Anticipated Growth and Business Cycles in Matching Models

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Abstract

In a business cycle model that incorporates a standard matching framework, employment increases in response to news shocks, even though the wealth effect associated with the increase in expected productivity reduces labor force participation. The reason is that the matching friction induces entrepreneurs to increase investment in new projects and vacancies early. If there is underinvestment in new projects in the competitive equilibrium, then the efficiency gains associated with an increase in employment make it possible that consumption, employment, output, as well as the investment in new and existing projects jointly increase before the actual increase in productivity materializes. If there is no underinvestment then investment in existing projects decreases, but total investment, consumption, employment, and output still jointly increase.

Keywords: Pigou Cycles, Labor Force Participation, Productivity Growth

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1 Introduction

Economists have long recognized the importance of expectations in explaining economic fluctuations. As early as 1927, Pigou postulated that '*the varying expectations of business men ... constitute the immediate cause and direct causes or antecedents of industrial fluctuations.*'[1] A recent episode where many academic and non-academic observers attribute a key role to expectations is the economic expansion of the 1990s. During the 1990s, economic agents observed an increase in current productivity levels, but also became more optimistic regarding future growth rates of productivity. In fact, there was a strong sense of moving towards a new era, the 'new economy', of higher average productivity growth rates for the foreseeable future. With the benefit of hindsight it is easy to characterize the optimism about future growth rates as 'unrealistic'. At the time, however, the signals about future productivity were in fact remarkable, and the view that a new era was about to begin was shared by many experts, including economic policy makers such as Alan Greenspan.[2] Similarly, the question arises whether the downward adjustment of these high expectations about future growth rates did not at least worsen, if not cause, the economic downturn that took place at the beginning of the new millennium.

More formal empirical evidence that business cycles are caused by anticipated changes in future productivity is provided by Beaudry and Portier (2006).[3] They use changes in stock prices to identify that fraction of future changes in productivity that is anticipated and argue that this fraction is actually quite large. They show that innovations in technology are small, but initiate substantial future increases in productivity. Moreover, this expectation shock leads to a boom in output, consumption, investment, and hours worked

[1] In Pigou (1927).

[2] See, for example, the following quote in Greenspan (2000): '... there can be little doubt that not only has productivity growth picked up from its rather tepid pace during the preceding quarter-century but that the growth rate has continued to rise, with scant evidence that it is about to crest. In sum, indications ... support a distinct possibility that total productivity growth rates will remain high or even increase further.'

[3] Schmitt-Grohé and Uribe (2008) estimate a model similar to the one in Jaimovich and Rebelo (2006) allowing both for anticipated and non-anticipated shocks and document the importance of anticipated shocks. They find that anticipated shocks are responsible for 71% of the fluctuations in output growth.

before the anticipated productivity growth actually materializes.

Beaudry and Portier (2007) analyze whether existing neoclassical models can generate Pigou cycles. In a Pigou cycle, output, consumption, investment, and hours worked jointly increase in response to an anticipated increase in productivity and these variables decline when the anticipated increase fails to materialize. They consider a large class of models and show that the answer is no.[4] Instead, the typical response is an increase in consumption, but a decrease in investment and hours worked. The reason is that the wealth effect induces agents to increase consumption and leisure. It is not difficult to generate an increase in investment, because the anticipated increase in productivity also causes the expected return on capital to go up.[5] The problem is, however, that higher levels of investment are typically financed by a reduction in consumption, not by an increase in hours worked. The real challenge is, therefore, to build a model in which hours worked increase in response to an increase in anticipated productivity growth.

Recently, some models have been developed where an increase in expected productivity generates a business cycle boom. Exemplary papers are Beaudry and Portier (2004, 2007), Christiano, Motto, and Rostagno (2006), and Jaimovich and Rebelo (2006, 2007). In Beaudry and Portier (2004, 2007) and Jaimovich and Rebelo (2006, 2007), the positive co-movement of investment and consumption is generated by using alternative preferences that eliminate the wealth effect on labor supply and/or by making it too costly for variables to move in the 'wrong' direction. The latter can be accomplished by complementarities in the production technology or particular forms of capital adjustment costs. Christiano, Motto, and Rostagno (2006) assume that nominal wages are sticky and argue that monetary policy is expansionary when expected future productivity increases. The reason is that the increase in the real wage caused by the expansion brings about a reduction in inflation when nominal wages are sticky. Since the expansion is anticipated, the news shock leads to a reduction in expected inflation, which in turn leads to a reduction in interest

[4] Cochrane (1994) and Danthine, Donaldson, and Johnsen (1998) have made the same observation for more specific models.

[5] If the elasticity of intertemporal substitution is high enough, then the substitution effect dominates the wealth effect, and investment increases.

rates when the central bank follows a Taylor rule.

This paper approaches the challenge to generate Pigou cycles from a different angle by considering a standard matching model augmented with endogenous labor force participation. There are no adjustment costs, except for the matching friction and the presence of a matching friction is clearly not sufficient to generate Pigou cycles. The parameters are chosen such that the matching model can generate enough employment volatility in the presence of the usual unanticipated shocks and is not subject to the critique of Shimer (2005). In particular, as in Hagedorn and Manovskii (2008) it is assumed that the entrepreneur receives on average a relatively small share of the surplus and it is also assumed that wages respond less than proportionally to increases in TFP. These assumptions ensure that investment in new projects increases sharply when productivity increases. The matching friction makes it costly to quickly increase the number of new projects. Consequently, the investment in new projects increases early in response to anticipated shocks.

Together with the increase in investment in new projects, vacancies robustly increase, that is, the demand for labor increases. Just as in the standard RBC model, however, the wealth effect associated with an increase in expected productivity growth has a downward effect on labor supply. Nevertheless, employment strongly increases for the following two reasons. First, the increase in the demand for labor dominates the reduction in labor force participation. Second, with a matching friction, in order to benefit from the increase in wages when they occur, workers have to start looking for a job early. The difficulty in generating Pigou cycles is that the wealth effect (which reduces labor supply) affects labor supply immediately, whereas the substitution effect (which increases labor supply) only affects labor supply when wages actually increase. The matching friction pulls the substitution effect forward in time. This dampens the reduction in labor force participation.

The question arises whether consumption and the investment in existing projects also increase. To shed light on this question, the analysis first focuses on the question whether the sum of consumption, C_t, and investment in existing projects, I_t, increases. $C_t + I_t$ is equal to output *minus* the investment in new projects, which will be referred to as net resources. When net resources increase, it is not difficult to generate an increase in both C_t and I_t, by choosing the right elasticity of intertemporal substitution.

Net resources increase whenever the increase in output—caused by the increase in employment—exceeds the cost of the increase in investment in new projects that induced the increase in employment. In other words, the increase in the investment of new projects must—from a social planner's point of view—be self-financing. For this to be possible, there must be underinvestment in new projects in the competitive equilibrium. In this case, the sharp increase in investment in new projects in response to an anticipated shock leads to efficiency gains, which make it possible for net resources to increase.[6] Underinvestment happens when the share of the surplus the entrepreneur receives is sufficiently small.[7] As mentioned above, this is exactly the condition that make it possible for matching models to generate a realistic amount of employment volatility.

In the benchmark calibration, the entrepreneur's share is indeed low enough so that the efficiency gains achieved in response to an anticipated shock make it possible that consumption, both types of investment, employment, as well as output increase.

In the alternative calibration, the entrepreneur's share is also low, but not that low and there is no underinvestment in new projects. Output net of investment in new projects now decreases, but the model still generates Pigou cycles under a slightly weaker definition of Pigou cycles, namely one that only requires *total* investment to increase in response to an anticipated shock and not both the investment in new and the investment in old projects. The division of the surplus between entrepreneur and worker is chosen to match employment volatility in response to the usual unanticipated shocks. At these higher average profit levels, this requires a higher amount of wage stickiness. As in the benchmark calibration, the division of the surplus is such that the competitive equilibrium is not Pareto optimal. Since there is no underinvestment in new projects, the precipitous increase in investment in new projects by the entrepreneurs during the anticipation phase is undesir-

[6] Although there are efficiency gains, aggregate TFP as measured by the Solow residual is unaffected by the news shock.

[7] Underinvestment occurs because the entrepreneur pays the full cost of creating a new project, but has to share the revenues with a worker.

able from a social planner's point of view, there are no efficiency gains, and output net of investment in new projects displays a (moderate) decrease. The household could counteract the undesirable sharp increase in investment in new projects with a sharp decrease in investment in existing projects. This would result in an increase in consumption that is closer to the socially desirable increase. The increase in employment leads, however, to an increase in the expected return on the investment in existing projects. Consequently, the increase in investment in existing projects decreases only slightly and by less than the increase in investments in new projects; total investment as well as consumption increase.

2 Model

The economy consists of entrepreneurs and workers. Both can perfectly ensure idiosyncratic risk, which is ensured by the following modelling device. At the end of the period, all agents become part of a representative household and share the net revenues earned during the period. The household decides how much to consume, how much to save, and the level of labor force participation. The labor force consists of the mass of workers searching for a job, i.e., the unemployed, plus the mass of workers returning to continuing jobs. Workers can only become employed after they have searched for a job for at least one period.

The key decision that is not made by the household is how many new projects to start. This decision is made by individual entrepreneurs. In the planning phase, each new project requires a periodic fixed investment until production starts. Starting a new project also entails posting a vacancy. The number of vacancies and the number of workers searching for a job determine—using a standard matching function—the number of new productive relationships. Exogenous separation occurs with probability ρ^x. Productivity is high enough so that endogenous separation does not occur.

2.1 Production

Production takes place within a relationship consisting of one worker and one entrepreneur. The production technology is given by:

$$y_t = Z_t k_t^{\alpha}, \tag{1}$$

where Z_t stands for aggregate productivity, y_t for firm output, and k_t for firm capital.[8] The law of motion for Z_t is given by

$$\ln Z_t = \rho \ln Z_{t-1} + \varepsilon_t. \tag{2}$$

When analyzing whether this model can generate Pigou cycles, the assumption is made that Z_t is known at $t - \tau < t$ with $\tau > 0$.

Capital is rented by the firm at rate R_t. Each period the worker and the entrepreneur divide revenues net of capital payments:

$$\overline{p}_t = Z_t k_t^{\alpha} - R_t k_t. \tag{3}$$

The law of motion for the wage rate, W_t, is given by:

$$W_t = (1 - \bar{\omega}) \left[\omega \overline{p}_t + (1 - \omega) E \left[\overline{p}_t \right] \right], \tag{4}$$

where $\bar{\omega}$ and ω are fixed parameters and $E\left[\overline{p}_t\right]$ is the unconditional expectation of $\overline{p}_t$. The parameter ω controls how the wage rate responds to changes in net revenues; wages are fixed when $\omega = 0$, whereas wages are proportional to net revenues when $\omega = 1$.[9] The average wage rate, $E[W_t]$, is equal to $(1 - \bar{\omega}) E[\overline{p}_t]$. Thus, $(1 - \bar{\omega})$ determines the fraction of net revenues the worker receives.

The firm chooses the capital stock that maximizes $\overline{p}_t$. Thus:

$$k_t = \left(\frac{Z_t \alpha}{R_t} \right)^{1/(1-\alpha)}. \tag{5}$$

[8] Throughout this paper, firm level variables are denoted with lowercase and aggregate variables with uppercase characters.

[9] If $0 \leq \omega < 1$, then wages respond less than proportionally to changes in $\overline{p}_t$; such wage rules are discussed in the section on strategic wage bargaining of Mortensen and Nagypál (2007)

2.2 New projects

Entrepreneurs decide whether they want to start a new project. During the planning phase, projects require an investment equal to ψ each period. If the plan turns out to be successful, production can start. During the planning phase, entrepreneurs also search for a worker. The number of entrepreneurs with projects in the planning phase is determined by the free-entry condition, that is, the cost, ψ, has to equal the value of a successful project times the probability of being successful.

Profits of successful projects, p_t, are equal to revenues (net of capital payments) minus the transfer to the worker, i.e., $p_t = \overline{p}_t - W_t$. The value of a successful project to the entrepreneur is simply the discounted value of profits, taking into account that the project is subject to the possibility of exogenous destruction in subsequent periods. Thus:

$$J_t = \beta \mathrm{E}_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\gamma} (p_{t+1} + (1-\rho^x) J_{t+1}) \right], \tag{6}$$

where $(C_{t+1}/C_t)^{-\gamma}$ is the marginal rate of substitution. The free-entry condition can then be written as:

$$\psi = \lambda_t^f J_t, \tag{7}$$

where λ_t^f is the probability that a project in the planning phase is successful and a suitable worker is found. If J_t increases then an increase in the amount invested in new projects, $I_{N,t}$, brings the economy back into equilibrium by lowering λ_t^f. Fujita (2003) models the planning and hiring phase of the project separately. For parsimony, the standard convention is used here, planning and searching are subsumed under one phase, and the probability λ_t^f describes success on both counts.[10]

[10] For the calibration of ψ, the interpretation of what is behind creating a new job is essential. If the only cost in creating a new job is the cost associated with placing an advertisement for a new worker, then entry would be so high that the matching friction would be non-existent. For the calibrated parameters, the cost of starting a new project, ψ, is equal to 17% of the firm's monthly output level and aggregate investment in new projects (successful and not successful) is on average equal to 1.4% of aggregate output.

2.3 Matching market

On the matching market, entrepreneurs post vacancies and search for a worker. The number of matches, M_t, is determined by the number of searching workers, i.e., the unemployed, U_t, and the number of vacancies, V_t, which is equal to the number of projects in the planning phase, $I_{N,t}/\psi$. The matching process is modeled with the standard constant returns to scale matching function.[11] That is:

$$M_t = \bar{\mu} U_t^{\mu} V_t^{1-\mu}, \tag{8}$$

$$\lambda_t^w = \frac{M_t}{U_t}, \text{ and } \lambda_t^f = \frac{M_t}{V_t}. \tag{9}$$

2.4 The household

The household chooses consumption, C_t, total labor supply, and next period's beginning-of-period capital stock, K_{t+1}. Labor supply is equal to the sum of employed workers, N_t, and workers searching for a job, U_t. The labor force, $N_t + U_t$, is assumed to be endogenous.[12] Capital earns a rate of return R_t and depreciates at rate δ.

Next period's beginning-of-period employment consists of those workers that have not experienced exogenous separation, $(1-\rho^x)N_t$, and those workers that are matched during the current period, $\lambda_t^w N_t$. Thus:

$$N_{t+1} = \lambda_t^w U_t + (1-\rho^x)N_t. \tag{10}$$

Searching is assumed to be a full-time activity. Consequently, the time spent on leisure and home production, L_t, is equal to $L^* - U_t - N_t$.

[11] Strictly speaking, there is a constraint that M_t cannot be less than either U_t or V_t, but this constraint turns out not to be binding.

[12] In the matching literature, it is more common to model changes in the labor supply by means of endogenous search intensity. The advantage of endogenizing the labor force is that there is a clear empirical counterpart, which facilitates the calibration of the model.

The household's maximization problem is as follows:

$$\max_{\{C_{t+j},U_{t+j},N_{t+j+1}\}_{j=0}^{\infty}} \mathrm{E}_t \sum_{j=0}^{\infty} \beta^j \left[\frac{C_{t+j}^{1-\gamma} - 1}{1-\gamma} + \phi \frac{(L^* - U_{t+j} - N_{t+j})^{1-\kappa} - 1}{1-\kappa} \right], \tag{11}$$

s.t.

$$N_{t+j+1} = \lambda_{t+j}^w U_{t+j} + (1-\rho^x) N_{t+j}, \tag{12}$$

$$C_{t+j} + I_{t+j} = W_{t+j} N_{t+j} + R_{t+j} K_{t+j} + P_{t+j}, \tag{13}$$

$$I_{t+j} = K_{t+j+1} - (1-\delta) K_{t+j}. \tag{14}$$

$P_t = p_t N_t^w - I_{N,t}$ is equal to total profits made by the entrepreneurs minus the costs made by entrepreneurs in creating new projects, $I_{N,t} = \psi V_t$. This is taken as given by the household.

Endogenous labor force participation. This specification of the utility function for the representative agent assumes that there is perfect risk sharing, not only in terms of consumption, but also in terms of leisure.[13] An alternative would be to use the lottery setup of Rogerson (1988), where agents use lotteries to insure consumption against unfavorable labor market outcomes.[14] This approach seems less suitable for a model with endogenous labor force participation, since it indicates that labor force status is a random outcome. It seems plausible that the employment status is not fully under the control of workers, but it is more difficult to justify that labor force entry is subject to randomization. Moreover, Ravn (2008) shows that the implied linear utility function leads to a relationship between aggregate consumption and labor market tightness, V_t/U_t, that is inconsistent with the empirical properties of smooth aggregate consumption on one hand and volatile tightness on the other. The approach adopted here avoids Ravn's consumption-tightness puzzle.[15]

First-order conditions. Let η_t be the Lagrange multiplier of the constraint of the law of motion of N_t. This multiplier represents the shadow price for a worker in a productive

[13] A similar approach is followed by Hornstein and Yuan (1999), Shi and Wen (1999), and Tripier (2003).

[14] The utility of leisure would then be given by $\phi \times \left[(L^* - U_t - N_t) \times 1^{1-\kappa} + (U_t + N_t) \times 0^{1-\kappa} \right] / (1-\kappa)$, which is equal to $\phi \times [L^* - U_t - N_t] / (1-\kappa)$, i.e., utility would be linear in leisure.

[15] See den Haan and Kaltenbrunner (2007) for details.

relationship. The first-order conditions are as follows:

$$C_t^{-\gamma} = \mathrm{E}_t \left[\beta C_{t+1}^{-\gamma} \left(R_{t+1} + (1-\delta) \right) \right], \tag{15}$$

$$\phi L_t^{-\kappa} = \lambda_t^w \eta_t, \tag{16}$$

$$\eta_t = \beta \mathrm{E}_t \left[W_{t+1} C_{t+1}^{-\gamma} - \phi L_{t+1}^{-\kappa} + (1-\rho^x) \eta_{t+1} \right]. \tag{17}$$

Equation (15) is the standard intertemporal Euler equation. Equation (16) is the first-order condition of leisure. The left-hand side of this equation is the disutility of entering the labor market, i.e., the disutility of searching, and the right-hand side is the expected benefit of searching, $\lambda_t^w \eta_t$, that is, the worker gets η_t with probability λ_t^w. Equation (17) specifies the expected benefit of leaving period t employed, η_t. First, a matched worker obtains a wage payment worth $W_{t+1} C_{t+1}^{-\gamma}$. Second, the worker has to put in a unit of labor hours, generating for the household a disutility of leisure equal to $-\phi L_{t+1}^{-\kappa}$. Finally, in case the match continues the worker gets the expected benefits of leaving period $t+1$ employed, η_{t+1}.

2.5 Recursive equilibrium

Equilibrium on the market for rental capital requires that total demand for capital is equal to the available aggregate capital stock:

$$N_t k_t = K_t. \tag{18}$$

The aggregate budget constraint can be written as

$$C_t + I_t + I_{N,t} = Z_t N_t k_t^\alpha = Z_t K_t^\alpha N_t^{1-\alpha}. \tag{19}$$

The state variables of the model, s_t, consist of $Z_t, \cdots, Z_{t+\tau}$, K_t, and N_t. An equilibrium is a set of functions $C(s_t)$, $K'(s_t)$, $U(s_t)$, $N(s_t)$, $I_N(s_t) = \psi V(s_t)$, $J(s_t)$, $\eta_t(s)$, $R(s_t)$, $\lambda_t^w(s)$, $\lambda_t^f(s)$, and $k(s_t)$ that are consistent with: (i) household optimization, that is, the first-order conditions (15), (16), and (17), the budget constraint (13), and the law of motion for matched workers (12); (ii) optimal demand for capital by existing firms, that is, the first-order condition (5); (iii) equilibrium level of investment in new projects, i.e., the free-entry condition (7); (*iv*) the value of a successful project to the entrepreneur given by (6); (*v*) the definition of the matching probabilities given in (9); and (*vi*) the capital market clearing condition (18).

2.6 Definition of Pigou cycles

The idea behind a Pigou cycle is that the economy expands in anticipation of a future increase in Z_t. The variables K_t and N_t are predetermined and resources cannot increase during the period in which positive news about future productivity is received. It is, thus, impossible that consumption as well as both investment components increase in the first period. The analysis, therefore, focuses on the question whether the spending components jointly increase shortly after the economy has received positive news. Two different types of Pigou cycles are considered. The model is said to generate "full Pigou cycles", if in response to positive news about future productivity consumption, employment, output, and *both* types of investment, jointly increase shortly after the news has hit the economy and remain at elevated levels during the anticipation phase. The requirements for "regular Pigou cycles" are the same, except that only *total* investment has to increase and not necessarily both investment components.

2.7 Calibration

The model period is one month. Calibrated parameter values are given in Table 1; parameter values are either set to standard values or calibrated to match observed properties of key macroeconomic and labor market variables. This table also reports either the source for the parameter value or the empirical moment that is most relevant for the identification of the parameter value. Most of the targets are first-order moments. The three second-order moments used as targets are the volatility of wages, the volatility of the employment ratio, and the volatility of labor force participation, all three relative to the volatility of labor productivity. The calibration is done under the assumption that shocks are not anticipated. The idea is to choose the parameters such that the model can generate sensible business cycle statistics in the presence of regular unanticipated shocks, and then see whether the model with this calibration can generate Pigou cycles. The outcome of calibration would not be very different, however, if the three second-order moments that are used in the calibration are calculated using the model with anticipated shocks.

Preferences. Using a standard annual discount rate of 4% implies for a monthly model a value of β equal to 0.9966. The coefficient of relative risk aversion, γ, plays a key role in the model and several values will be considered. The benchmark value is 0.43 and the reason for this choice will become clear in Section 3. The scaling factor of the utility of leisure, ϕ, is chosen so that the steady state labor force, $U + N$, is equal to 1. To ensure that labor force participation, $(U + N)/L^*$, is equal to the observed value of 0.6274, L^* is set equal to 1.5938. The curvature parameter in the utility function of leisure, κ, is chosen to ensure that the model matches the volatility of labor force participation. The calibrated value of κ implies an elasticity of labor supply with respect to the expected benefit of being matched, $\lambda^w \eta$, equal to 0.22.[16] This is less than values typically used in real business cycle and New-Keynesian models. Pistaferri (2003) is an influential empirical study that finds an elasticity of 0.7 with a standard error of 0.09. With a Frisch elasticity equal to 0.7 the model can still generate full Pigou cycles, but for a smaller range of values for γ.[17] In the alternative calibration considered in section 3.2, the Frisch elasticity is equal to 0.54, which differs from the estimate of Pistaferri (2003) by less than 2 standard errors.

Production technology. The standard annual depreciation of 10% corresponds to a value of δ equal to 0.0084 on a monthly basis. The value for α is chosen so that the labor share is equal to the standard value of two thirds. The remaining one third is divided between capital providers, who get a share α of total output, and entrepreneurs, who get $\bar{\omega}(1-\alpha)$. Thus, $\alpha + \bar{\omega}(1-\alpha) = 1/3$. The calibrated value for $\bar{\omega}$ is equal to 0.0228 (see discussion below). Thus, $\alpha = 0.3178$. This implies a steady state ratio of physical capital

[16] The elasticity of labor supply with respect to the expected benefit of being matched is equal to $(L^*/(U+N) - 1)/\kappa$.

[17] See footnote 28.

to output, k/y, equal to 2.24 on an annual basis. The ratio of total capital to output $(Nk + NJ)/Ny$ is equal to 2.28 on an annual basis, which is fairly close to the typical value of 2.5.

Productivity process. The values of ρ and σ are such that the volatility and autocorrelation of the quarterly series, which are generated by time aggregation of monthly observations, correspond roughly to the corresponding moments of the standard specification for quarterly productivity: $\ln(\widetilde{Z}_t) = 0.95 \ln(\widetilde{Z}_{t-1}) + 0.007\widetilde{\varepsilon}_t$.

Wage process. The parameter ω controls the sensitivity of wages to changes in net revenues, $Z_t k_t^{\alpha} - R_t k_t$. To match observed wage volatility a relatively high value of ω is needed, namely 0.7547. The degree of wage stickiness is obviously a contentious issue and the case when wages are completely acyclical is also considered. The value of $\bar{\omega}$ represents the share of net revenues that entrepreneurs receive. A smaller value of $\bar{\omega}$ implies that firm value, J_t, is more responsive to changes in productivity and implies a higher level of employment volatility.[18] The value of $\bar{\omega}$ is chosen to match the volatility of the employment ratio, N_t/L^*, relative to the volatility of labor productivity, which results in a value for $\bar{\omega}$ equal to 0.0228. This value and the value for α imply that workers obtain 66.67% of value added, providers of capital receive 31.78%, and entrepreneurs receive 1.55%.

Matching technology. The matching elasticity with respect to labor market tightness, μ, is taken from Petrongolo and Pissarides (2001). The values of $\bar{\mu}$, ψ, and ρ^x are chosen to match (i) a steady state matching probability for the worker equal to the empirical average of 45.4%, (ii) a steady state matching probability for the firm equal to 33.8%, and

[18] To understand this claim, consider the case for which wages are completely sticky and normalize the pre-shock value of the surplus to 1. Before the shock, the worker, thus, gets $(1 - \bar{\omega})$ and the entrepreneur gets $\bar{\omega}$. A 1% increase in revenues (after rental payments), then implies that profits increase by $\left[(1 + 0.01 - (1 - \bar{\omega})) - \bar{\omega}\right]/\bar{\omega} = 0.01/\bar{\omega}$, which is decreasing with the entrepreneurs share, $\bar{\omega}$. As long as wages are partially sticky it remains true that the percentage increase in the entrepreneur's revenues is higher than the percentage increase in net revenues.

(*iii*) a steady state unemployment rate equal to the empirical average of 5.7%.[19]

3 Results

Section 3.1 documents that there are sensible parameter values for which the model can generate full Pigou cycles; that is, in response to an anticipated shock, the model predicts that output, employment, consumption, and both the investment in new and the investment in old projects increases. Section 3.2 shows that for a much wider range of parameter values the model can generate regular Pigou cycles; that is, in response to an anticipated shock total investment increases together with the other macro variables, but it is possible that not all investment components increase. Section 3 reports standard business cycle moments and shows that consumption, investment, and employment are all procyclical variables, also when all shocks are anticipated.

3.1 Full Pigou cycles with benchmark calibration

Figure 1 plots the responses of key variables after it has become known that productivity will increase in 12 months; it plots the responses during the anticipation phase (open markers) and during the phase when the increase in productivity has been realized (filled markers).

Responses of key variables during anticipation and realization phase. Consumption and investment in new projects increase in the first period. The increase in the investment in new projects leads to an increase in vacancies, which leads to an increase in employment, even though labor force participation initially decreases. Because of the matching friction, employment increases with a delay of one period; in the first period, capital and employment—and thus output—cannot respond to the shock. The increases in consumption and investment in new projects, thus, have to be financed out of a decrease

[19] A monthly matching probability for the firm equal to 33.8% implies that the probability of not being matched within any given quarter is equal to 29%, which corresponds to the value reported in van van Ours and Ridder (1992).

in investments in existing projects. Investment in existing projects decreases in the first two periods, but turns positive in the third period. Thus, with a delay of two months, this economy can generate full Pigou cycles. Total investment turns positive already after one month, thus, this model can generate a regular Pigou cycle with a delay of only one month.

For employment, the responses during the anticipation phase are substantial and the responses during the realization phase are a gradual continuation of the expansion started in the anticipation phase. The matching friction is clearly important for this property, but it will be shown that in itself it is not sufficient for the ability of the model to generate Pigou cycles. Whereas the employment response displays a smooth transition when the economy goes from the anticipation to the realization phase, total investment and output display a sharp increase when the realization phase starts and the increase in productivity directly affects output. But the increase during the anticipation phase is still substantial. For example, the response in output at the end of the anticipation phase is equal to 21% of the largest response observed during the realization phase.

Additional responses during anticipation and realization phase. Figure 2 plots the IRFs of some additional variables. The first two panels plot profits and firm value. Despite the fact that profits per firm decline during the anticipation phase, firm value increases sharply when the shock occurs.[20] In fact, most of the increase in firm value occurs when news hits the economy and not when the productivity increase is realized. The next two panels display the responses of the wage rate and the rental rate. The rental rate displays a moderate increase during the anticipation phase reflecting the increase in the marginal product of capital due to the increase in employment. The wage rate falls but drops by less than profits. What matters for the results is that wages are somewhat sticky when the realization phase occurs. This causes the sharp increase in firm value that is behind the increase in investment in new projects and employment. Without the drop

[20] According to Beaudry and Portier (2006), anticipated TFP shocks are associated with increases in stock prices. A sharp rise in equity values during the anticipation phase is, thus, a desirable feature of a model to have.

in wages during the anticipation phase, firm value would have increased somewhat less, but this would not have made much difference given the huge immediate increase in firm value. The drop in wages during the anticipation phase is likely to have a negative effect on labor force participation making it harder to generate Pigou cycles.[21]

Finally, the figure reports the behavior of the unemployment rate and total matches. Matches immediately increase when the news shock occurs, then tapper off as the pool of unemployed workers decreases, and increase again just before the realization of the increase in productivity. The number of unemployed, i.e., searching workers, first decreases as more workers find a job and also increase a few periods before the realization of the shock as labor force participation increases.

IRFs under optimal revenue sharing. Essential for the ability of the model to generate full Pigou cycles is that there is underinvestment in new projects. In the benchmark calibration this is due to the entrepreneur's share $\bar{\omega}$ being too low. If revenues are shared optimally and the competitive equilibrium coincides with the social planner's problem, then the model does not come close to generating Pigou cycles. Figure 3 plots the IRFs for this case and documents that in each period in the anticipation phase consumption displays a positive and investment in existing projects a negative response. Investment in new projects and labor force participation display a (small) negative response during most of the anticipation phase, but both display a sharp increase in the three periods before the realization of the shock. The sharp increase at the end of the anticipation phase is caused by the matching friction. The matching friction is similar to an adjustment cost for changes in employment, which makes it optimal to increase employment not too abruptly.[22] So although the matching friction does make it possible to generate a sharp

[21] Wages could be set according to different rules during the anticipation and the realization phase, but it is not clear how to justify this. With sticky wages there obviously is no drop in wages during the anticipation phase and this case is discussed below.

[22] It is easy to see that the matching friction is like an adjustment cost when the unemployment rate does not affect the matching probability. The law of motion for employment is then given by $N_{t+1} = (1-\rho^x)N_t + \bar{\mu}V_t^{\mu}$. With $0 < \mu < 1$, the effect of V_t on N_{t+1} is decreasing in the level of V_t, which means that it is worthwhile to spread out vacancies (and investment in new projects) through time.

increase in employment before the realization of the shock occurs, it only does so at the end of the anticipation phase. In addition, this increase in employment does not cause the other variables to increase. The surge in investment in new projects is financed by a further decrease in investment in existing projects, leaving the response for total investment negative throughout the anticipation phase. Output only displays a minuscule positive increase in the last period of the anticipation phase.

Explaining the results. The last set of results makes clear that the matching friction by itself is not enough to generate Pigou cycles and that just choosing a different way to divide revenues between the entrepreneur and the worker leads to quite different results. The question arises what explains these differences. Key is that the benchmark parameters are calibrated to generate sufficient employment volatility in response to the usual unanticipated shocks. If revenues are split optimally, then there is not sufficient employment volatility. This becomes apparent when comparing Panel A of Figure 1 with the corresponding panel in Figure 3; the employment response at the time the productivity increase is materialized for the case when revenues are divided optimally is only a fraction of the response under the benchmark calibration.

The large increase in the desired level of employment at the time of the productivity increase together with the matching friction ensure that a robust prediction of the model is a substantial increase in vacancies during the anticipation phase. This increase in the demand for labor dominates the reduction in labor supply induced by the wealth effect.[23] It is also a robust finding that output increases.[24]

[23] The sharp increase in investment in new projects, which is socially desirable given the underinvestment in new projects, implies that the wealth effect is larger in the competitive economy than in the social planner's solution. This explains why the reduction in labor force participation is larger in the competitive equilibrium than in the social planner's version of the model. In the competitive equilibrium, the observed increase in vacancies clearly dominates this reduction in labor force participation and employment increases.

[24] Changes in output are dominated by changes in employment and changes in capital are quantitatively not important. The average value of K_t is 40 times the average value of investment, so investment should display huge changes for K_t to change substantially. Moreover, a 1% change in K_t changes output by only α%. Consequently, changes in N_t dominate any possible changes in K_t.

These are only two of the necessary ingredients of a full Pigou cycle. The question remains why consumption, C_t, as well as investment in existing projects, I_t, increases. The first and hardest part of the explanation consists of explaining why $C_t + I_t$ increases. $C_t + I_t$ is equal to $Y_t - I_{N,t}$, that is, output net of the investment in new projects increases. If net resources increase, then the increase in investment in new projects is self-financing in terms of measured output. This is made possible by the efficiency gains that occur because there is underinvestment.[25] In Appendix B, a simple version of the model is presented in which it is shown analytically that if the revenues are divided optimally between the market participants that it is *impossible* for $Y_t - I_{N,t}$ to increase, that is, it would be impossible to have a full Pigou cycle. It is also shown, that $Y_t - I_{N,t}$ does increase if the entrepreneurs gets a small enough share of the revenues and there is underinvestment in $I_{N,t}$; in this case an increase in $I_{N,t}$ has a larger effect on Y_t.

If there is underinvestment, then it is a robust finding that $Y_t - I_{N,t}$ and, thus, $C_t + I_t$ increases. The only requirement is that the intertemporal elasticity of substitution $(1/\gamma)$ is not too low. If γ is above a threshold level $\bar{\gamma}$, then the reduction in the discount factor dominates and firm value actually decreases. But this threshold level $\bar{\gamma}$ is quite high. In particular, when γ equals 6.75 then the first-quarter response of investment in new projects is just about zero.[26]

Since $Y_t - I_{N,t}$ increases for a large range of values of γ, there are values of γ such that both consumption, C_t, and investment in existing projects, I_t, increase. To understand why consider the following two cases. First, if $\gamma = 0$, then investment in existing projects increases, because the increase in employment increases the rental rate. Second, when γ is sufficiently high, then the consumption smoothing motive dominates and consumption increases. Let $\tilde{\gamma}$ be the lowest value of γ for which consumption increases. For the model

[25] In Chen and Song (2008), news shocks lead to an increase in aggregate TFP because of a reallocation of capital. Equation (19) makes clear that in the model presented here there is no increase in aggregate TFP until the technological improvement materializes, which an answer to the challenge put forward in Beaudry and Portier (2006) requires.

[26] But the response then turns sharply positive in the subsequent periods. Consequently, investment in new projects will be increasing in the second quarter for an even larger range of values of γ.

to be able to generate full Pigou cycles, the only thing that is needed is that $\tilde{\gamma} < \bar{\gamma}$, but this never seems to be a binding constraint. Thus, I_t increases when $\gamma = 0$, C_t increases when $\gamma = \tilde{\gamma}$, and $C_t + I_t$ increases when $\gamma < \tilde{\gamma}$. Because of continuity, there must be a value of γ in between 0 and $\tilde{\gamma}$ such that both consumption and investment in existing projects increase.

Correct revenue sharing rule. The analysis above made clear that the model can generate Pigou cycles, but that the division of the revenues (after rental payments) between the entrepreneur and the worker is key. In particular, when the revenues are such that the competitive equilibrium is Pareto optimal, then the model does not even come close to generating Pigou cycles. This raises the question whether the calibrated sharing rule is the right one and in particular whether a sharing rule closer to the optimal division of the surplus isn't at least equally sensible. There is a lot of debate in the literature about the sharing rule and this debate is closely related to the critique of Shimer (2005) that matching models cannot generate sufficient employment volatility. The sharing rule used in this paper is calibrated so that the matching model generates sufficient employment volatility in response to the usual unanticipated shocks.[27] The contribution of this paper is to document that the model can then also generate Pigou cycles. By widening the set of realistic predictions, the paper provides additional support for the matching model and the use of a sharing rule with (i) a low value for $\bar{\omega}$ and (ii)some wage stickiness.

Robustness. Panel A of Table 2 reports the range of values of γ for which the model with the benchmark calibration can generate Pigou cycles. If the definition of a full Pigou cycle requires that the responses of C, I, I_N, N, and Y are positive starting in the second quarter then the admissible range for γ is $[0.3950, 0.4898]$.[28] If these responses are required to be jointly positive in the fourth quarter, then the range increases to $[0.3515, 0.5183]$. The range of values for γ with which the model with the benchmark calibration can gen-

[27] Hagedorn and Manovskii (2008) argue that $\bar{\omega}$ should be low and that this resolves the Shimer critique.

[28] When the Frisch elasticity is equal to 0.7 then the values of γ for which the model generates Full Pigou cycles starting in the second quarter are in the range $[0.387, 0.4314]$.

erate regular Pigou cycles is, of course, larger but not much larger. In contrast to many alternative models, a standard matching model can, thus, generate full Pigou cycles for realistic values of γ, even when it is augmented with endogenous labor force participation that reduces labor supply when an anticipated shock occurs. The success of the benchmark calibration is limited by the fact that the model does not generate Pigou cycles for alternative equally plausible values of γ.

There are basically two problems. The first problem is that there is not that much underinvestment. Investments in new projects are higher in the social planner's solution, but the employment rate is only 1.4 percentage points higher. Consequently, the increase in net resources during the anticipation phase, $Y_t - I_{N,t}$, is also not that large. The second problem is that investment in new projects, which are the engine that generates the Pigou cycles are relatively small. This is where there is some degree of freedom. If the share the entrepreneur receives, $\bar{\omega}$, increases then investment in new projects as a fraction of GDP and total investment increases. At this higher level of $\bar{\omega}$, there no longer is underinvestment in new projects in the competitive equilibrium and the model can no longer generate full Pigou cycles, but it can generate regular Pigou cycles for a substantially larger range of values for γ.

3.2 Regular Pigou cycles with alternative calibration

In the benchmark calibration, investment in new projects is on average only 1.4% of GDP and 5.8% of total investment. This could be too low given the high turnover in the US economy. For example, Davis, Haltiwanger, and Schuh (1996) argue that job destruction on an annual basis is equal to 36.8%. Because of the free entry condition, the amount invested in new projects is closely related to the share of profits that entrepreneurs receive, $\bar{\omega}$. But an increase in $\bar{\omega}$ implies that employment volatility decreases below its empirical counterpart. Employment volatility can be kept at its target by decreasing the responsiveness of wages. Under the alternative calibration, ω is set equal to zero so that wages are fully fixed.[29] This means that the model no longer matches observed wage

[29] The household always chooses an interior solution for the number of searching workers. This means that the wage rate is always within the bargaining set, that is, when all workers receive the same wage, it

volatility, but the relevance of aggregate data to pin down the volatility of individual wages is limited anyway. To match the other targets the parameters are recalibrated. In particular, the entrepreneur's share, $\bar{\omega}$, and the curvature parameter of the leisure component in the utility function, κ, are again such that the model matches the observed volatility of the employment rate and labor force participation. The new values are given in Table 1 under model II.

Responses of key variables during anticipation and realization phase. Figure 4 plots the responses during the anticipation and realization phase. The results are very similar to those reported in Figure 1. The only difference is that investment in existing projects now decreases. That is, the economy generates a regular Pigou cycle, but not a full Pigou cycle.

Since the economy operates at employment levels that are above the social planner's values, it is no longer the case that an increase in investment in new projects leads to an increase in net resources. That is, $Y_t - I_{N,t}$ now robustly decreases, which means that consumption and investment in existing projects cannot both increase. But the requirement that all types of investment should decrease is a very strict one. Beaudry and Portier (2006) only show that *total* investment increases in response to an anticipated increase in future productivity. It is far from obvious, however, that a model can generate Pigou cycles even with this somewhat weaker definition. One indication for this is the set of responses when revenues are shared between the entrepreneur and the worker such that the allocations are Pareto optimal. These are reported in Figure 5. Consumption increases, but all the other key variables decrease, including the investment in new projects. The reductions in employment, output, and both types of investment are substantially larger than those for social planner's solution reported in Figure 3. That is, based on the responses in the social planner's solution, it seems that it would be even more difficult to generate Pigou cycles for the parameter values of Model II.

Why is it possible that in the competitive equilibrium, consumption, employment, total investment, and output can jointly increase? Again it is easy to explain why investment in

doesn't make sense for a worker to quit while the household still lets workers search for jobs.

new projects increases. Because of sticky wages, the expected share entrepreneurs receive increases, which makes it attractive for them to increase investment in new projects. Because of the recalibration, the response of employment is basically identical to the response of employment in the model discussed above. A strong early increase in the demand for labor is due to (*i*) a substantial increase in the desired employment level when the productivity increase is realized and (*ii*) the matching friction.

Creating resources without changing total investment. Because there is no underinvestment in new projects, there are no efficiency gains associated with the increase in $I_{N,t}$. The puzzling aspect that needs to be explained, therefore, is where the resources come from to make it possible that both consumption, C_t, and total investment, $I_t + I_{N,t}$, can increase. The following analysis makes clear why this is possible by showing that it is possible to create resources (and, thus, increase consumption) even when labor force participation, $N_t + U_t$, and total investment $I_t + I_{N,t}$ remain unchanged. The idea is that a change in the composition of total investment creates new resources.

Starting at the steady state, consider a permanent increase in one type of investment with one unit, keeping labor force participation and the other type of investment at its steady state level. Figure 6 documents what happens with available resources. In the first period, the increase in investment leads to a reduction in available resources for both types of investment. Investment is increased in each period, but the associated increase in the capital stock or employment level increases resources and this counteracts the reduction in available resources. If investment in existing projects is permanently increased, then the increase in the capital stock very gradually reduces the reduction in available resources and available resources turn positive after 160 periods. If investment in new projects is permanently increased, then the reduction in available resources quickly increases. There is always a reduction, however, which is due to the fact that there is overinvestment in new projects for this alternative calibration. In other words, one can permanently increase resources with the opposite action, namely a permanent decrease in $I_{N,t}$. But this aspect is not important for the analysis here. The key aspect of Figure 6 is that there is a big gap between the two responses. This means that resources can be created—at least initially—while keeping $I_t + I_{N,t}$ unchanged, namely by increasing in each period the type of investment that has the least negative response, i.e., $I_{N,t}$, and by decreasing in each period the type of investment that has the most negative response, i.e., I_t. The cost of the change in the composition of investment is by construction zero. Resources increase, however, until the two IRFs in Figure 6 cross, that is after around 90 periods.

Explaining the results. The hypothetical case considered in the last paragraph made clear that it is feasible to increase available resources and employment for some time by simply changing the composition of investment. Resources do not increase permanently; at some point, the IRFs in Figure 6 cross and available resources decrease. But available resources do not have to increase permanently; they only have to increase in the anticipation phase, before the increase in productivity is realized. In the hypothetical example, total investment remains unchanged and the increase in available resources would result in an increase in consumption. If $I_{N,t}$ increases a bit more than I_t decreases, then total investment increases and consumption, of course, still increases. But this analysis just makes clear that it is *feasible* to have a regular Pigou cycle, not that it will actually happen in a competitive equilibrium.

To ensure that consumption increases in equilibrium, the value of γ needs to be high enough. It is documented below that this happens already for quite low values of γ. To generate Pigou cycles, it also must be the case that the reduction in investment in existing projects is less than the increase in investment in new projects; without this total investment would not increase. This turns out to be a robust finding. The question arises why this is the case, because the social planner would like to reduce both types of investment. That is, why wouldn't the household undo the (undesirable) increase in the investment in new projects by a sharper reduction in the investment in existing projects, thus generating the same large initial increase in consumption the household enjoys in the social planner's solution. The reason is that the increase in employment increases the rental rate. Confronted with this increase in the rental rate, the household has less incentive to increase consumption and to reduce investment in existing projects sharply.

Robustness. Table 2 documents that for the alternative calibration and the weaker definition of Pigou cycles, the model can generate Pigou cycles for a much larger range of values for γ. In particular, when consumption, investment, employment, and output are required to display a positive response starting in the second quarter, then the range of γ is equal to [0.807,1.89] and for the fourth quarter it is equal to [0.677,3.019].

3.3 Standard business cycle and labor market statistics

Table 3 reports standard business cycle as well as labor market statistics for the model and the data. It reports statistics when shocks are not anticipated (Model I) and when shocks are anticipated one year in advance (Model I "news"). To generate model statistics, the monthly data is first transformed into quarterly data and then HP-filtered.

Model properties when shocks are not anticipated. Investment in new projects is on average equal to 1.4% of GDP. This number is closely related to the share the entrepreneur receives ($\bar{\omega}$), because the free-entry condition relates the cost of posting a vacancy to the benefit when matched. Volatilities from the model for consumption, investment, and output have the standard ordering. That is, consumption is less volatile and investment is more volatile than to output.[30] Output and labor productivity are not quite as volatile as in the data.[31]

Shimer (2005) argues that standard matching models cannot generate sufficient volatility in these statistics. Here, the share that accrues to the entrepreneur is—as in Hagedorn and Manovskii (2008)— relatively small, inducing volatile profits, which in turn generate sufficiently volatile labor market statistics. One labor market statistic that the model does not fit well is the volatility of the labor share. In the standard RBC model, the labor share

[30] The model underestimates the relative volatility of consumption. The same is true for standard business cycle models. See, for example, Cooley and Hansen (1995). Employment fluctuates less than hours in the standard RBC model, which implies that the marginal productivity of aggregate capital and the rental rate are less volatile as well. This explains why investment is somewhat less volatile than in the standard RBC model.

[31] HP-filtered output is 42% more volatile than total factor productivity, Z_t, and more magnification is needed to match the observed volatility of output given the volatility of Z_t.

does not fluctuate at all and is equal to $1-\alpha$ in every period. In this model, the combined share that goes to the worker and the entrepreneur is fixed and equal to $1-\alpha$. This fixed share, however, is divided in non-constant proportions, so that the labor share does fluctuate. The standard deviation of the labor share, relative to the standard deviation of labor productivity is, however, still only 25% of its empirical counterpart.

The model generates a strong negative correlation between unemployment and vacancies, -0.69, although not as strong as the empirical counterpart, which is equal to -0.93. In contrast, the correlation between the unemployment rate and labor productivity is somewhat stronger in the model than in the data.

Model properties when shocks are anticipated. Table 3 also reports business cycle statistics when shocks are anticipated. In generating these statistics, the parameter values are not recalibrated. The table documents that second-order moments are not affected very much. That is, the pattern of second-order moments when $\tau = 12$ is roughly similar to the pattern when $\tau = 0$. There are some differences, however. Employment displays a stronger initial increase when shocks are not anticipated. The gradual increase caused by the presence of the anticipation phase means that a larger fraction of the increase in employment will be part of the trend and explains why HP-filtered employment is less volatile when shocks are anticipated. The strong increase in employment during the anticipation phase implies that this is a period in which both unemployment and labor productivity are falling, explaining the smaller negative correlation between the unemployment rate and labor productivity when shocks are anticipated.

The table also reports the correlation of consumption, employment, and both types of investment with output. They make clear that an economy that is driven solely by anticipated shocks can generate strongly cyclical consumption, employment, and investment series. In fact, the correlation coefficients are very similar to the values when shocks are not anticipated.[32] The only exception is the correlation between the cyclical component of $I_{N,t}$ and the cyclical component of output; this correlation is much lower for the case

[32] This is not very surprising given that even with anticipated shocks the realization phase is the most important part of the shock.

with anticipated shocks. This seems inconsistent with Figure 1 which shows that $I_{N,t}$ is the variable that responds most strongly when the news shock occurs. The low correlation coefficient is due to the detrending procedure.[33] The HP-filter is a two-sided filter and faced with a sharp increase in output during the realization phase, it generates a strong increase in the trend value during the anticipation phase that exceeds the actual increase. In other words, the positive response of output during the anticipation phase does not imply that the *cyclical* component increases when it is calculated using the HP-filter.[34]

Model properties under alternative calibration. Table 3 also reports the business cycle statistics for the alternative calibration under the heading model II. Average investment in new projects is now equal to 5.4% of GDP. At this higher level, there is no longer underinvestment in new projects in the competitive equilibrium and the average unemployment rate in the competitive equilibrium is now 0.8 percentage points *below* the social planner's level. To compensate for the higher value of $\bar{\omega}$, wages are assumed to be completely sticky. The results for the second-order moments are roughly similar to those when wages are not sticky. Note that with sticky wages the model actually generates a volatility of the labor share (relative to labor productivity) that is almost identical to its empirical counterpart.

3.4 Countercyclical unemployment rate

Tripier (2003), Haefke and Reiter (2006), and Veracierto (2004) argue that RBC models with a matching framework as well as endogenous labor force participation cannot generate a countercyclical unemployment rate. The model presented here, however, does generate a countercyclical unemployment rate; the correlation coefficient is equal to -0.87 when shocks are not anticipated and equal to -0.62 when shocks are anticipated.

The question arises why a simple standard matching model with endogenous labor force

[33] When the data are not HP-filtered, then the correlation coefficients are much more similar, namely 0.965 for unancitipated and 0.8807 for anticipated shocks.

[34] The empirical analysis in Beaudry and Portier (2006) documents that the response of output to a news shock should be positive, not that the response of HP-filtered output is positive.

participation can generate a countercyclical unemployment rate after all.[35] The difficulty in generating a countercyclical unemployment rate is related to the challenge for matching models to generate sufficient volatility in tightness, V_t/U_t. If tightness and therefore the matching probability is not very responsive to a positive productivity shock, then the increase in labor force participation, induced by an increase in TFP, leads to an increase in the unemployment rate. With the calibrations used here, profits and, therefore, vacancies do respond strongly to an increase in productivity. The sharp increase in vacancies allows the model to generate an increase in labor force participation *and* a reduction in the unemployment rate at the same time.

[35] Haefke and Reiter (2006) develop a much more intricate model with heterogeneity in home production that also generates a countercyclical unemployment rate.

A Data sources

Summary statistics reported in Table 3 are based on HP-filtered quarterly data. Variables not expressed as a rate are logged. From Federal Reserve Economic Data (FRED): Real gross domestic product, GDPC96; real gross private domestic investment, GPDIC96; real personal consumption expenditures (nondurable goods) PCNDGC96; index of help wanted advertising in newspapers, HELPWANT. From Shimer: Job finding and job separation probabilities. These are obtained from continuous-time 'rates' using: $probability = 1 - \exp(-rate)$; see Shimer (2005) for details. From the current population survey: Unemployment rate, LNS14000000Q; employment population ratio, LNS12300000Q; civilian labor force participation rate, LNS11300000Q. From the Bureau of Labor Statistics: Output, PRS85006043; current $ output, PRS85006053; employment, PRS85006033; nominal compensation, PRS85006063; and labor share, PRS85006173. These series are for the non-farm business sector. Real output and employment are used to construct labor productivity. The wage rate was calculated using: wage rate = (compensation/employment) $\times$ (output/current$output). The labor share index was turned into an actual labor share series by rescaling the index so that the observed value in 2002Q3 is equal to 78%, the value reported in Gomme and Rupert (2004).

B Simplified version with analytical results

Using a two-period version of the model, it is shown that Pigou cycles are not possible when the Hosios condition holds, that is, when the surplus is divided such that the competitive equilibrium corresponds to the social planners problem. It is available, in the online version, at http://xxx

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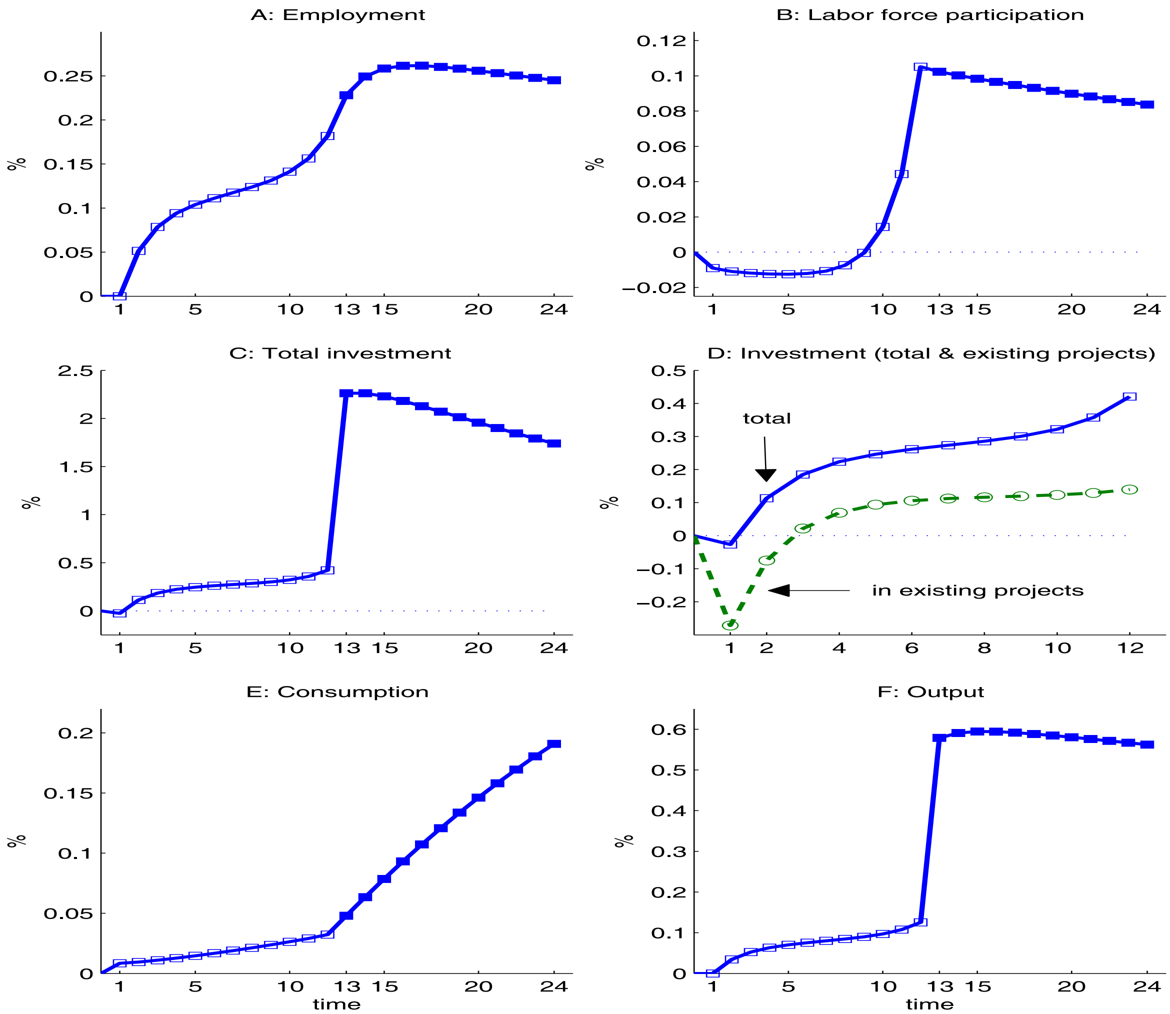
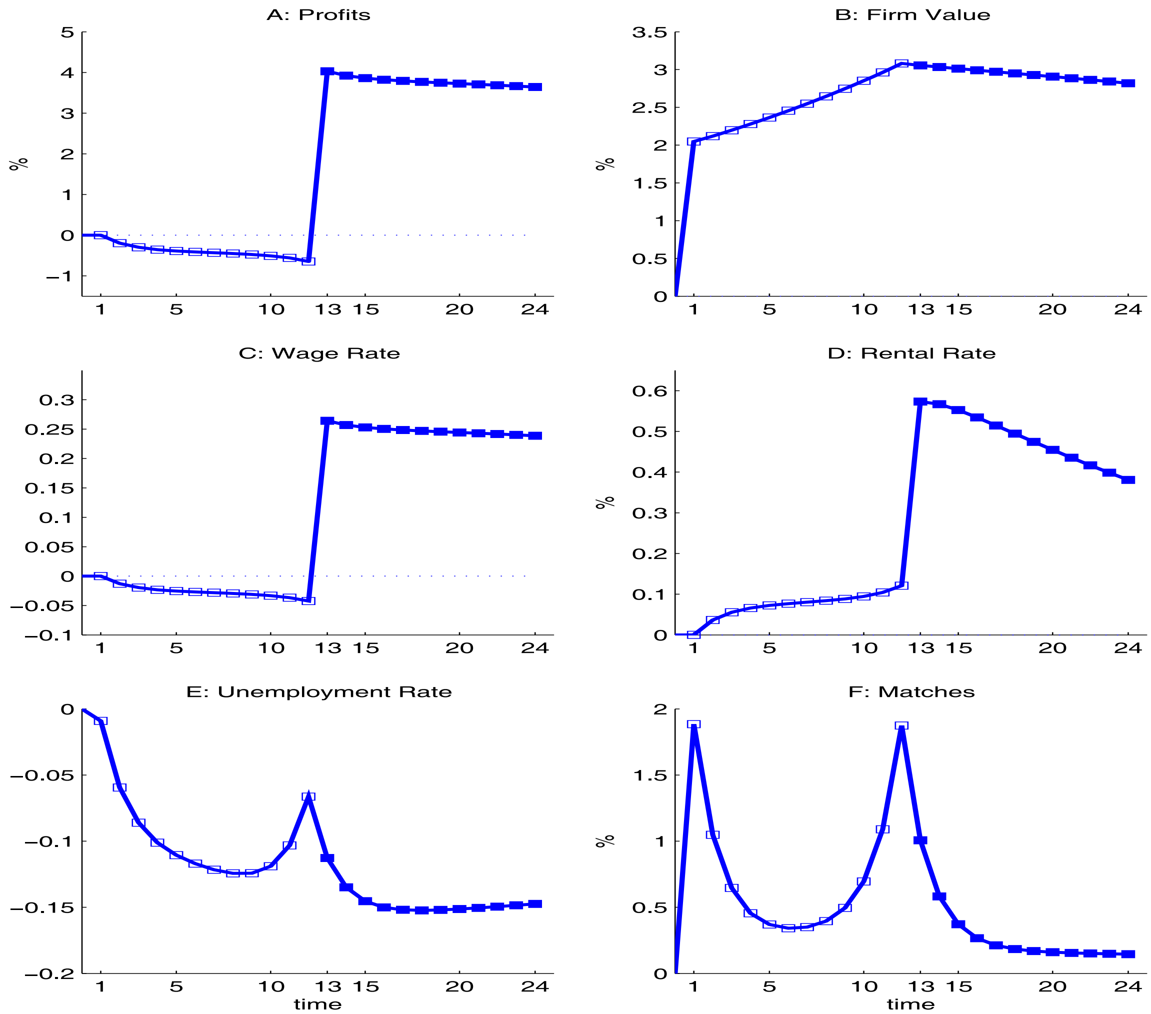
Figure 1: CE responses before and after anticipated shock is realized



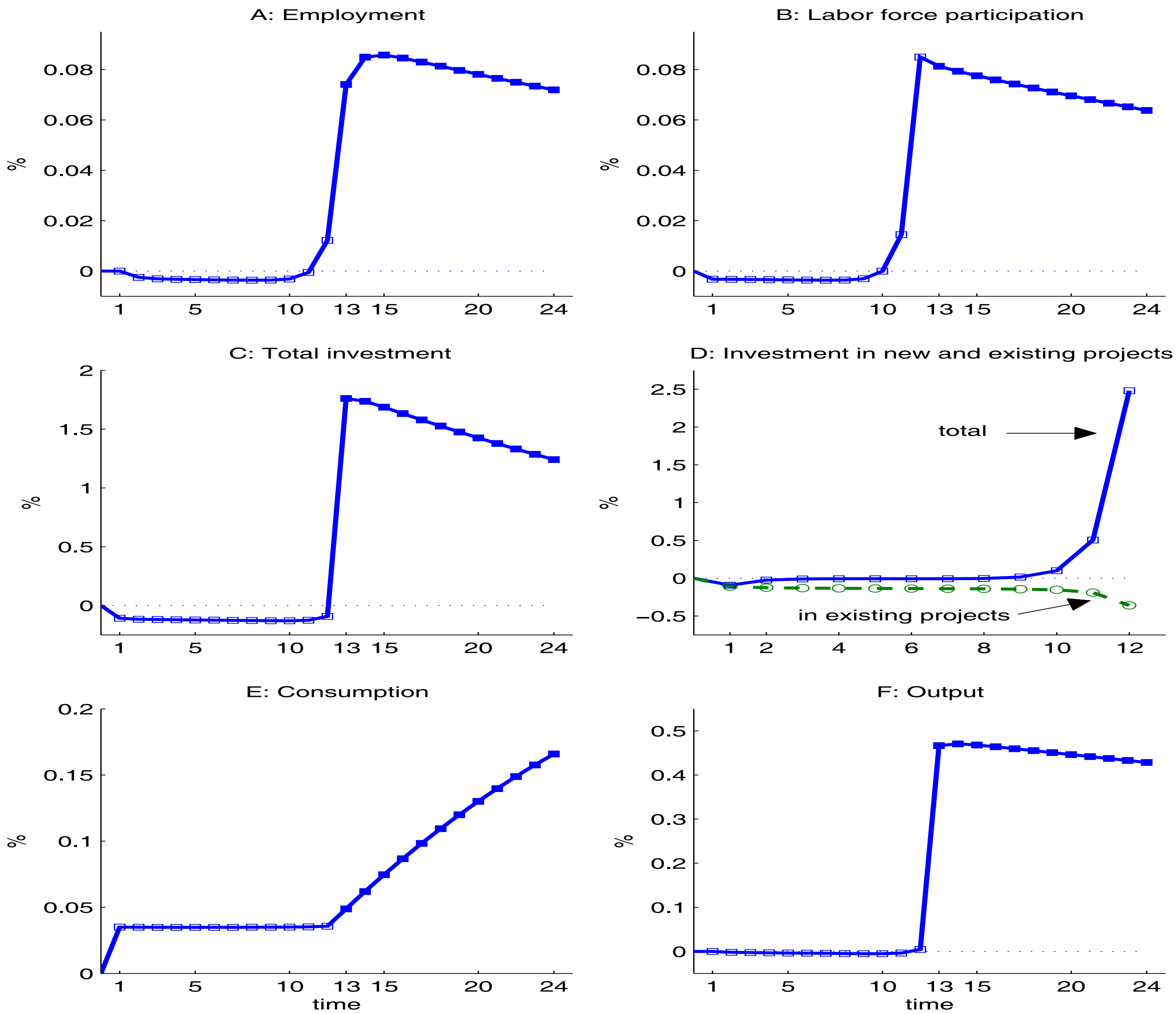
Notes: The shock occurs in period 13 but is anticipated in period 1. Markers that are (not) filled indicate the periods when the shock has (not yet) been realized.

Figure 2: Additional CE responses before and after anticipated shock is realized



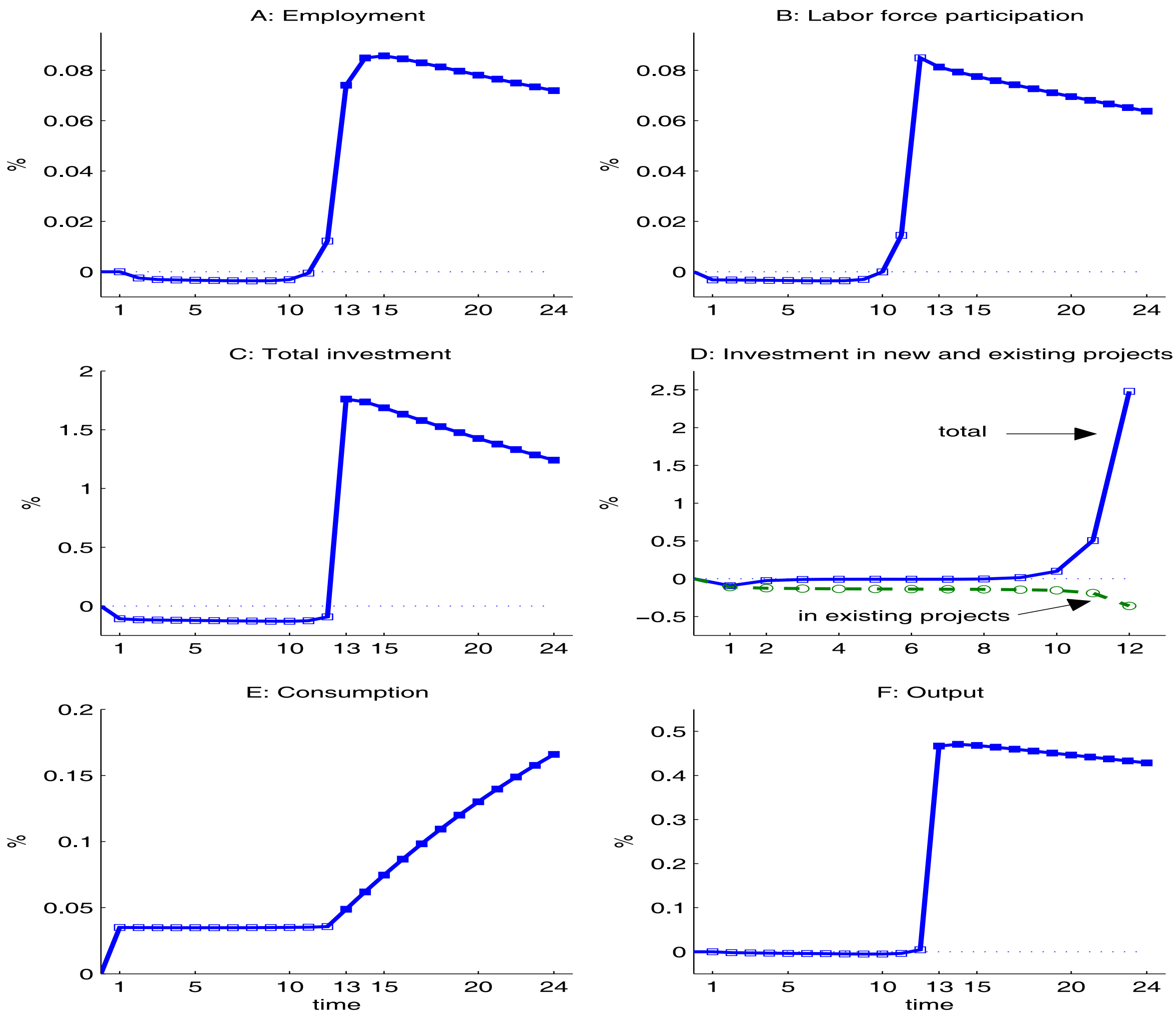
Notes: The shock occurs in period 13 but is anticipated in period 1. Markers that are (not) filled indicate the periods when the shock has (not yet) been realized.

Figure 3: Social planner responses before and after anticipated shock is realized



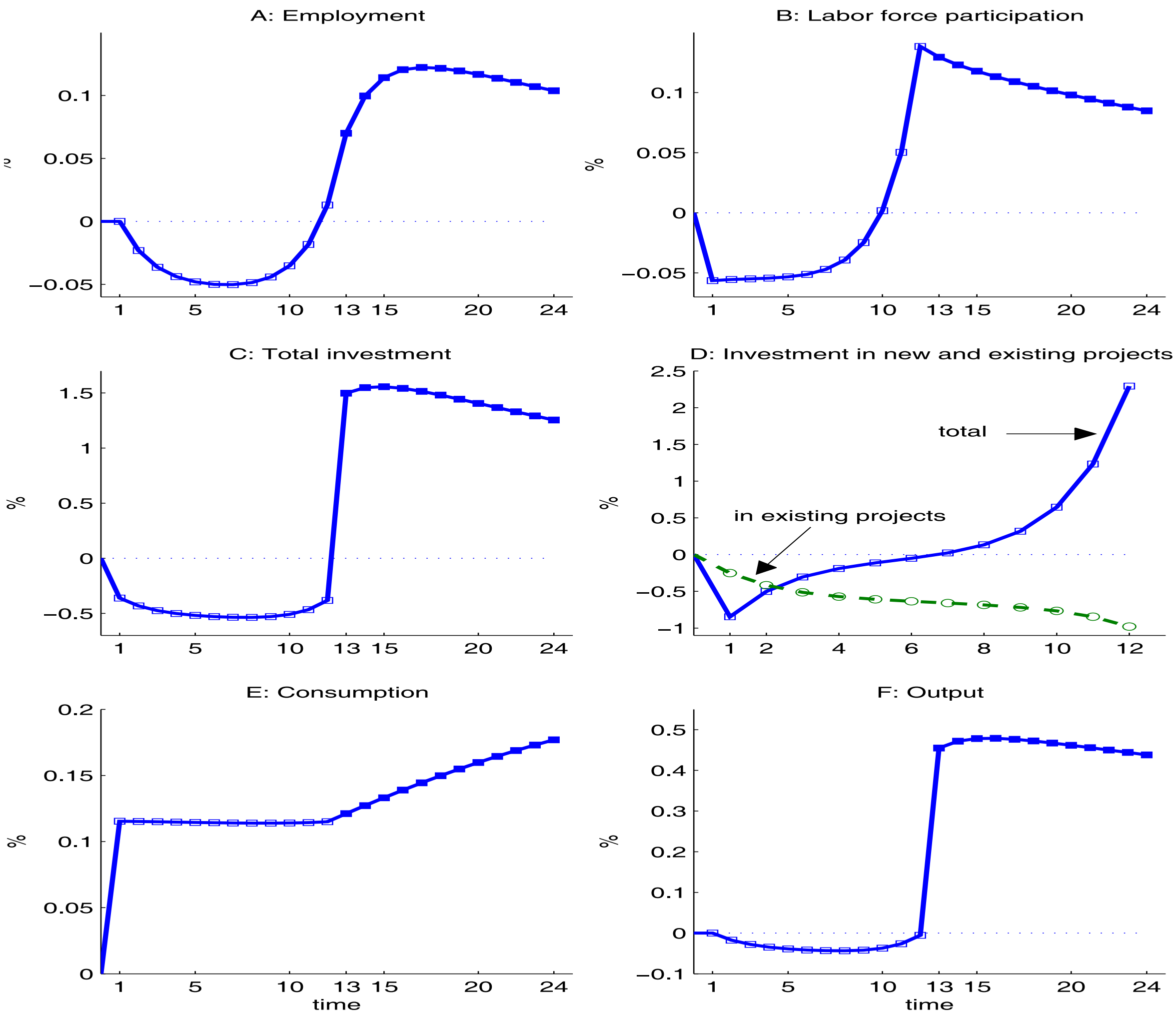
Notes: The shock occurs in period 13 but is anticipated in period 1. Markers that are (not) filled indicate the periods when the shock has (not yet) been realized.

Figure 4: CE responses before and after anticipated shock is realized (sticky wages)



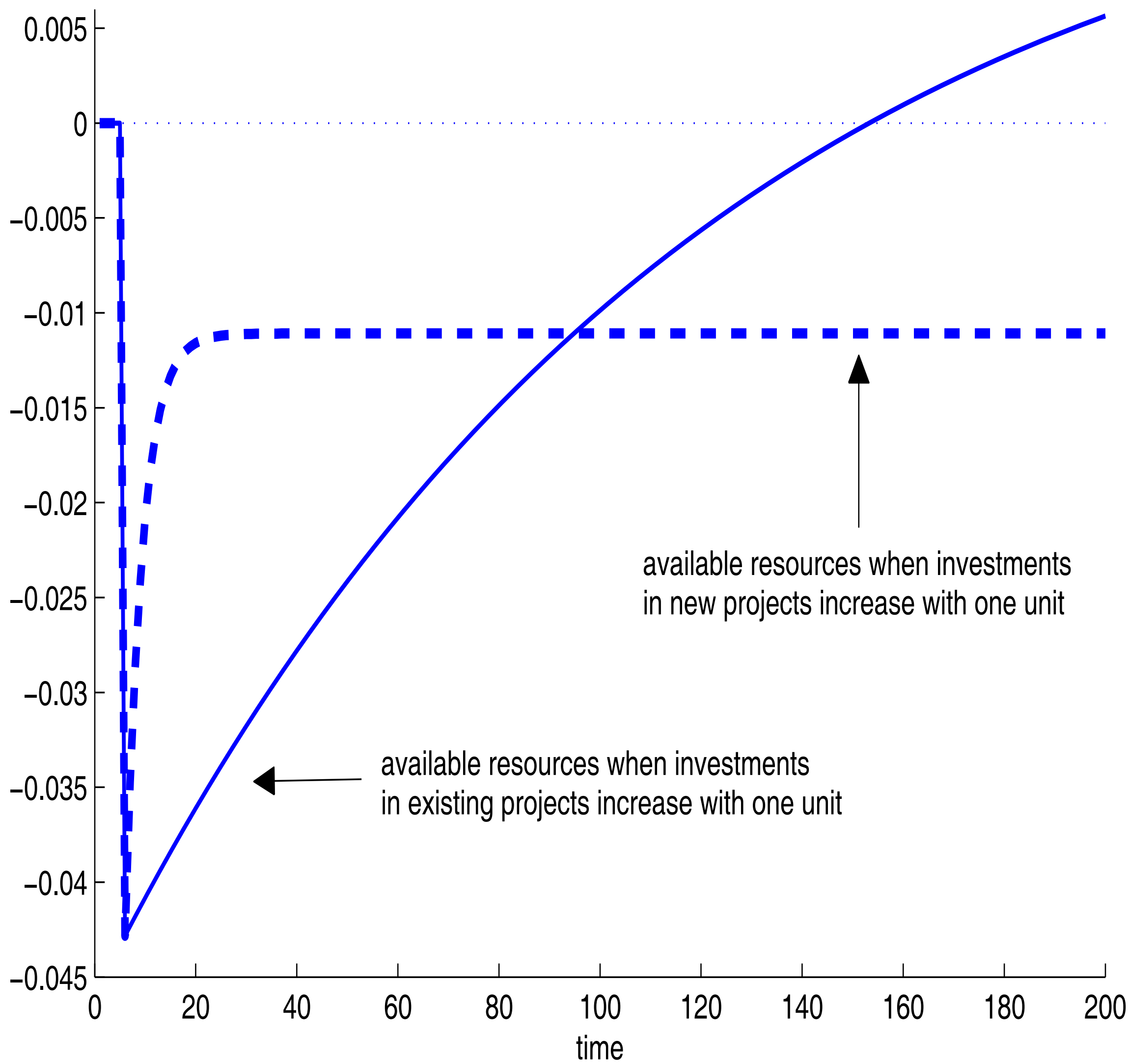
Notes: The shock occurs in period 13 but is anticipated in period 1. Markers that are (not) filled indicate the periods when the shock has (not yet) been realized.

Figure 5: Social planner responses before and after anticipated shock is realized (sticky wages)



Notes: The shock occurs in period 13 but is anticipated in period 1. Markers that are (not) filled indicate the periods when the shock has (not yet) been realized.

Figure 6: Change in available resources following permanent increase in investment



Notes: The graph plots the change in net resources when the indicated type of investment is permanently increased with one unit.

Table 1: Calibration

Parameter	Model I	Model II	Target / Source
Discount factor, β	0.9966	0.9966	Standard annual value = 0.96
Relative risk aversion, γ	0.43	1	Range of values considered
Scaling utility of leisure, ϕ	0.4334	0.4958	$U + N = 1$
Curvature utility of leisure, κ	2.652	1.1	$\sigma\left[\frac{U+N}{L^*}\right]/\sigma\left[\ln\frac{Y}{N}\right] = 0.182$
Time endowment, L^*	1.5938	1.5938	$\frac{U+N}{L^*} = 0.6274$
Curvature production function, α	0.3178	0.2746	$\alpha + \omega_0(1-\alpha) = 1/3$
Depreciation rate, δ	0.0084	0.0084	standard annual value = 0.10
Persistence parameter, ρ	0.98	0.98	match quarterly analogue
Innovation standard deviation, σ	0.0042	0.0042	match quarterly analogue
Wage sensitivity, ω	0.7547	0	$\sigma[\ln W]/\sigma\left[\ln\frac{Y}{N}\right] = 0.755$
Share of entrepreneur, $\bar{\omega}$	0.0228	0.091	$\sigma\left[\frac{N}{L^*}\right]/\sigma\left[\ln\frac{Y}{N}\right] = 0.437$
Match elasticity, μ	0.50	0.50	Petrongolo and Pissarides (2001)
Scaling match function, $\bar{\mu}$	0.3917	0.3917	$\lambda^w = 45.4\%$
Period entry cost, ψ	0.7937	2.128	$\lambda^f = 33.8\%$
Exogenous destruction rate, ρ^x	0.027	0.027	$\frac{U}{U+N} = 5.7\%$

Table 2: Robustness: Values of γ that generate Pigou cycles

A: Model I (model with underinvestment)

Start of the Pigou Cycle	Regular	Full
1^{st} quarter	$[0.4075, 0.5061]$	
2^{nd} quarter	$[0.3950, 0.6697]$	$[0.3950, 0.4898]$
4^{th} quarter	$[0.3593, 0.8988]$	$[0.3593, 0.5142]$
12^{th} month	$[0.3515, 1.122]$	$[0.3515, 0.5183]$

B: Model II (model with no underinvestment)

Start of the Pigou Cycle	Regular
1^{st} quarter	$[0.850, 1.322]$
2^{nd} quarter	$[0.807, 1.890]$
4^{th} quarter	$[0.677, 3.019]$
12^{th} month	$[0.647, 5.970]$

Notes: For values of γ in the indicated range the responses of consumption, employment, output, and total investment (for regular Pigou cycles) and the responses of consumption, employment, output, and both types of investment (for full Pigou cycles) are jointly positive starting in the indicated period.

Table 3: Summary Statistics

	Data	Model I	Model I "news"	Model II	Model II "news"
Anticipated shocks		No	Yes	No	Yes
ω		0.7547	0.7547	0	0
Used for calibration					
$\mathrm{E}[U/(U+N)]$	0.057	0.058	0.058	0.058	0.059
$\mathrm{E}[N/L^*]$	0.592	0.592	0.592	0.592	0.592
$\sigma\left[\frac{U+N}{L^*}\right]/\sigma\left[\ln\frac{Y}{N}\right]$	0.182	0.185	0.185	0.185	0.212
$\sigma\left[\frac{N}{L^*}\right]/\sigma\left[\ln\frac{Y}{N}\right]$	0.437	0.436	0.352	0.438	0.378
$\sigma[\ln W]/\sigma\left[\ln\frac{Y}{N}\right]$	0.755	0.755	0.755	0	0
Comovement					
$\mathrm{COR}(\ln C, \ln Y)$	0.78	0.48	0.42	0.67	0.41
$\mathrm{COR}(\ln(I_N+I), \ln Y)$	0.88	0.97	0.97	0.99	0.99
$\mathrm{COR}(\ln I_N, \ln Y)$	-	0.85	0.32	0.85	0.32
$\mathrm{COR}(\ln I, \ln Y)$	-	0.97	0.98	0.94	0.94
$\mathrm{COR}(\ln N, \ln Y)$	0.77	0.96	0.89	0.96	0.90
Other statistics					
$\mathrm{E}[\psi V/Y]$	-	0.014	0.014	0.053	0.059
$\sigma[\ln Y]$	0.016	0.013	0.012	0.0125	0.012
$\sigma[\ln(I_N+I)]/\sigma[\ln Y]$	4.56	3.82	3.89	3.73	3.90
$\sigma[\ln C]/\sigma[\ln Y]$	0.696	0.305	0.306	0.175	0.147
$\sigma\left[\ln\frac{N}{L^*}\right]/\sigma[\ln Y]$	0.466	0.437	0.396	0.437	0.415
$\sigma[\ln Y]/\sigma[\ln Z]$		1.42	1.35	1.43	1.34
$\sigma\left[\ln\frac{Y}{N}\right]$	0.013	0.0074	0.0079	0.0074	0.0077
$\sigma\left[\frac{NW}{Y}\right]/\sigma\left[\ln\frac{Y}{N}\right]$	0.644	0.164	0.164	0.668	0.668
$\sigma\left[\frac{V}{U}\right]/\sigma\left[\ln\frac{Y}{N}\right]$	19.0	26.9	23.9	28.0	24.7
$\sigma[\lambda^w]/\sigma\left[\ln\frac{Y}{N^w}\right]$	2.64	4.06	3.55	4.24	3.69
$\mathrm{COR}\left[\ln Y, \frac{U}{U+N}\right]$	-0.86	-0.87	-0.62	-0.96	-0.68
$\mathrm{COR}\left[\ln\frac{Y}{N}, \frac{U}{U+N}\right]$	-0.33	-0.72	-0.48	-0.73	-0.49
$\mathrm{COR}\left[\ln V, \frac{U}{U+N}\right]$	-0.93	-0.69	-0.78	-0.70	-0.77

Notes: Monthly data from the model are transformed into quarterly data and then filtered using the HP-filter. Model statistics are averages across 1,000 Monte Carlo samples of 218 quarterly observations, which corresponds to the length of the empirical sample. Data sources used to construct the empirical counterparts are discussed in Appendix A.