0110 (0.0012)	0.0135 (0.0015)
Efficiency wage Partial income insurance	0.2687 (0.0297)	4.6308 (0.9045)	0.6752 (0.1119)	0.0286 (0.0061)	0.0064 (0.0011)	0.0263 (0.0041)
p-value	0.0000	0.0919	0.0921	0.0016	0.0074	0.0040
Efficiency wage Full income insurance	0.2830 (0.0300)	4.9895 (0.3247)	0.6945 (0.0689)	0.0273 (0.0036)	0.0072 (0.0006)	0.0255 (0.0024)
p-value	0.0000	0.0000	0.0571	0.0000	0.0021	0.0000
Standard limited participation	0.3885 (0.0448)	5.0222 (0.8796)	1.0895 (0.1031)	0.0126 (0.0021)	0.0113 (0.0017)	0.0163 (0.0014)
p-value	0.0000	0.0328	0.3114	0.1011	0.8830	0.1767

Table 5
Second moments

	$v = 0.9$					
Moment	$\frac{\sigma_c}{\sigma_y}$	$\frac{\sigma_i}{\sigma_y}$	$\frac{\sigma_g}{\sigma_y}$	σ_n	σ_w	σ_y
Canadian data	0.8674 (0.0501)	2.9587 (0.3916)	0.9445 (0.1265)	0.0085 (0.0011)	0.0110 (0.0012)	0.0135 (0.0015)
Efficiency wage Partial income insurance	0.5834 (0.0602)	3.6206 (0.4973)	1.0145 (0.1038)	0.0165 (0.0029)	0.0097 (0.0016)	0.0175 (0.0016)
p-value	0.0009	0.3000	0.6309	0.0141	0.5319	0.0722
Efficiency wage Full income insurance	0.6007 (0.0350)	3.7061 (0.3045)	1.0438 (0.0900)	0.0158 (0.0022)	0.0102 (0.0010)	0.0170 (0.0012)
p-value	0.0000	0.0771	0.4520	0.0045	0.5437	0.0895
Standard limited participation	0.6654 (0.0327)	3.6281 (0.2442)	1.3301 (0.1088)	0.0091 (0.0012)	0.0120 (0.0011)	0.0133 (0.0009)
p-value	0.0012	0.1434	0.0055	0.7702	0.5518	0.9221

Table 6
Second moments

	$v = 0.8$					
Moment	$\frac{\sigma_c}{\sigma_y}$	$\frac{\sigma_i}{\sigma_y}$	$\frac{\sigma_g}{\sigma_y}$	σ_n	σ_w	σ_y
Canadian data	0.8674 (0.0501)	2.9587 (0.3916)	0.9445 (0.1265)	0.0085 (0.0011)	0.0110 (0.0012)	0.0135 (0.0015)
Efficiency wage Partial income insurance	0.7898 (0.0670)	2.9948 (0.3166)	1.2046 (0.1199)	0.0135 (0.0025)	0.0113 (0.0016)	0.0145 (0.0012)
p-value	0.3851	0.9426	0.0951	0.0807	0.8935	0.5405
Efficiency wage Full income insurance	0.7931 (0.0520)	2.9754 (0.2546)	1.2393 (0.1075)	0.0127 (0.0022)	0.0114 (0.0013)	0.0143 (0.0010)
p-value	0.2840	0.9661	0.0470	0.0916	0.8134	0.6751
Standard limited participation	0.9973 (0.1094)	3.7253 (0.5692)	1.3823 (0.1405)	0.0103 (0.0017)	0.0164 (0.0031)	0.0128 (0.0011)
p-value	0.3111	0.2786	0.0076	0.4027	0.1170	0.7220

(ii) a worker's effort level is only imperfectly observed by firms; and (iii) detected shirkers forgo an increase in their compensation. The first two assumptions are common in limited-participation models and shirking efficiency wage models, respectively. However, the assumption that detected shirkers forgo a raise or a bonus is a departure from the assumption made in the standard shirking efficiency wage models. This difference in the punishment is largely responsible for the model's ability to produce large employment variation and small real-wage variation without relying on a high labour-supply elasticity or a high markup. As a result, this model is more consistent with microeconomic evidence about the size of markups and the value of the labour-supply elasticity of individuals.

The paper's findings also illustrate that the quantitative results are sensitive to the type of income insurance provided to the unemployed. In particular, it is found that the efficiency wage model with partial income insurance tends to overshoot the employment variation seen in the data, and that the model's performance is improved by small adjustment costs on capital. Since the model is able to generate very large employment fluctuations, adjustment costs on labour may further improve the model's performance.

The model's impulse responses to monetary and fiscal policy shocks as well as technology shocks are examined. Consistent with the existing empirical evidence, the monetary efficiency wage model predicts that, in response to a positive monetary policy shock, real wages, output, employment, investment, and prices increase, while the gross interest rate decreases.

In response to a positive fiscal policy shock, employment, output, and investment increase, the gross interest rate weakly increases, while real wages and consumption decrease. Although these responses are consistent with the empirical findings in Ramey and Shapiro (1998) and Edelberg, Eichenbaum, and Fisher (1998), the model also predicts that the price level decreases in response to the shock, which is inconsistent with the evidence.

Finally, the model's responses to a positive technology shock are examined. The responses to the technology shock are qualitatively consistent with the predictions of the standard limited-participation model. In particular, the monetary efficiency wage model predicts that in response to an exogenous increase in the level of technology, real wages, employment, output, investment, and the capital rental rate increase, and the price level decreases. Although there is evidence that positive technology shocks are eventually expansionary, the model does not replicate the findings in papers such as Basu, Fernald, and Kimball (1999), that an increase in the level of technology may initially be contractionary.

By examining the implied impulse responses to fiscal policy, technology, and monetary policy shocks for the standard limited-participation model, and comparing them to the corresponding figures for the efficiency wage model, it is evident that the models produce different quantitative results. For example, the efficiency wage model produces larger increases in employment, output, and investment in response to all of the shocks considered. However, the responses of wages, prices, and consumption depend on the type of shock. In particular, the estimated efficiency wage model predicts larger movements in real wages and smaller movements in consumption in response to a fiscal policy shock, while technology and monetary policy shocks predicted smaller wage movements with larger movements in consumption. In the efficiency wage model, prices respond less to a monetary policy shock and respond more to fiscal policy and technology shocks, in comparison with the standard limited-participation model.

The results support the hypothesis that introducing efficiency wage considerations can help reproduce the real-wage variation and high employment variation seen in the data without relying on the presence of a high labour-supply elasticity. Furthermore, the model is consistent with empirical evidence on how economies respond to fiscal and monetary policy shocks. Future work should concentrate on: (i) improving the predicted response to a technology shock and the price responses to a fiscal policy shock; and (ii) eliminating the need for adjustment costs on the flow of funds to the goods.

Appendix 1
The Data

To estimate the models, a data set similar to the one used in Burnside and Eichenbaum (1996a), was built using quarterly time series from the OECD quarterly national accounts, Statistics Canada, the OECD International sectoral database, and historical estimates of M2 for the period 1961–97. The official capital stock was obtained from the International sectoral database. Using these statistics, the capital stock, K_t, includes the producer structures, equipment, and private residential capital, plus the government non-residential capital.

Private consumption, C_t, investment, I_t, and government expenditures, G_t, are defined as in the OECD national accounts. The GDP deflator is for base year 1992 and is used to convert data variables between their nominal and real levels. The interest rate was measured using data available from Statistics Canada on the prime lending rate on loans. Finally, the monetary aggregate represented in the model was measured by M2. The series for M2 was obtained by combining the numbers available from Statistics Canada with earlier estimates from Metcalf, Redish, and Shearer (1998).

Two additional variables were needed to estimate the model: wages and employment/hours. The employment data were created using Statistics Canada's unemployment rate, while the wage series was defined as total compensation reported in the OECD quarterly national accounts. Although the employment rate is directly used in the efficiency wage models, the standard limited-participation model is estimated using the number of hours worked normalized by the number of leisure/labour hours available to individuals over the period.

To keep the data set as consistent as possible across the different models, all data were converted to per-capita terms by dividing by the size of the labour force, obtained from Statistics Canada. This normalization then allowed for a computation of an implied hourly employment series by taking a stand on the number of hours an individual worked per week. For this model, individuals were assumed to work 40 hours per week. The series for quarterly hours worked was then created using the formula $\frac{40 \times 52}{4}(1 - \mu_t)$ where μ_t is the unemployment rate. This series was used in the divisible and indivisible labour models after it was normalized by the number of leisure/labour hours available to individuals during the quarters.

Appendix 2
The Estimated Equations

The monetary efficiency wage model's parameters,

$$\left\{\frac{d}{\theta}, \delta, \tau_g, \mu_g, \rho_g, \sigma_g, \ln(A), \rho_A, \sigma_A, A_y, \ln(\gamma), \alpha, \ln\left(\frac{g}{y}\right), \mu_x, \mu, \rho_x, \sigma_x\right\},$$

are simultaneously estimated from the following exactly identifying restrictions:

$$E\left(\frac{(1-\alpha)}{\mu} - \frac{R_t w_t N_t}{Y_t}\right) = 0$$

$$E(\ln(A_t) - \ln A - \rho_A \ln(A_{t-1})) = 0$$

$$E((\ln(A_t) - \ln A - \rho_A \ln(A_{t-1})) \times \ln(A_{t-1})) = 0$$

$$E((\ln(A_t) - \ln A - \rho_A \ln(A_{t-1}))^2 - \sigma_A^2) = 0$$

$$E(\ln(Y_t) - A_y - t \times \ln(\gamma)) = 0$$

$$E\left((\ln(Y_t) - A_y - t\ln(\gamma)) \times \frac{t}{149}\right) = 0$$

$$E\left(I_t - \delta^{\left(1-\frac{1}{\upsilon}\right)}(K_{t+1}^{\upsilon} - (1-\delta)K_t^{\upsilon})^{\frac{1}{\upsilon}}\right) = 0$$

$$E\left(\begin{array}{c} muc_t \delta^{\left(1-\frac{1}{\upsilon}\right)}(K_{t+1}^{\upsilon} - (1-\delta)K_t^{\upsilon})^{\frac{1}{\upsilon}-1} K_{t+1}^{\upsilon-1} \\ -\beta muc_{t+1}\left(\frac{\alpha}{\mu}\frac{Y_{t+1}}{K_{t+1}} + (1-\delta)\delta^{\left(1-\frac{1}{\upsilon}\right)}(K_{t+2}^{\upsilon} - (1-\delta)K_{t+1}^{\upsilon})^{\frac{1}{\upsilon}-1} K_{t+1}^{\upsilon-1}\right)\end{array}\right) = 0$$

$$E(N_t - N^{ss}) = 0$$

$$E\left(\ln(G_t) - \ln(Y_t) - \ln\left(\frac{g}{y}\right)\right) = 0$$

$$E\left(\ln\left(\frac{G_t}{\gamma^t}\right) - \mu_g - t \times \tau_g\right) = 0$$

$$E\left(\left(\ln\left(\frac{G_t}{\gamma^t}\right) - \mu_g - t \times \tau_g\right) \times \frac{t}{149}\right) = 0$$

$$E\left(\left((1-\rho_g L) \times \left(\ln\left(\frac{G_t}{\gamma^t}\right) - \mu_g - t \times \tau_g\right)\right) \times \left(\ln\left(\frac{G_{t-1}}{\gamma^{t-1}}\right) - \mu_g - \tau_g \times (t-1)\right) \right) = 0$$

$$E\left(\left((1-\rho_g L) \times \left(\ln\left(\frac{G_t}{\gamma^t}\right) - \mu_g - t \times \tau_g\right)\right)^2 - \sigma_g^2\right) = 0$$

$$E(x_t - (1-\rho_x)\mu_x - \rho_x x_{t-1}) = 0$$

$$E((x_t - (1-\rho_x)\mu_x - \rho_x x_{t-1}) \times x_{t-1}) = 0$$

$$E((x_t - (1-\rho_x)\mu_x - \rho_x x_{t-1})^2 - \sigma_x) = 0,$$

where muc_t is the marginal utility of c_t^f for the family. The parameters of the standard limited-participation model are estimated using the same identification scheme with this model's marginal utility of consumption data, muc_t, hourly employment data, N_t, and its expression for the steady-state value of employment, N^{ss}. In this case, the equation equating the employment hours and the steady-state value of employment hours identifies the parameter value θ, instead of the variable $\frac{d}{\theta}$, as in the efficiency wage model.

The identifying restrictions for the *J*-test are described below.

To test the models' predictions for $\left\{\frac{\sigma_c}{\sigma_y}, \frac{\sigma_i}{\sigma_y}, \frac{\sigma_g}{\sigma_y}, \sigma_w, \sigma_n, \sigma_y\right\}$, the HP-filtered data, $\left\{c_t^{hp}, i_t^{hp}, g_t^{hp}, y_t^{hp}, n_t^{hp}, w_t^{hp}\right\}$, are used along with the following equations:[1]

$$E\left(\left(y_t^{hp}\right)^2\left(\frac{\sigma_c}{\sigma_y}\right)^2 - \left(c_t^{hp}\right)^2\right) = 0$$

$$E\left(\left(y_t^{hp}\right)^2\left(\frac{\sigma_i}{\sigma_y}\right)^2 - \left(i_t^{hp}\right)^2\right) = 0$$

$$E\left(\left(y_t^{hp}\right)^2\left(\frac{\sigma_g}{\sigma_y}\right)^2 - \left(g_t^{hp}\right)^2\right) = 0$$

$$E\left(\left(n_t^{hp}\right)^2 - (\sigma_n)^2\right) = 0$$

$$E\left(\left(y_t^{hp}\right)^2 - (\sigma_y)^2\right) = 0$$

$$E\left(\left(w_t^{hp}\right)^2 - (\sigma_w)^2\right) = 0.$$

These moments were simultaneously estimated with the models' parameters.

1. $\lambda = 1{,}600$ when the data were filtered.

Appendix 3
The Standard Limited-Participation Model

The standard limited-participation model with divisible labour is based on Christiano, Eichenbaum, and Evans (1997) and has the same six sectors as the efficiency wage model presented in the paper. The problems facing the monetary authority, the final good firms, and the government are identical to those described in the efficiency wage model. However, the individual's problem, the intermediate goods firms' problems, and the loan market clearing condition differ slightly due to the observability of effort and the divisibility of labour.

The individual's problem in the standard limited-participation model is:

$$\max_{\{c_t, K_{t+1}, M_{t+1}, D_t\}_{t=0}^{\infty}} E_0\left\{\sum_{t=0}^{\infty} \beta^t \left\{\ln(C_t) + \theta \ln(1 - N_t) - \theta \ln(1 + H(Q_t, Q_{t-1}))\right\}\right\},$$

subject to $P_t C_t \leq M_t - D_t - P_t Tax_t + P_t r_t K_t - P_t I_t + W_t N_t$, and

$$M_{t+1} = M_t - D_t - P_t C_t - P_t Tax_t + P_t r_t K_t + W_t N_t - P_t I_t + R_t[D_t + X_t] + PR_t,$$

where $H(Q_t, Q_{t-1}) = a_0\left\{\exp\left[a_1\left(\frac{Q_t}{Q_{t-1}} - 1 - x^s\right)\right] + \exp\left[-a_1\left(\frac{Q_t}{Q_{t-1}} - 1 - x^s\right)\right] - 2\right\}.$

$Q_t = M_t - D_t$, C_t is the individual's consumption, N_t is the percentage of time the individual spends working for firms, r_t is the real return on capital, K_t is the amount of capital available during time t, P_t is the price level, M_t is the beginning of period stock of money, I_t is investment, W_t is the nominal wage, D_t is the amount of nominal deposits chosen in advance of the shocks, R_t is the nominal interest rate, Tax_t is the amount of taxes owed at time period t, and $R_t X_t$ and PR_t are the profits received from financial intermediaries and intermediate goods firms, respectively.

In the limited-participation model, firms do not require effort from workers for production. The resulting intermediate goods firm's period t problem in this case is:

$$\max_{\{P_{it}, N_{it}, K_{it}\}} \left\{P_{it}\left(A_t K_{it}^{\alpha} (N_{it})^{1-\alpha}\right) - R_t P_t w_{it} N_{it} - P_t r_t K_{it}\right\}$$

subject to the period-by-period demand functions:

$$P_{it}^{\frac{-\mu}{1-\mu}}\left(A_t K_{it}^{\alpha}(N_{it})^{1-\alpha}\right) - P_t^{\frac{-\mu}{1-\mu}} Y_t = 0 .$$

Finally, using the fact that the intermediate goods firms borrow their wage bill from the financial intermediaries, the loan market clearing condition becomes:

$$\int_0^1 W_{it} N_{it} di = D_t + X_t ,$$

where $W_{it}N_{it}$ is firm i's wage bill in period t, D_t are the deposits, and X_t is the amount of the monetary injection.

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