Pigou Cycles in Closed and Open Economies with Matching Frictions

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Abstract

Den Haan and Kaltenbrunner (2009) show that a simple labor market matching model can generate Pigou cycles—i.e., a positive comovement in consumption, investment, and employment in response to *news* about *future* macroeconomic developments. However, investment moves in the right direction only for a small set of parameter values. This paper shows that an open-economy version in which international capital flows dampen domestic interest rate responses can robustly generate Pigou cycles. In models with a spot market for labor, sticky interest rates reinforce the wealth effect and make it *more* difficult to generate Pigou cycles. In a matching model, however, both the demand and the supply of labor are investment decisions and sticky interest rates reinforce the increase in these investments following a positive news shock. The stronger employment response raises the expected return on capital, which ensures a robust increase in capital investment as well.

Keywords: Small open economy, sticky interest rate, news shock

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1 Introduction

The idea that widespread beliefs about *future* macroeconomic developments can affect *current* economic conditions has a long tradition in economics and recently there has been a renewed interest in this research topic.[1] Limited attention has been given, however, to the question whether the effects of such changes in beliefs about future (domestic) growth depend on how easy it is to trade commodities and financial assets with the rest of the world.[2] The objective of this paper is to shed light on this question.

We focus on two specific questions. First, we will investigate whether *news shocks*, i.e. changes in the expectations about future growth, have a larger effect on output in closed or in open economies. The characterizing aspect of a news shock is that the underlying fundamental characteristics of the economy like preferences, productivity levels, and government policies remain unchanged for the time being. Only *beliefs* about future developments are affected. Second, we address the question whether the increase in output induced by a positive news shock is part of a Pigou cycle. A news shock is said to generate a Pigou cycle if output, consumption, investment, and employment move in the same direction, that is, if these key aggregate variables behave according to a typical business cycle pattern.

An open economy differs in several aspects from a closed economy. Two of these differences are important for the question addressed here. The first difference is related to what is feasible when aggregate employment is either decreasing or unchanged. In a closed economy, consumption and investment cannot both increase when productivity is

[1] See, for example, Pigou (1927), Beaudry and Portier (2004, 2006, 2007), Jaimovich and Rebelo (2008, 2009), Schmitt-Grohé and Uribe (2008), and Walentin (2008). Related is the analysis in Lorenzoni (2009) in which "noise" shocks to aggregate productivity make agents believe they face a (persistent) change in economic conditions, while the environment has in fact not changed.

[2] Two exceptions are Jaimovich and Rebelo (2008) and Beaudry, Dupaigne, and Portier (2009). The main difference between the model developed in this paper and the models of these two papers is that our model is simpler and close to standard models used in the macro-labor literature.

unchanged unless employment increases.[3,4] If a country can import commodities, however, then it is possible for all domestic spending components to increase without an increase in employment. The second difference is related to the endogeneity of prices. In an open economy, domestic asset and commodity prices are at least *to some extent* sheltered from domestic events, because they are determined by world prices.

The question arises how to model the effect of international trade on domestic prices. Interest rates at which domestic residents borrow and lend from abroad and the prices at which they buy (sell) imported (exported) goods cannot be completely exogenous to domestic development, because this would lead to unrealistically high fluctuations in the trade balance.[5] Therefore, we assume that domestic prices are determined by world prices *and* a markup or markdown that depends on the amount of international trade. For example, if the net amount borrowed by a country increases, then this puts upward pressure on the interest rate paid. In the open economy, prices and interest rates are, thus, still affected by domestic developments, but less so than in the closed economy.

Beaudry and Portier (2007) point out that it is not trivial to generate Pigou cycles in closed-economy models. The reason is the following. A more favorable outlook for the future is likely to lead to an increase in consumption. Given that there is not yet a change in the economic environment, this can only occur if either investment or leisure decreases. If investment drops, then there is no Pigou cycle. Thus, leisure has to decrease, but this is unlikely to happen. With regular preferences, the increase in consumption leads to a reduction in the benefits of working, which would lead to an *increase* in leisure.

Jaimovich and Rebelo (2008) point out that one can expect this increase in leisure to be larger in an open economy, which in turn implies that positive news shocks lead to

[3] An increase in both consumption and investment could be financed out of a decrease in government expenditures. But it is unlikely that good news about the future leads to a reduction in government expenditures.

[4] It is possible that output increases, because inputs are used more efficiently, while structural measures of productivity remain unchanged. But this would correspond to an upward shift of the production function, while the challenge in generating Pigou cycles is to see whether it is possible to generate them without such shifts.

[5] In fact, most models would not be well behaved if the interest rate is completely fixed.

smaller output increases (or larger output decreases) in an open economy. The reason is the following. In a closed economy, agents face a trade-off between consumption smoothing and an increase in investment when capital is most productive. In an open economy, agents can smooth consumption by borrowing from abroad and simply invest the most when capital is most productive. Consequently, an increase in productivity is more valuable for agents in an open economy. The wealth effect, which is behind the increase in leisure, is therefore also larger in an open economy. The larger drop in employment in turn implies a larger drop in the marginal productivity of capital, which also results in a lower capital response during the anticipation phase in the open economy.[6] Consequently, one can expect a positive news shock to generate a larger *reduction* in output in an open-economy RBC model than in the corresponding closed-economy version.

The reasoning above is based on standard RBC models with a spot market for labor. We model the labor market, however, using a standard matching framework, modified to allow for endogenous labor force participation.[7] With this model, we reach a conclusion that is the opposite from the one obtained with the standard RBC model. That is, we show that in an open economy with a sticky interest rate, news shocks have *larger* effects on output than in a closed economy. In a matching model, the employment decision is an investment decision. This is true for both labor supply and for labor demand. The reason why the increases in labor demand and labor supply are larger in the open economy is the following. To take advantage of the increase in productivity both employers and employees have to start searching for a match before the anticipated increase occurs. In anticipation of higher future consumption levels, interest rates increase in our closed-economy matching models. *Real* interest rates can still change in the open economy with sticky interest rates. Not surprisinly, the increase turns out to be smaller than the one observed in the closed economy. A lower real interest rate implies that the proceeds of investments, including the investment in employment relationships by employers and employees, are discounted less.

[6] In Appendix A, we document these claims using a simple RBC model.

[7] Labor force participation is usually exogenous in matching models. Endogenous labor force participation makes the model more realistic, but also makes it more difficult to generate Pigou cycles, because it introduces the wealth effect on labor supply into the model.

This makes the NPV of the investment more valuable. Moreover, there is an interaction between the investment to search for work by workers and the investment to search for workers by firms. An increase in labor demand increases the job finding rate for a worker and thus the benefits of a worker of searching for a job. Similarly, an increase in labor supply increases the probability that a firm finds a worker, making it more attractive to post vacancies.

So although the wealth effect is larger in the open-economy version of the model, employment still increases by more due to the smaller increase in the (real) interest rate. Given the large size of the capital stock and the relatively small impact of changes in capital on output, large changes in investment are needed to have sizeable effects on output capacity. Consequently, output basically follows employment, which means that output also responds more strongly to news shocks in the open-economy version with sticky interest rates. Although changes in the capital stock are unlikely to be quantitatively important for changes in output, the question whether investment decreases or increases is a key element of the analysis of Pigou cycles.

A positive response for employment and output is not enough for favorable news shocks to also generate positive responses for both consumption and investment. Den Haan and Kaltenbrunner (2009) address this question in a closed-economy matching model and find that the increase in employment robustly generates an increase in the *sum* of consumption and investment, but that an increase in both spending components is found for only a small subset of parameters.

In the open-economy version of the model with sticky interest rates, the larger increases in employment and output imply that the sum of consumption and investment also increases by more. For both consumption and investment to increase, however, this should not only be feasible. The incentives to increase both spending components should also be present. Den Haan and Kaltenbrunner (2009) find that consumption increases for most parameter values, but that investment does not. Here we find that investment does robustly increase in the open-economy version of the model with sticky interest rates. The reason is that the larger increase in employment puts upward pressure on the expected rate of return on capital, which in turn leads to an increase in investment.

Recently, a discussion has emerged about the robustness of the claim made in Beaudry and Portier (2006) that Pigou cycles are quantitatively important for business cycle fluctuations. This paper does not take a stand on whether changes in beliefs about future events play a quantitatively important role in explaining business cycles. Studying Pigou cycles is also interesting if they are only important during specific episodes and it seems improbable that news shocks never play an important role. One episode during which changes in anticipated growth are likely to have been important is the second half of the nineties. During this period, many academics and non-academics—including prominent economists like Alan Greenspan—were hopeful that we were at the dawn of an era with high productivity growth.[8] And it seems plausible that this positive outlook was an important factor behind the boom of the second half of the nineties and it also seems plausible that the downward adjustment of beliefs played a role during the recession at the beginning of the new Millennium.

The question how news shocks affect the economy may very well be of importance in the current environment in which the market anxiously awaits how governments will (or will not) restructure the financial system. A poorly developed plan that is believed to be harmful for future economic growth could affect current economic activity through its negative effects on expectations.

The rest of this paper is organized as follows. Section 2 lays out the model. Section 3 discusses the calibration strategy and the ability of the model to describe regular business cycles. Section 4 discusses the ability of the closed and open-economy versions of the model to generate Pigou cycles.

[8] 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.'

2 Model

The economy consists of firms and workers. Both can perfectly insure 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 in an ongoing employment position.

The key decision that is *not* made by the household is the investment decision. This decision is made by firms. There are two types of investments. The first type is investment in capital of existing projects. The second type is the investment to create new projects. To create a new project, the firm has to invest a periodic fixed amount until a suitable project and a worker have been found.

The probability that an operating project remains viable and continues to operate in the next period is equal to $1 - \rho_x$. Productivity is high enough so that endogenous separation does not occur.

There are two sectors, a sector to produce consumption commodities and a sector to produce investment commodities. Firms have to search for workers in the matching market of their own sector, whereas workers can choose in which labor market to search.[9]

2.1 New operational projects

A part of getting a project ready for production is the search for a worker and for each project in the planning phase a vacancy is posted. The total number of projects that become operational in sector j, $m_{j,t}$, is determined by the number of projects in the planning phase in sector j, $v_{j,t}$, and the number of workers that is searching in section

[9] Without doubt, there are restrictions on worker flows across sectors. Such restrictions would make it easier to generate Pigou cycles, because they make it more difficult for consumption and investment to move in different directions. The problem is that it is not obvious which particular friction to choose and determining the appropriate severity of the friction is hard. Instead, we ask the question how far we get with this type of model without imposing such additional frictions.

j, $\tilde{u}_{j,t}$.[10] For the functional form we use a standard constant returns to scale function.[11] That is:

$$m_{j,t} = \bar{\mu}\tilde{u}_{j,t}^{\mu} v_{j,t}^{1-\mu}, \quad j \in \{c, i\}. \tag{1}$$

The matching probabilities for the worker and the firm are given by

$$\tilde{\pi}_{j,t} = \frac{m_{j,t}}{\tilde{u}_{j,t}} \text{ and } \pi_{j,t} = \frac{m_{j,t}}{v_{j,t}}, \quad j \in \{c, i\}. \tag{2}$$

This formulation corresponds exactly to the standard matching framework. The only difference is that we make explicit in our interpretation of the formulas that creating a new job involves more than placing an ad in the newspaper.[12] Although the costs of creating new jobs/projects should be nontrivial and definitely exceed the cost of placing an ad, they are calibrated to be modest. In particular, they are below 3% of aggregate output.

2.2 Firms

In this subsection, we describe the firm problem. Domestic firms sell their products to domestic consumers, domestic firms, or the exporting company. The exporting company pays the firm the same price as the domestic users of the products so the firm is indifferent to whom it sells its products.[13]

Employment and production. The total number of commodities allocated to investment in new projects is equal to $\widehat{i}_{j,t}$. The per-period cost in the planning phase is equal to ψ_j. Thus the total number of projects in the planning phase is equal to $\widehat{i}_{j,t}/\psi_j$. Given the success rate defined in Equation (2), the law of motion for the number of operational

[10] Throughout this paper, we indicate variables chosen by the household with a tilde.

[11] Strictly speaking, there is a constraint that $m_{j,t}$ cannot be more than either $\tilde{u}_{j,t}$ or $v_{j,t}$, but this constraint turns out not to be binding in any of the cases we considered.

[12] The formulation in Equation (2) captures the probability that a suitable plan and a suitable worker is found. Fujita (2003) models these aspects separately, but for our purposes the key aspect is success on both fronts.

[13] The exporting firm is discussed in more detail in Section 2.4.

projects, $n_{j,t}$, can be written as

$$n_{j,t+1} = \pi_{j,t} \frac{\widehat{i}_{j,t}}{\psi_j} + (1 - \rho_x) n_{j,t}, \qquad j \in \{c, i\}. \tag{3}$$

This equation also gives the law of motion for employment in sector j, since each operational project requires one worker.

Firms use labor and capital as inputs. The total amount of capital is equal to $k_{j,t}$. Because of decreasing returns to scale, each project is allocated an equal amount of capital. Total production in sector j, $y_{j,t}$, is given by

$$y_{j,t} = z_t n_{j,t} \left(\frac{k_{j,t}}{n_{j,t}} \right)^{\alpha} = z_t k_{j,t}^{\alpha} n_{j,t}^{1-\alpha}, \qquad j \in \{c, i\}, \tag{4}$$

where z_t denotes aggregate productivity. The law of motion for z_t is given by

$$\ln z_t = \rho \ln z_{t-1} + \varepsilon_t. \tag{5}$$

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

Wages. The equation that determines the nominal wage rate in sector j, $w_{j,t}$, is given by:

$$w_{j,t} = \bar{\omega} \left[\omega p_{j,t} \frac{y_{j,t}}{n_{j,t}} + (1 - \omega) \left[\bar{p}_j \frac{\bar{y}_j}{\bar{n}_j} \right] \right], \quad j \in \{c, i\}, \tag{6}$$

where $\bar{\omega}$ and ω are fixed parameters, $p_{j,t}$ is the output price in sector j, and $[\bar{p}_j \bar{y}_j / \bar{n}_j]$ is the steady state value of $p_{j,t} y_{j,t} / n_{j,t}$. The parameter ω controls how the wage rate responds to changes in revenues. Wages are fixed when $\omega = 0$, whereas wages are proportional to the marginal revenue of an extra unit of labor when $\omega = 1$. We will choose the value of ω to match the observed wage volatility. The steady state wage rate is equal to $\bar{\omega}[\bar{p}_j \bar{y}_j / \bar{n}_j]$. Thus, $\bar{\omega}$ determines the fraction of revenues the worker receives in the steady state.

We set $\bar{\omega}$ equal to $(1 - \alpha)(1 - \omega_e)$ and calibrate the value of ω_e. The parameter ω_e can be thought of as the compensation for the entrepreneurial activity of initiating the project. In the steady state, the wage rate is, thus, equal to the marginal product of labor scaled down by $(1 - \omega_e)$ and total wages are equal to the fraction $(1 - \alpha)$ of total revenues, again scaled down by $(1 - \omega_e)$.

Firm problem. The firm maximizes the net present value of firm profits, using the marginal rate of substitution of the household, $\beta^{\tau}\tilde{\lambda}_{t+\tau}/\tilde{\lambda}_t$, to discount future profits. The maximization problem of the firm in sector j is given by

$$\max_{\left\{\begin{array}{c} n_{j,t+\tau+1}, y_{j,t+\tau}, k_{j,t+\tau+1}, \\ i_{j,t+\tau}, \widehat{i}_{j,t+\tau}, \widehat{\widehat{i}}_{j,t+\tau} \end{array}\right\}_{\tau=0}^{\infty}} \mathrm{E}_t \left[\sum_{\tau=0}^{\infty} \beta^{\tau} \left(\frac{\tilde{\lambda}_{t+\tau}}{\tilde{\lambda}_t}\right) \left(\begin{array}{c} p_{j,t+\tau} y_{j,t+\tau} \\ -w_{j,t+\tau} n_{j,t+\tau} - p_{i,t+\tau} i_{j,t+\tau} \end{array} \right) \right]$$

s.t.

$$n_{j,t+\tau+1} = \tilde{\pi}_{j,t+\tau} \frac{\widehat{i}_{j,t+\tau}}{\psi_j} + (1-\rho_x) n_{j,t+\tau} \tag{7}$$

$$y_{j,t+\tau} = z_{t+\tau} k_{j,t+\tau}^{\alpha} n_{j,t+\tau}^{1-\alpha} \tag{8}$$

$$k_{j,t+\tau+1} = (1-\delta) k_{j,t+\tau} + \widehat{\widehat{i}}_{j,t+\tau} \tag{9}$$

$$i_{j,t+\tau} = \widehat{i}_{j,t+\tau} + \widehat{\widehat{i}}_{j,t+\tau} \tag{10}$$

Here, $\widehat{\widehat{i}}_{j,t}$ is the investment in existing projects in sector j. The first-order conditions of the optimization problem for a firm in sector $j \in \{c, i\}$ are the following:

$$p_{i,t} \psi_j = \pi_{j,t} V_{j,t} \tag{11}$$

$$V_{j,t} = \beta \mathrm{E}_t \left[\frac{\tilde{\lambda}_{t+1}}{\tilde{\lambda}_t} \left(\begin{array}{c} (1-\alpha)\, p_{j,t+1} z_{t+1} k_{j,t+1}^{\alpha} n_{j,t+1}^{-\alpha} \\ -w_{j,t+1} + (1-\rho_x) V_{j,t+1} \end{array} \right) \right] \tag{12}$$

$$p_{i,t} = \beta \mathrm{E}_t \left[\frac{\tilde{\lambda}_{t+1}}{\tilde{\lambda}_t} \left(\alpha p_{j,t+1} z_{t+1} k_{j,t+1}^{\alpha-1} n_{j,t+1}^{1-\alpha} + p_{i,t+1} (1-\delta) \right) \right] \tag{13}$$

Here V_t is the Lagrange multiplier of the constraint on labor adjustment and can be interpreted as the value to the firm of an extra operating project.

2.3 The household

The representative household chooses consumption, $\tilde{c}_t$, and the amount of time spent on leisure and home production, $\tilde{l}_t$. The endogenous labor supply is equal to the amount of time not spent on leisure and home production, $l^* - \tilde{l}_t$.[14] Total labor supply consists of

[14] 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

(i) employment in the sector producing consumption commodities, $\tilde{n}_{c,t}$, (ii) employment in the sector producing investment commodities, $\tilde{n}_{i,t}$, and (iii) unemployment in the two sectors, $\tilde{u}_{c,t}$ and $\tilde{u}_{i,t}$. We let $\tilde{n}_t = \tilde{n}_{c,t} + \tilde{n}_{i,t}$ and $\tilde{u}_t = \tilde{u}_{c,t} + \tilde{u}_{i,t}$. Thus,

$$l^* - \tilde{l}_t = \tilde{n}_t + \tilde{u}_t. \tag{14}$$

Next period's beginning-of-period employment consists of those workers that have not experienced exogenous separation, $(1-\rho_x)\tilde{n}_{j,t}$, and those workers that are matched during the current period, $\tilde{\pi}_{j,t}\tilde{u}_{j,t}$. Thus:

$$\tilde{n}_{j,t+1} = \tilde{\pi}_{j,t}\tilde{u}_{j,t} + (1-\rho_x)\tilde{n}_{j,t}, \quad j \in \{c, i\}. \tag{15}$$

The household can borrow and lend at an interest rate r_t. The interest rate depends on the *aggregate* amount borrowed from international investors. In particular, we assume that

$$r_t = r_t^w + \eta_r d_{t+1}, \tag{16}$$

where d_{t+1} is the aggregate amount the economy borrows.[15] If d_{t+1} is negative, then the domestic economy is a net lender. Since r_t depends on the aggregate and not the individual debt level, it is taken as given by the household. Finally, as owner of the firm the household receives dividends, q_t.

counterpart, which facilitates the calibration of the model.

[15] This specification not only assumes that the interest rate increases as debt ($d_{t+1} > 0$) increases, but also that one obtains a lower rate of return as the amount invested abroad ($d_{t+1} < 0$) increases.

The household's maximization problem is as follows:

$$\max_{\left\{\begin{array}{c}\tilde{u}_{c,t+\tau},\tilde{u}_{i,t+\tau},\tilde{u}_{t+\tau},\\ \tilde{n}_{c,t+\tau+1},\tilde{n}_{i,t+\tau+1},\tilde{n}_{t+\tau+1},\\ \tilde{c}_{t+\tau},\tilde{l}_{t+\tau},\tilde{d}_{t+\tau+1}\end{array}\right\}_{\tau=0}^{\infty}} \mathrm{E}_t \sum_{\tau=0}^{\infty} \beta^{\tau} \left[\frac{(\tilde{c}_{t+\tau})^{1-\gamma}-1}{1-\gamma} + \phi \frac{\left(\tilde{l}_{t+\tau}\right)^{1-\kappa}-1}{1-\kappa} \right],$$

s.t.

$$\tilde{n}_{j,t+\tau+1} = \tilde{\pi}_{j,t+\tau}\tilde{u}_{j,t+\tau} + (1-\rho_x)\tilde{n}_{j,t+\tau} \tag{17}$$

$$\begin{gathered} p_{c,t+\tau}\tilde{c}_{t+\tau} + (1+r_{t+\tau-1})\tilde{d}_{t+\tau} = \\ w_{c,t+\tau}\tilde{n}_{c,t+\tau} + w_{i,t+\tau}\tilde{n}_{i,t+\tau} + \tilde{d}_{t+\tau+1} + q_{t+\tau} \end{gathered} \tag{18}$$

$$\tilde{n}_{t+\tau} = \tilde{n}_{c,t+\tau} + \tilde{n}_{i,t+\tau} \tag{19}$$

$$\tilde{u}_{t+\tau} = \tilde{u}_{c,t+\tau} + \tilde{u}_{i,t+\tau} \tag{20}$$

$$\tilde{l}_{t+\tau} = l^{*} - \tilde{u}_{t+\tau} - \tilde{n}_{t+\tau} \tag{21}$$

Here, $p_{c,t}$ denotes the domestic price of one unit of consumption, w_t denotes the wage rate, $\tilde{d}_{t+1}$ denotes the amount borrowed in period t to be paid back (or rolled over) in period $t+1$, and q_t denotes the profits the household receives from the firms.

Endogenous labor force participation. The 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.[16] An alternative would be to use the lottery framework of Rogerson (1988) in which agents use lotteries to insure consumption against unfavorable labor market outcomes. This approach seems less suitable for a model with endogenous labor force participation, since it assumes 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 that is inconsistent with

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

the empirical properties of smooth aggregate consumption on the one hand and volatile tightness on the other. The approach adopted here avoids Ravn's consumption-tightness puzzle.[17]

First-order conditions. Labor supply is determined by the following two equations:

$$\begin{gathered}\phi \tilde{l}_t^{-\kappa} = \tilde{\pi}_{j,t} \tilde{W}_{j,t}, \qquad j \in \{c, i\} \quad \text{and} \\ \tilde{W}_{j,t} = \beta \left(\tfrac{w_{j,t+1}}{p_{c,t+1}} \tilde{c}_{t+1}^{-\gamma} - \phi \tilde{l}_{t+1}^{-\kappa} + (1-\rho_x) \tilde{W}_{j,t+1} \right), \qquad j \in \{c, i\}.\end{gathered} \tag{22}$$

The first equation equalizes the marginal disutility of searching to the expected benefits of searching. The latter is equal to the probability of getting a job in sector j, $\tilde{\pi}_{j,t}$, times the period t value of being in a productive relationship in sector j at the beginning of the next period, $\tilde{W}_{j,t}$. The second equation gives the law of motion for $\tilde{W}_{j,t}$.[18] It consists of the net current-period benefits, i.e., the value of the wage minus the disutility of working, plus the continuation value.

The first-order condition for debt is given by

$$\tilde{\lambda}_t = \beta \mathrm{E}_t \left[\tilde{\lambda}_{t+1} (1 + r_t) \right] = \beta \mathrm{E}_t \left[\tilde{\lambda}_{t+1} \left(1 + r_t^w + \eta_r d_{t+1}\right) \right] \tag{23}$$

$$\text{with } \tilde{\lambda}_t = \frac{\tilde{c}_t^{-\gamma}}{p_{c,t}}. \tag{24}$$

2.4 International trade

We take world prices for the consumption and investment good as given and we normalize both to be equal to 1, which are the steady state values for both prices in the closed-economy version of the model. This normalization implies that all our prices are in terms of the world consumption (or investment) commodity.

Export/Import company. There is a wedge between domestic and world prices. Reasons for such a wedge are the presence of shipping costs and the presence of frictions in

[17] See Den Haan and Kaltenbrunner (2007) for details.

[18] Note that $\tilde{W}_{j,t}$ is defined at the end of period t (i.e., the beginning of period $t+1$) *after* the separation shock has been realized. This makes it possible to use $\tilde{W}_{j,t}$ as the worker's value of a new and a continuing match.

finding international transaction partners. The wedge between the domestic and the world price is assumed to depend on the *aggregate* amount of net imports. As a modeling device, we assume that there is a company that imports and exports in a competitive market. Consequently, the profits are zero and the markup exactly covers the transaction costs.

The costs of international transactions are assumed to be equal to

$$s_{c,t} = \eta_c \frac{(y_{c,t} - c_t)^2}{\bar{c}} \text{ and } s_{i,t} = \eta_i \frac{(y_{i,t} - i_t)^2}{\bar{\imath}}, \tag{25}$$

where a bar indicates that the steady state value is used and the variables are aggregate variables. The zero profit condition implies that[19]

$$p_{c,t} = \begin{cases} 1 + \eta_c \frac{(y_{c,t} - c_t)}{\bar{c}} = p_{m_c,t} \text{ if } c_t \geq y_{c,t} \\ 1 + \eta_c \frac{(y_{c,t} - c_t)}{\bar{c}} = p_{x_c,t} \text{ if } y_{c,t} \geq c_t \end{cases} \tag{26}$$

Note that the formula for $p_{c,t}$ is always the same, but whether this is also equal to the domestic price paid for imported commodities, $p_{m_c,t}$, or equal to the domestic price received for exported commodities, $p_{x_c,t}$, depends on whether the economy is exporting or importing consumption commodities. Similarly, we get

$$p_{i,t} = \begin{cases} 1 + \eta_i \frac{(y_{i,t} - i_t)}{\bar{\imath}} = p_{m_i,t} \text{ if } i_t \geq y_{i,t} \\ 1 + \eta_i \frac{(y_{i,t} - i_t)}{\bar{\imath}} = p_{x_i,t} \text{ if } y_{i,t} \geq i_t \end{cases} \tag{27}$$

2.5 Equilibrium

Small open economy. In the household and firm problem described above, the values of the following eight variables are taken as given: aggregate debt, d_{t+1}, prices, $p_{c,t}$, $p_{i,t}$, and r_t, as well as the matching probabilities, $\pi_{c,t}$, $\pi_{i,t}$, $\tilde{\pi}_{c,t}$, and $\tilde{\pi}_{i,t}$.[20] Thus, we need eight more conditions to solve the full model. By using the definitions of the four matching probabilities given in Equation (2) we ensure that the matching probabilities are consistent

[19] If the costs of international transactions depend on the transactions done by the *individual* export firm, then these costs could be avoided by having many little export firms. The idea here is that as more firms export these costs increase, for example, because it becomes more difficult to find a cheap shipping company or it takes more time to find a suitable buyer.

[20] The wage rate is also taken as given. Its value is determined by Equation (6), not by an equilibrium condition.

with the choices for vacancies and labor force participation. The zero-profit conditions for the export/import firm gives us the extra equations to solve for $p_{c,t}$ and $p_{i,t}$. These pricing equations ensure that the gap between what is domestically produced and what is domestically demanded at these prices is consistent with these prices. The interest rate is given by Equation (16). Finally, we impose that $d_{t+1} = \tilde{d}_{t+1}$, i.e., consistency between the choice of the representative household and the aggregate outcome.

Closed economy. In the closed-economy version of the model the values of $p_{c,t}$, $p_{i,t}$, r_t and the matching probabilities are taken as given. The matching probabilities are again equal to the expressions given in Equation (2). To close the model we need three more conditions. We choose the (domestic) price of consumption as the numeraire, that is, $p_{c,t} = 1$. Even though workers can choose to search for work in either market, labor cannot switch freely between sectors because of the matching friction. Consequently, $p_{i,t}$ and $p_{c,t}$ are in general not equal to each other. Equilibrium in the market for investment commodities, i.e.,

$$i_t \equiv \widehat{i}_{c,t} + \widehat{i}_{i,t} + \widehat{\widehat{i}}_{c,t} + \widehat{\widehat{i}}_{i,t} = y_{i,t} \tag{28}$$

and equilibrium in the bond market, $d_{t+1} = 0$, make it possible to solve for $p_{i,t}$ and r_t. Walras' law ensures that the market for consumption commodities is also in equilibrium.

2.6 Definitions of a Pigou cycle

We say that at period t a "news shock" occurs if at period t it becomes known that productivity will increase for sure in period $t+12$, i.e., after twelve months.[21] We distinguish between *full* and *regular* Pigou cycles. During a full Pigou cycle, it is the case that in response to a news shock output, consumption, employment, and investment in *both* new and old projects move in the same direction. During a regular Pigou cycle, *total* investment moves in the same direction as the other key aggregate variables, but one of the two

[21] It would be more realistic to consider news shocks that affect the probability distribution of future productivity levels as is done in Den Haan and Kaltenbrunner (2007). Such news shocks affect the *expected* value of future productivity levels, but the change would not be a certainty. The definition of a news shock used here follows the convention adopted in the literature.

investment components could move in the opposite direction.

The news shock impulse response functions (IRFs) determine whether a model can generate Pigou cycles. It is not that interesting to require that all variables already move in the right direction in the first period the shock occurs. In the closed economy, capital and employment are predetermined, so it would not be possible for all spending components to increase in response to a favorable news shock in the first period. Therefore, a model is set to generate Pigou cycles if the responses of consumption, investment, employment, and output following a news shock move in the right direction starting in the third month, that is, within a quarter. We will also report results when we focus on the sixth instead of the third month.

2.7 Definition of output and trade balance

Output. It is easy to measure the number of consumption commodities and the number of investment commodities produced. It is a bit trickier to calculate real output, since the relative price of these two commodities changes. We use as our definition of real output

$$y_t = \frac{p_{c,t}y_{c,t} + p_{i,t}y_{i,t}}{p_{c,t}\bar{y}_c + p_{i,t}\bar{y}_i} = \frac{p_{c,t}y_{c,t} + p_{i,t}y_{i,t}}{p_t}. \tag{29}$$

Real trade balance. Using the definition for firm profits, q_t, we can rewrite the budget constraint of the household as

$$p_{c,t}(c_t - y_{c,t}) + p_{i,t}(i_t - y_{i,t}) = d_{t+1} - (1 + r_{t-1})d_t, \tag{30}$$

which is expressed in terms of the unit of account. Using the implicit deflator of domestic output, we get that the real value of the trade balance, t_t, is equal to

$$t_t = \frac{d_{t+1} - (1 + r_{t-1})d_t}{p_t}.$$

3 Calibration and fit

3.1 Data used to construct moments

The calibration is based on target moments calculated with quarterly U.S. data from 1951Q1 to 2004Q4. To evaluate the ability of the model to match additional moments, we also use U.S. data. The main reasons to use U.S. data is the availability of good labor market data and the fact that the same data were used in Den Haan and Kaltenbrunner (2009).

A key moment used in our calibration is the volatility of the trade balance. The U.S. is relatively closed and the observed volatility of its trade balance may very well not be representative for the volatility of the trade balance of other countries. In particular, Mendoza (1991) finds for Canada, a country for which international trade as a fraction of GDP is more important than for the U.S., a much more volatile trade balance than we find using U.S. data. Instead of trying to obtain a full set of labor market and macro statistics for a range of open economies, we simply study how the results change when the target for the volatility of the trade balance is increased and the other targets, which are not related to international trade, remain equal to their U.S. values.

3.2 Targeted moments

Groups of parameters. The parameters of the model are divided into four groups. The first group consists of β, α, δ, ρ, σ, and μ for which we use standard values from the literature. The only parameter in the second group is γ, the inverse of the elasticity of intertemporal substitution. Den Haan and Kaltenbrunner (2009) document that the positive comovement of consumption and investment is very sensitive to the choice of this parameter, so it is important to consider a range of different values.

The parameters of the third group are ϕ, l^*, $\bar{\mu}$, ψ, ρ_x and they are chosen to ensure that steady state values of the model correspond to average values observed in the data. The parameters of the fourth group are ω, $\bar{\omega}$, κ, and one open-economy parameter[22]

[22] As discussed in the next subsection, the open-economy parameter in the version with fixed prices is η_r

and they are chosen to match (i) the observed wage volatility, (ii) the volatility of labor force participation, (iii) the volatility of employment (relative to the volatility of labor productivity), and (iv) the volatility of the current account (relative to the volatility of output).

The values of ϕ and ψ depend on the values of the parameters in the fourth group, whereas that is not the case for the other parameters in the third group. Thus, we solve for ϕ, ψ, ω, $\bar{\omega}$, κ, and the open-economy parameter using an equation solver to match the target moments. For each different value of γ considered, we recalibrate the values of the other parameters. Table 1 reports the calibrated parameter values when γ is equal to 1.5. Although we solve a system of equations, there is one moment that is most important for each parameter and this moment is indicated in the last column of Table 1.

Open-economy parameters. We consider two approaches to choose the values for the open-economy parameters, η_r, η_c, and η_i, which control the amount of international trade in bonds and commodities. In the first approach, we set $\eta_c = \eta_i = 0$ and we calibrate η_r. In the second approach, we calibrate η_c and η_i and set η_r to a small positive number to ensure that the Blanchard-Kahn conditions remain satisfied.[23] In the second approach, we set η_c and η_i equal to each other, so that for both open economies there is only one penalty parameter to determine. The target under both approaches is the volatility of the trade balance, scaled by output. We express the volatility of the trade balance relative to the volatility of output, since one should not expect to fully match observed volatility in a model with only productivity shocks.

The higher the volatility of the trade balance, the easier it turns out to be to generate Pigou cycles. The observed volatility may overstate the appropriate target for the model, since the observed trade balance is affected by factors not present in our model, like exchange rates. If changes in exchange rates are important for observed import and export prices, then it would make sense to try to filter out these effects and define the

and the open-economy parameter in the version with sticky interest rates is equal to η_c (which is assumed to be equal to η_i).

[23] If $\eta_r = 0$, then the Euler equation for debt implies that consumption is a non-stationary variable.

trade balance using trend prices, that is,

$$t_t = \frac{x_t p_{x,t}^{HP} - m_t p_{m,t}^{HP}}{y_t}, \tag{31}$$

where x_t stands for real exports, m_t for real imports, y_t for real GDP, $p_{x,t}^{HP}$ for the HP-trend of the relative price of exports, i.e., the deflator of exports divided by the deflator of output, and $p_{m,t}^{HP}$ for the HP-trend of the relative price of imports.[24]

Anticipated versus unanticipated shocks. The empirical relevance of news shocks is a controversial topic.[25] Therefore, we assume that the productivity shocks are the commonly used *un*anticipated shocks when calibrating the parameters. Thus, we ask the question whether a model that is calibrated in the regular way, i.e., based on unanticipated shocks, can generate Pigou cycles if a news shock would occur.[26]

3.3 Model fit for non-targeted moments

Table 2 reports some standard business cycle and labor market statistics for the case when γ is equal to 1.5.[27] Besides the results for the closed economy and the two open economies, the table also reports the empirical counterparts.

As documented by the table, the moments generated by the closed and the two open economies are close to each other and to their empirical analogues. In particular, the

[24] The results presented in this paper are based on this definition, but whether trend or actual prices are used makes almost no difference. In fact, we find that the volatility is slightly higher when trend prices are used, which is due to the correlation between prices and quantities. This is true *both* in the data and in the model.

[25] Sims (2009) challenges the conclusion of Beaudry and Portier (2006) that anticipated shocks play a quantitatively important role in generating business cycles. However, Beaudry and Lucke (2008) and Schmitt-Grohé and Uribe (2008) confirm the results of Beaudry and Portier (2006) that news shocks are important using a very different empirical methodology.

[26] It actually makes little difference whether the models' parameters are calibrated using anticipated or unanticipated shocks. The reason is that given the persistence of shocks the anticipation phase is only a small part of the responses following a news shock and the responses during the realization phase of a news shock are similar to those of a regular unanticipated shock.

[27] These summary statistics do not depend much on the value of γ chosen. Table 5, discussed in Appendix B, reports the results when γ is equal to 0.45.

models do not suffer from the Shimer criticism.[28] In fact, for all three models we find that the amount of volatility in tightness, $v_t/\tilde{u}_t$, is somewhat *higher* than the observed volatility. The reason the model is able to avoid the Shimer criticism—even though wages are quite volatile—is that the share of revenues that accrues to the investor creating the firm is sufficiently low.[29] The biggest weakness of the model is that the correlation between the unemployment rate and vacancies is not as strong as it is in the data. The biggest gap is observed for the open economy with varying domestic prices (and sticky interest rate) in which case the correlation is -0.39 compared to -0.93 in the data.[30]

4 Pigou cycles

All three models can generate Pigou cycles for some values of γ, the free parameter in our calibration. Although all three models can generate Pigou cycles, the robustness of this result varies considerably among them. Table 3 displays the range of values for γ for which each model can generate full and regular Pigou cycles. When we change the value of γ, we recalibrate the other parameters. The most interesting parameter is the one that affects the labor supply elasticity, κ. Therefore, the table also reports the corresponding range for κ.

The table documents that both the closed economy and the open economy in which the interest rate responds to the volume of international transactions can only generate Pigou

[28] Shimer (2005) argues that textbook matching models cannot generate enough volatility in employment, because vacancies do not respond strongly enough to productivity increases.

[29] This is basically the solution to the Shimer puzzle proposed by Hagedorn and Manovskii (2008). The idea is that with a low value of ω_e the revenues the firm receives can be quite volatile even if total revenues, which include wage payments, are not.

[30] The unemployment rate initially *in*creases when a positive unanticipated productivity shock occurs, because labor force participation increases. This short-lived increase is followed by a very persistent decrease in unemployment which mimics the persistent increase in vacancies well. The HP filter gives less weight to the comovement observed at lower frequencies so that the correlation between u and v at business cycle frequencies is less than the correlation coefficient for the unfiltered series. When the HP filter is not applied to the data generated by the model, then the correlation between vacancies and unemployment is much stronger, namely -0.92.

cycles for a narrow range of values of γ. In contrast, Pigou cycles are a robust outcome in the international economy in which the interest rate does (almost) not respond to aggregate borrowing. In the remainder of this section, we explain these findings.

4.1 Pigou cycles in the closed economy

Figure 1 displays the responses of some key variables during the anticipation phase and during the first year of the realization phase when $\gamma = 0.45$. For this value of γ the closed economy generates a full Pigou cycle. For consumption and employment, we find that the increase during the anticipation phase relative to the increase when the productivity increase is realized is quite large. But even for output, which is directly affected by productivity, there is a substantial increase before productivity actually increases; the increase in output just before the productivity increase is realized is equal to 21% of the increase when the productivity increase is realized.

Labor supply decreases, i.e., leisure increases, during most of the anticipation phase because of the wealth effect. This decrease is dampened by the matching friction, because the matching friction induces workers to start searching early to ensure that they have secured an employment position when productivity and wages increase. But this only leads to an increase in labor supply at the end of the anticipation phase.

How is it possible that all expenditure components increase before the increase in productivity has been realized, even though labor force participation decreases? The intuition for the closed economy is as follows. An increase in productivity leads to an increase in profits, which in turn leads to a rise in the investment in new projects. Because of the matching friction, the increase in the investment in new projects starts as soon as news about the increase in productivity is received and, thus, before the productivity increase has been realized. The increase in the investment in new projects leads to an increase in the demand for labor which outweighs the decrease in labor supply.

The increase in employment is not enough to generate a Pigou cycle. Increasing employment requires resources and the increase in $\widehat{i}_t$ lowers the amount of commodities available for consumption and investment in existing projects, which is equal to $y_t - \widehat{i}_t$.

If $y_t - \widehat{i}_t$ increases, then the investments in new projects "pay" for themselves. This may seem odd, but this is exactly what happens for the parameter values that come out of the calibration procedure. The key parameter value is ω_e, i.e., the average share of revenues that is paid out as the reward for initiating the project. To generate a realistic amount of employment volatility, ω_e has to be relatively small. For the closed economy, the calibrated value is equal to 2.62%.[31] At this low value of ω_e, there is *under*investment in new projects and from society's point of view the investments in new projects do pay for themselves.[32]

Conditional on the model being able to generate a realistic amount of employment volatility, the increase in employment and net resources, $y_t - \widehat{i}_t$, are robust outcomes. Since

$$y_t - \widehat{i}_t = c_t + \widehat{\widehat{i}}_t$$

and $y_t - \widehat{i}_t$ increases, it is feasible that *both* c_t and $\widehat{\widehat{i}}_t$ increase. The elasticity of intertemporal substitution, $1/\gamma$, plays a key role in determining whether indeed both c_t and $\widehat{\widehat{i}}_t$ increase or only one of these two expenditure components. It is easy to see that there are always some values for γ for which the model can generate Pigou cycles given that $y_t - \widehat{i}_t$ increases. If γ is close enough to zero, then consumption smoothing is not important and $\widehat{\widehat{i}}_t$ increases. If instead γ is sufficiently large, then consumption smoothing is important and consumption increases. Given the continuity of the problem and given that $c_t + \widehat{\widehat{i}}_t$ increases, there must be values of γ such that both c_t and $\widehat{\widehat{i}}_t$ increases.

As documented in Table 3, the range of values of γ for which both c_t and $\widehat{\widehat{i}}_t$ increase is unfortunately very small.[33] That is, the division of the increase in $y_t - \widehat{\widehat{i}}_t$ over c_t and $\widehat{\widehat{i}}_t$ is very sensitive to small changes in γ. The responses of $\widehat{\widehat{i}}_t$ decrease so fast as γ increases that the range of values for which total investment, $\widehat{i}_t + \widehat{\widehat{i}}_t$, increases is also small even

[31] This value does not seem implausible, given that ω_e captures only the reward for initiating the project and does not include the reward for providing capital after the project has been initiated.

[32] Appendix B of Den Haan and Kaltenbrunner (2009) provides more information using a simple two-period model.

[33] The range of values for γ reported here is even smaller than the one reported in Den Haan and Kaltenbrunner (2009). The reason is that Den Haan and Kaltenbrunner (2009) kept the other parameters constant when γ was varied, whereas here the other parameters are recalibrated.

though the increase in $\widehat{i}_t$ is a robust result.

4.2 Pigou cycles in the two open economies

The open economy in which an increase in the aggregate amount borrowed from abroad puts upward pressure on the interest rate and the closed economy turn out to behave in a quite similar way. The reason is the following. To match the observed volatility in the U.S. trade balance, the penalty parameter in the interest rate equation has to be such that the magnitude of changes in the interest rate are quite similar to those generated in the closed economy.[34]

The results are quite different for the other open economy with sticky nominal interest rates. There are two possible reasons. First, the fact that nominal interest rates almost do not adjust, makes it a different model.[35] Second, the values of the calibrated parameters, i.e., κ, ω, and ω_e, are different. The difference is mainly due to the fact that the nominal interest rate is sticky, not to differences in the parameter values used. In the main text, we therefore only compare the three models when the parameters of the two open economies are equal to the calibrated parameters of the closed economy. In Appendix C, we discuss the differences due to the recalibration of the parameters.

Table 4 reports the business cycle statistics of the three models when the parameter values are equal. The parameters of the two international economies are no longer calibrated except the one related to international trade.[36] Consequently, there is no longer an exact match for the target moments. But the changes are relatively small. This is true for both the target moments and the other moments.

[34] In Section 4.5, we investigate how the results change when we increase the target for the volatility of the trade balance which leads to a decrease in the calibrated value of the open-economy parameter.

[35] Recall that we allow for minor adjustments in the interest rate to ensure that the Blanchard-Kahn conditions are satisfied.

[36] There is no open-economy parameter in the closed economy, so its value still has to be determined when considering the open economies. We set its value to match the observed volatility of the trade balance.

4.2.1 What is similar to closed-economy responses?

In this subsection, we will document that the responses for the two key macro aggregates employment and output are *qualitatively* similar to the ones observed for the closed economy. Quantitatively, however, there are some differences which turn out to be important for the qualitative differences for the other variables. Figures 2 through 5 plot the responses following a news shock for a wide range of variables.

Responses for firm value and the marginal rate of substitution. Figure 2 plots the variables related to creating new projects, which are the expected marginal rate of substitution, firm value (averaged across the two sectors), and investment in new projects.[37] In all three models, firm value increases substantially as soon as the news shock occurs. Firm value increases because expected profits increase. This increase in firm value is dampened a bit by the decrease in the expected marginal rate of substitution; that is, agents value future profits less, since they expect to become richer.

The key difference between the three models turns out to be the time path of the expected marginal rate of substitution, which is of course related to the real interest rate. The smaller the fluctuations in the real interest rate, the smaller the fluctuations in the expected marginal rate of substitution, the bigger the fluctuations in firm values,[38] and the bigger the fluctuations in vacancies. Whereas firm value increases by 1.85% in the closed economy, it increases by 2.35% in the open economy in which the interest rate is (almost) not affected by increased international borrowing. In this open economy, the world interest rate does not pin down the *real* interest rate from a domestic investor's point of view, since domestic prices fluctuate and it is not clear how many domestic commodities correspond to the fixed nominal debt payment. Nevertheless, the world nominal interest rate still

[37] The figure does not plot the expected marginal rate of substitution in the first period. Because of the inability to adjust resources during the period in which the shock occurs, consumption responds quite differently in the first than in the second period in the closed economy. This leads to a large one-time fluctuation in the expected marginal rate of substitution that distorts the picture.

[38] As pointed out above, reductions in the expected marginal rate of substitution dampen increases in firm value.

serves as an anchor that dampens fluctuations in the real interest rate.

Responses for labor market variables. Figure 3 plots the job finding rate (a weighted average across the two sectors), labor force participation, and employment. The larger increase in vacancies in the open economy with an (almost) sticky interest rate leads to a larger increase in the job finding rates during the anticipation phase, which in turn dampens the reduction in labor force participation due to the wealth effect. There is another reason why labor force participation decreases by less in this open economy during the anticipation phase. The reduction in the expected marginal rate of substitution during the anticipation phase reduces the benefits of workers to search, since it reduces the discounted potential benefits. When the interest rate is relatively sticky, then the expected marginal rate of substitution falls by less, which in turn implies that the expected discounted value of working falls by less, which dampens the reduction in labor force participation.

The last panel of Figure 3 documents the consequences of these different responses in labor demand and labor supply for employment. It shows that employment increases by more in the economy in which agents can borrow on a world market at almost constant interest rates.

Quantitative impact of news shocks on output in closed and open economies. In the introduction, it was pointed out that positive news shocks imply larger *reductions* in output in open-economy RBC models than in the closed-economy counterpart.[39] In the model with matching frictions, however, we find that positive news shock already generates the correct response of output during the anticipation phase. We now turn to the question whether news shocks have a larger impact on employment in the closed or open-economy versions of our model with matching frictions. The analysis also answers the question in which type of economy the largest *output* response is observed, because—as is documented

[39] In the standard business cycle model, the increase in consumption lowers the value of working. As discussed in the introduction, this wealth effect has a larger negative effect on labor supply in the open-economy version. This in turn implies a larger negative effect on investment. See Appendix A for a detailed discussion and a numerical example.

in the bottom panel of Figure 4—the differences in the output responses closely follow the differences in the employment responses.[40]

On the basis of the results from the matching model, we reach the opposite conclusion. The reason is that in the matching model the employment decision is not atemporal but intertemporal. That is, it is an investment decision. In fact, labor demand and labor supply are both investment decisions. In the closed economy, there is more upward pressure on interest rates. Even though most of the differences are observed during the realization phase, the larger increase in the interest rates in the closed economy leads to a lower increase in the NPV of the investments in the search for workers and jobs. The reason is that the higher interest rates correspond to lower discount rates for the revenues resulting from the investment decision. Moreover, there is an interaction between these two investments. As firms start more projects, the job finding rate increases and it becomes more attractive for workers to search for a job and vice versa.

4.3 Open-economy versus closed-economy responses

The responses discussed so far are qualitatively quite similar for both the closed and the open-economy versions of the model. Although news shocks have a more positive effect on employment during the anticipation phase (and the realization phase) in the open economy with sticky interest rates, the differences are not that large. This quantitative difference turns out to be important, though, to explain the *qualitative* differences for the consumption and investment responses across the different economies. And it is this difference that makes it possible to generate full Pigou cycles in the open economy with sticky interest rates and not in the other two economies.

Figure 4 illustrates this difference by plotting the responses of consumption and investment when γ is equal to 1.5. In the open economy with flexible prices and a sticky interest

[40] There are two reasons why changes in the capital stock are quantitatively not important for changes in output. First, for standard production functions a one percent change in employment has roughly twice the impact on output as a one percent change in capital. Second, the capital stock is so large relative to investment that enormous changes in investment are necessary to generate substantial percentage changes in the capital stock.

rate, consumption increases by less than in the other two economies, but the investment response is positive throughout the anticipation phase (except for the first period), whereas it is negative in the other two economies.

As shown in Table 3, there are values of γ for which consumption and investment increase in all three economies. However, as γ is increased, then the investment response quickly turns negative in the closed economy and in the open economy with flexible interest rates. It remains positive, however, in the open economy with sticky interest rates when γ increases.

The question arises why the positive comovement of consumption and investment is more robust in the open economy with sticky interest rates and flexible prices. In all three economies, there is a robust increase in the investment in new projects $\widehat{i}_t$, and a robust increase in net resources, $y_t - \widehat{i}_t$, which is equal to $c_t + \widehat{\widehat{i}}_t$, so it is possible for both consumption, c_t, and investment in existing projects, $\widehat{\widehat{i}}_t$, to increase. But it is not enough for this to be possible. The incentives have to be there as well. The reason why investment in existing projects robustly increases in the open economy with sticky interest rates is that the expected rate of return on investment in existing projects increases by more in this economy. The three components that influence the expected rate of return are (i) prices, $p_{c,t}$ and $p_{i,t}$, (ii) the marginal rate of substitution, and (iii) employment levels. The higher response of employment levels in the open economy with sticky interest rates, as documented in Figure 3, turns out to be the reason for the higher expected rate of return and, thus, the more robust increase in investment.[41] That is, the higher employment response makes it more attractive to also invest more in existing projects and postpone the increase in consumption somewhat.

[41] In particular, when the employment response is disorted to behave as in the closed-economy model, then the increase in investment is no longer robust. From Figure 2 it is clear that the time paths of the expected marginal rate of substitution and, thus, the responses of the real interest rate, are very similar across the three different models during the anticipation phase.

4.4 Effect of news shocks on international trade

Figure 5 documents the response of the trade balance, the net import of consumption commodities, and the net import of investment commodities. The pattern is very straightforward for the open economy with flexible prices. Following a news shock the imported amounts of both consumption and investment increase. This is true during the anticipation as well as during the realization phase. Consequently, the trade balance deteriorates substantially.

In the open economy with fixed prices, however, we find that during the anticipation phase the import of consumption increases and the import of investment actually decreases. That is, starting with balanced trade the economy would respond to a news shock by exporting investment commodities. During the realization phase the pattern is the opposite. Consider the realization phase. If productivity increases, then consumption smoothing induces a movement of employment out of the consumption sector into the investment sector.[42] Due to the matching friction, the investment sector already starts increasing employment during the anticipation phase. The excess production of investment is exported. The additional export almost offsets the additional imports of consumption commodities, resulting in only a small deterioration of the trade balance.

In the open economy with flexible prices, the import of consumption commodities and the import of investment commodities respond much more symmetrically. The reason is that a large import of investment commodities and a large export of consumption commodities, as observed during the realization phase in the open economy with fixed prices, would lead to a sharp reduction in the relative price of consumption received by domestic producers.

To sum up, in the open economy with flexible prices (and a sticky interest rate) there is a substantial inflow of commodities, whereas in the open economy with fixed prices the increased export of investment commodities implies that there is no such inflow of commodities.

[42] Without such a reallocation of labor, the increase in the production of consumption goods would be way too high.

There are thus two reasons why there are more resources available in the open economy with a sticky interest rate to let both consumption and investment in regular capital increase. The first is that employment increases by more and the second is that imports increase by more.

4.5 Effect of news shocks and openness of the economy

The results reported in this section make clear that one can robustly generate Pigou cycles in the open economy with an almost sticky interest rate and prices that adjust to international trade flows. This is not the case in the open economy in which the interest rate adjusts to international capital flows, at least not for the calibrated value of the open-economy parameter, η_r. If one was to lower the value of this parameter, then interest rates would become less sensitive to these international capital flows and the volatility of the trade balance would increase. But for some countries the volatility of the trade balance is higher than the value for the U.S., which we use as our target in the calibration. So then a lower value for η_r would be appropriate.

It is indeed possible to generate Pigou cycles much more robustly, but one has to lower the penalty parameter quite a bit. In particular, if one uses a value for η_r that is 30 times as low, then both investment in new and investment in existing projects are positive throughout the anticipation phase when $\gamma = 1.5$. But for this low penalty parameter, the standard deviation of the trade balance relative to output volatility is almost 14 times higher than the number estimated using U.S. data and investment volatility is almost 18 times the volatility of output.

A News shocks in closed and open-economy RBC models

In this section, we document the claim made in the introduction that in open-economy versions of standard RBC models it is more difficult to generate Pigou cycles than in the corresponding closed-economy version.

The closed-economy version of the model is characterized by the following social planner's problem.

$$\max_{\left\{\begin{array}{c} c_{t+\tau}, l_{t+\tau}, \\ i_{t+\tau}, k_{t+\tau+1} \end{array}\right\}_{\tau=0}^{\infty}} \mathrm{E}_t \sum_{\tau=0}^{\infty} \beta^{\tau} \left[\frac{(\tilde{c}_{t+\tau})^{1-\gamma} - 1}{1-\gamma} + \phi \frac{\left(\tilde{l}_{t+\tau}\right)^{1-\kappa} - 1}{1-\kappa} \right],$$

s.t.

$$c_{t+\tau} + i_{t+\tau} = z_{t+\tau} k_{t+\tau}^{\alpha} n_{t+\tau}^{1-\alpha} \tag{32}$$

$$k_{t+\tau+1} = i_{t+\tau} + (1-\delta) k_{t+\tau} \tag{33}$$

The law of motion for z_t is given by Equation (5). The open-economy version of the model is characterized by the following social planner's problem.

$$\max_{\left\{\begin{array}{c} c_{t+\tau}, l_{t+\tau}, \\ i_{t+\tau}, k_{t+\tau+1} \end{array}\right\}_{\tau=0}^{\infty}} \mathrm{E}_t \sum_{\tau=0}^{\infty} \beta^{\tau} \left[\frac{(\tilde{c}_{t+\tau})^{1-\gamma} - 1}{1-\gamma} + \phi \frac{\left(\tilde{l}_{t+\tau}\right)^{1-\kappa} - 1}{1-\kappa} \right],$$

s.t.

$$c_{t+\tau} + i_{t+\tau} + d_{t+\tau+1} = z_{t+\tau} k_{t+\tau}^{\alpha} n_{t+\tau}^{1-\alpha} + (1 + r_{t+\tau-1}) d_{t+\tau} \tag{34}$$

$$k_{t+\tau+1} = i_{t+\tau} + (1-\delta) k_{t+\tau} \tag{35}$$

The domestic interest rate is determined by

$$r_t = \frac{1}{\beta} - 1 + \eta_r d_{t+1}. \tag{36}$$

The value of η_r can be arbitrarily small, but has to be strictly positive to make sure that the problem remains well behaved. We choose a low value of η_r so that the interest rate changes very little in the open economy and the difference with the closed economy is most clear.

The results are displayed in Figures 6 and 7.[43] The top panel in Figure 6 makes clear that the interest rate does not move very much during the anticipation phase in neither

[43] Consistent with the choices made for the matching model, we set $\alpha = 0.33$, $\beta = 0.9966$, $\gamma = 1.5$, $\delta = 0.084$, $\rho = 0.98$, $\kappa = 1.4283$, and $l^* = 1.5938$. The value of ϕ is set equal to 0.38892 to get the same steady state value for employment, namely 0.943. The value of η_r is set equal to 0.00001. At this small value interest rates do not change very much, but the economy is well behaved because $\eta_r > 0$.

the closed nor the open economy model. The reason is that at a value of γ equal to 1.5 consumption is quite close to a random walk during the anticipation phase. During the realization phase, however, the interest rate increases by quite a bit in the closed economy. As interest rates remain low, agents in the open economy can really take advantage of the productivity increase by investing the most when capital is most productive without having to cut their consumption levels. It is this property that makes the productivity increase more valuable for agents in the open economy. This translates into a higher response of consumption during the anticipation phase in the open economy, as is documented in the middle panel of Figure 6.[44] The higher consumption response translates into a larger drop in the value of extra wage income, which in turn implies that employment drops by more in the open economy, as can be seen in the lower panel of Figure 6.

Figure 7 shows the results for capital, investment, and output. The stronger reduction in employment in the open economy means that the marginal product of capital drops by more during the anticipation phase. Consequently, capital also drops by more in the open economy. In terms of investment, this mainly shows up in a sharp initial decrease. Since both capital and employment drop by more during the anticipation phase in the open economy, the same is true for output. Quantitatively the differences are not huge. But the ability to borrow from abroad does make it *more* difficult to generate Pigou cycles with this type of model.

B Model moments when $\gamma = 0.45$

Table 5 reports the summary statistics when γ is equal to 0.45 instead of 1.5, the value used to construct the summary statistics discussed in the text. Recall that when $\gamma = 0.45$ all three models can generate Pigou cycles. But in terms of the summary statistics the model with $\gamma = 0.45$ is very similar to the model with $\gamma = 1.5$.

[44] During the realization phase, the consumption response in the open economy is for some time below the response in the closed economy. But the consumption response is more persistent in the open economy and at horizons outside the graphs the consumption response in the closed economy does drop below the consumption response in the open economy.

C Differences between models due to recalibration

The discussion in Section 4.2 was based on the case where the parameters were identical in all three models (except the parameter related to international trade).[45] By keeping the parameters equal across models, it is easier to understand how international trade affects the ability of the different models to generate Pigou cycles. But implementing our calibration procedure results in choosing different values for κ, ω_e, and ω in the different models. In particular, the calibrated value for κ, which controls the wage elasticity of labor supply, is not the same in each model. In this section, we will show that recalibration changes little to the comparison of the different models.

The recalibration of the open economy with fixed prices leads to only minor changes in the parameter values. This is not surprising given that—as is documented in Table 4—the values of the target moments in this open economy are already close to their empirical counterparts when the parameters of the closed economy are used.

The recalibration leads to larger changes in the parameter values for the open economy with flexible prices. In particular, recalibration leads to a higher value for κ in the open economy with flexible prices (and an almost fixed nominal interest rate) for the following reason. Recall that our calibration procedure is based on the usual unanticipated productivity shocks. The increase in the interest rate following an unanticipated productivity increase leads to a higher rate at which the higher future wage payments are discounted. This dampens the increase in labor supply. Stickiness of the nominal rate carries over to some extent to stickiness of the real rate and, thus, to less dampening in labor supply. To match the empirical target of employment volatility, the value of κ increases.

Recalibration also leads to a lower value of ω_e and a higher value of ω. According to Equation (6), wages depend on the value of the marginal product, so the behavior of prices affects the volatility of wages and, thus, with a fixed target for wage volatility, the value of ω.

The higher value of κ reduces the elasticity of labor supply and, thus, implies a lower

[45] To be precise, we used the parameters calibrated using the closed-economy version of the model and the open-economy parameter was calibrated separately to match the volatility of the trade balance.

reduction in labor supply during the anticipation phase following a news shock. The lower value of ω_e (together with somewhat sticky wages) implies larger percentage fluctuations in the revenues of the entrepreneur and, thus, larger fluctuations in investment in new projects. This would increase the demand for labor during the anticipation phase. The higher value of ω lowers the volatility of the entrepreneurs' revenues, however, and would reduce the effect of a news shock. The recalibration of κ and ω_e makes it easier to generate Pigou cycles, but the recalibration of ω makes it harder. We will show now that quantitatively, however, the recalibration has little impact on the results.

Figures 8, 9, and 10 compare the IRFs of the fully calibrated open economy with a sticky interest rate with the IRFs of this open economy displayed in the earlier figures that were based on the parameter values of the calibrated closed economy. The IRFs of the closed economy are also displayed.

In Figure 8 it is shown that firm value increases somewhat less when the parameters are recalibrated, indicating that the decrease in ω_e is dominated by the increase in ω. The figure also shows that the vacancy responses for most of the anticipation phase are not affected by the recalibration. The vacancy responses do not change very much even though recalibration leads to a smaller increase in firm value, because the higher value of κ in the calibrated open economy leads to smaller fluctuations in labor force participation, as is documented in Figure 9. The somewhat lower reduction in labor force participation together with the unchanged responses in vacancies lead to slightly higher responses in employment, but quantitatively the effect of the recalibration on employment is very small. As documented in Figure 10 the same is true for consumption, investment in physical capital, and output.

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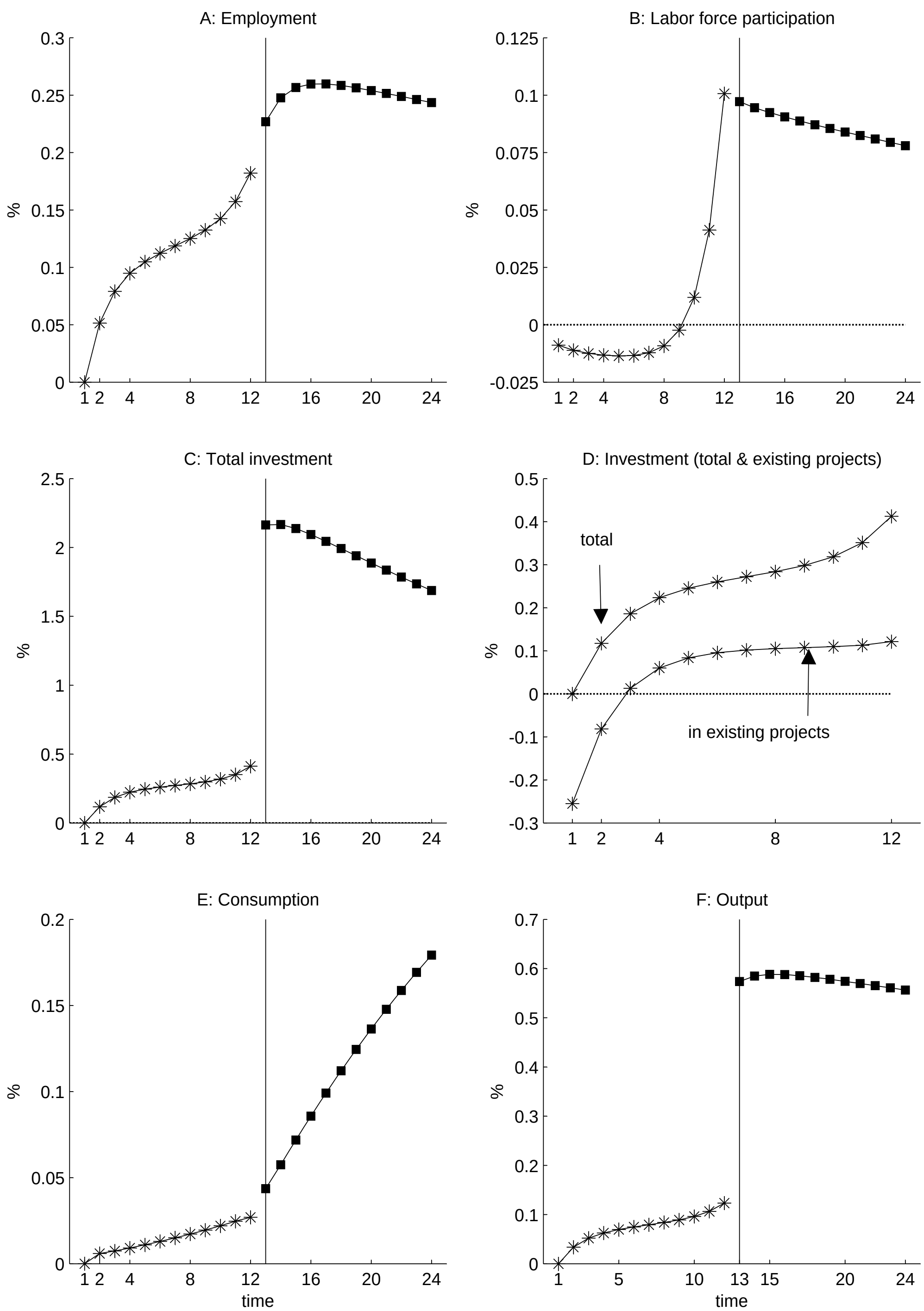
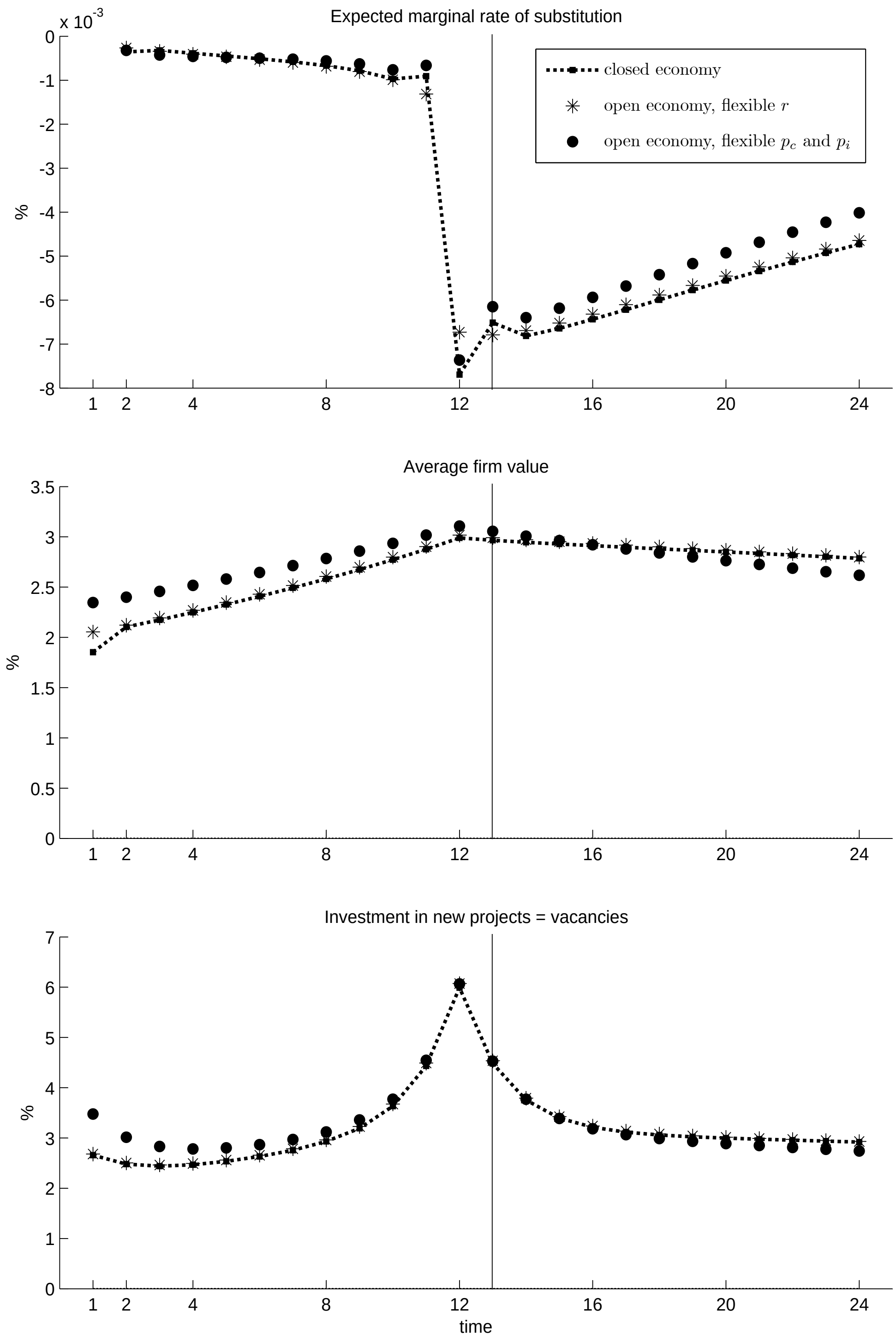
Figure 1: Responses to a news shock in the closed economy; $\gamma = 0.45$



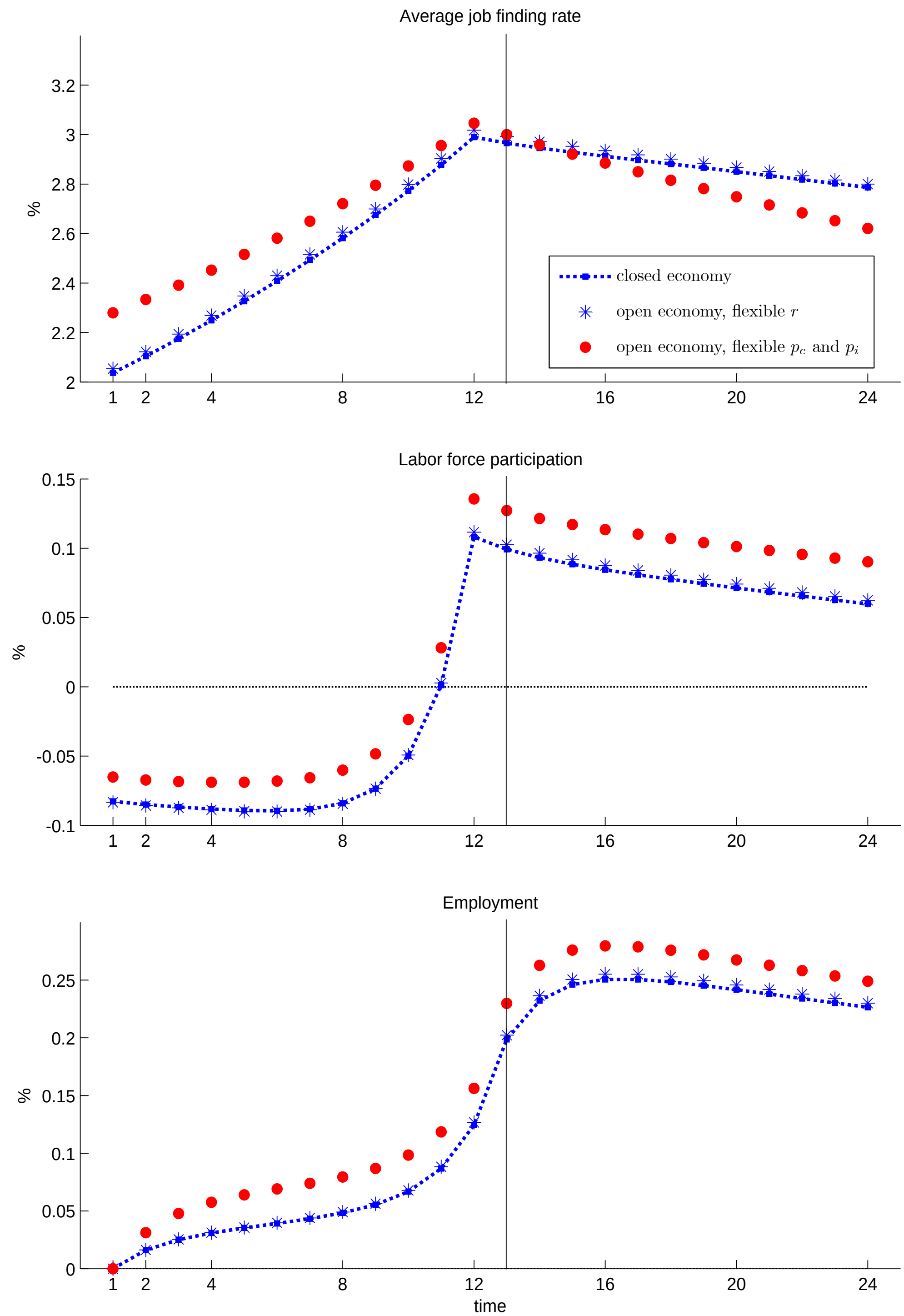
Notes: The panels plot the response of the indicated variable to a positive one-standard-deviation news shock; during the anticipation phase with stars and during the realization phase with squares.

Figure 2: Responses in closed and open economies I; $\gamma = 1.5$



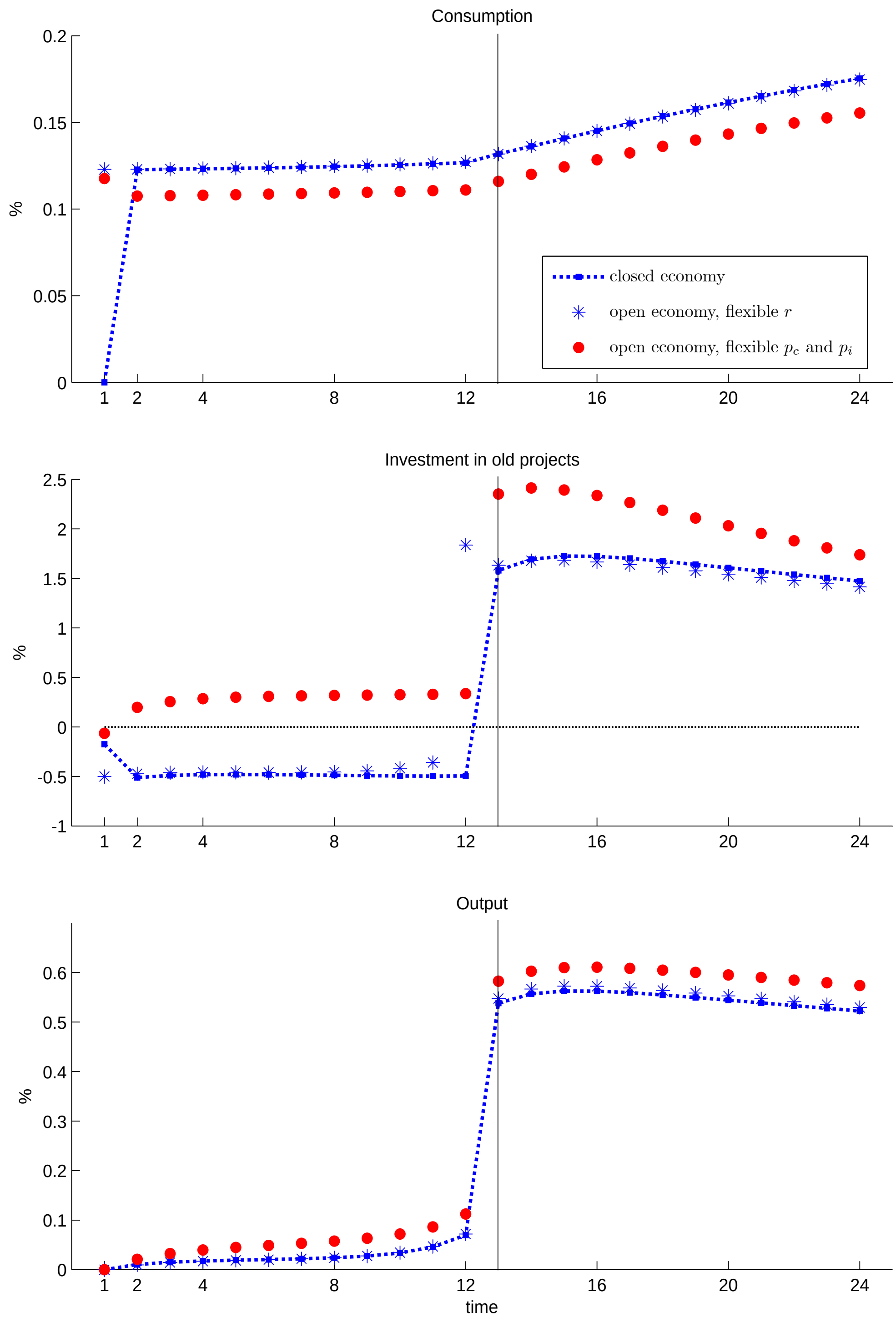
Notes: The panels plot the response of the indicated variable to a positive one-standard-deviation news shock; during the anticipation phase with stars and during the realization phase with squares.

Figure 3: Responses in closed and open economies II; $\gamma = 1.5$



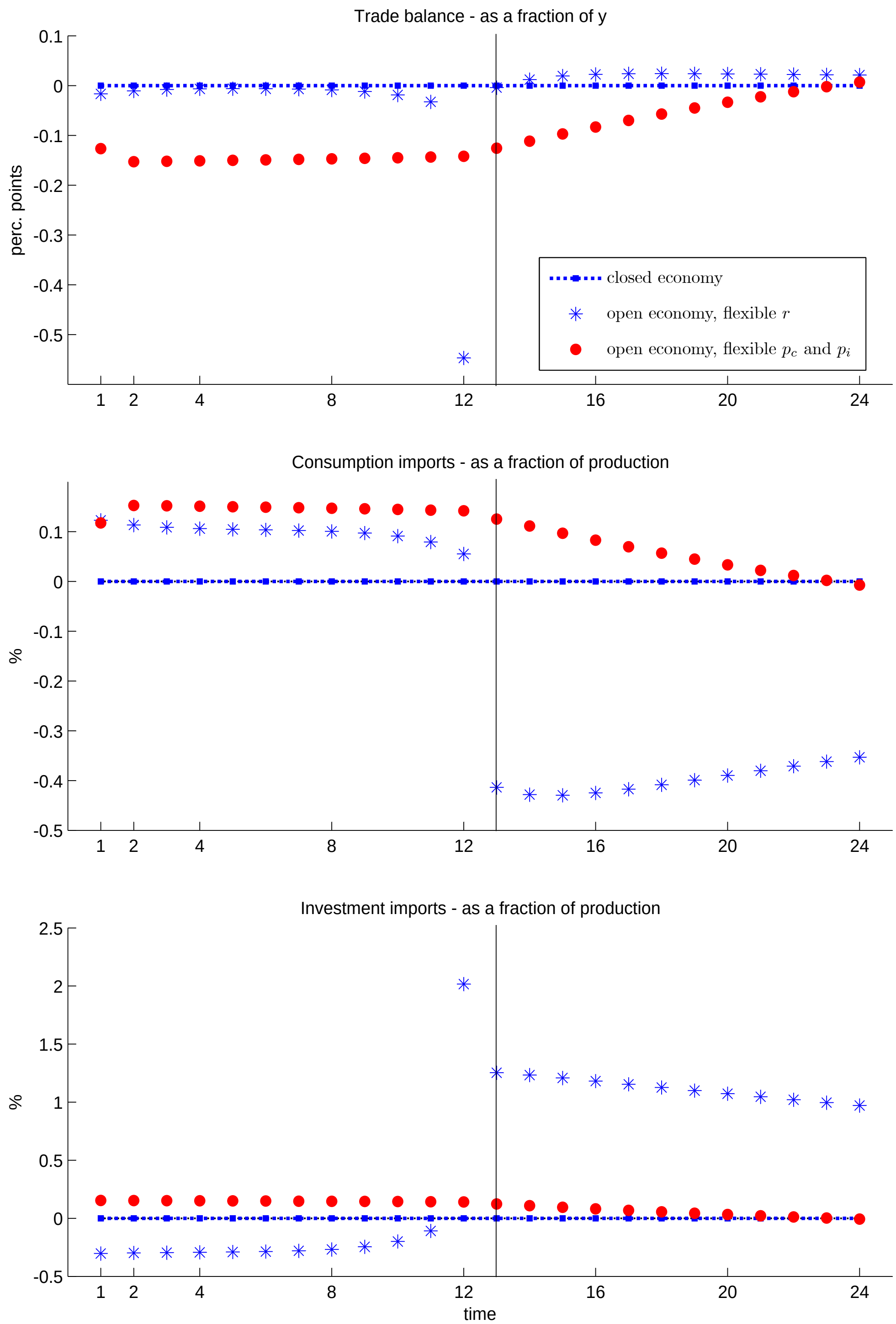
Notes: The panels plot the response of the indicated variable to a positive one-standard-deviation news shock; during the anticipation phase with stars and during the realization phase with squares.

Figure 4: Responses in closed and open economies III; $\gamma = 1.5$



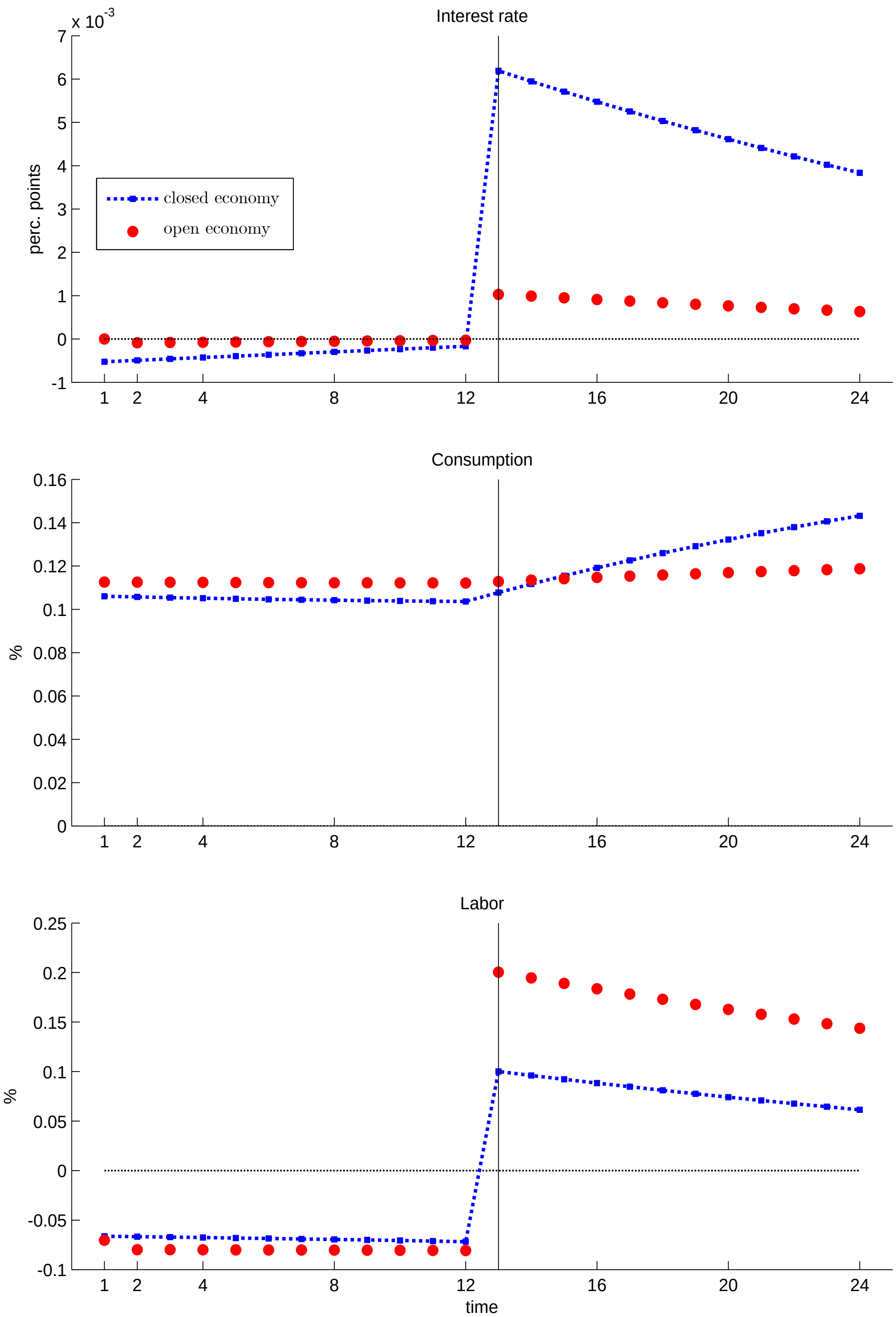
Notes: The panels plot the response of the indicated variable to a positive one-standard-deviation news shock; during the anticipation phase with stars and during the realization phase with squares.

Figure 5: Responses in closed and open economies IV; $\gamma = 1.5$



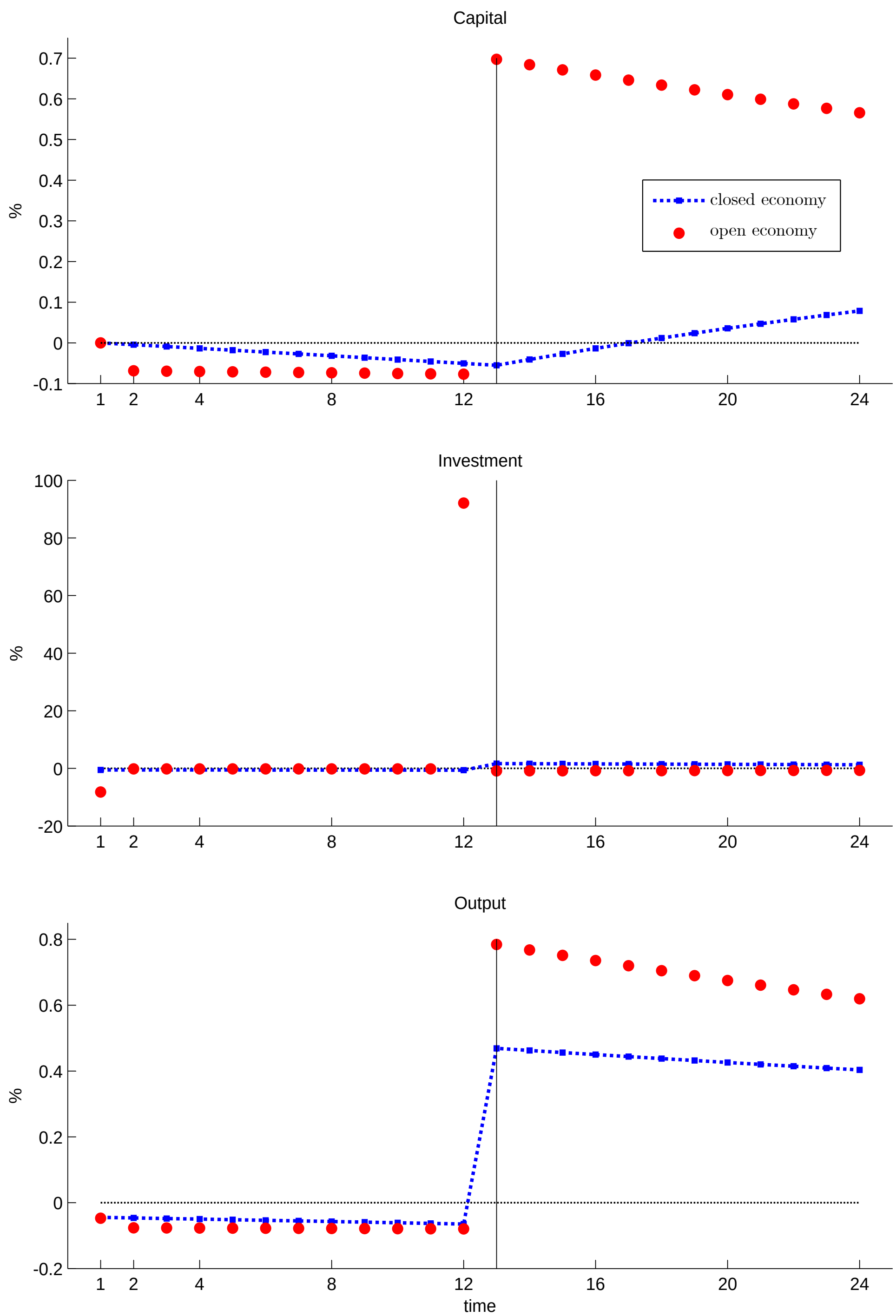
Notes: The panels plot the response of the indicated variable to a positive one-standard-deviation news shock; during the anticipation phase with stars and during the realization phase with squares.

Figure 6: Responses in a closed and open-economy RBC model I



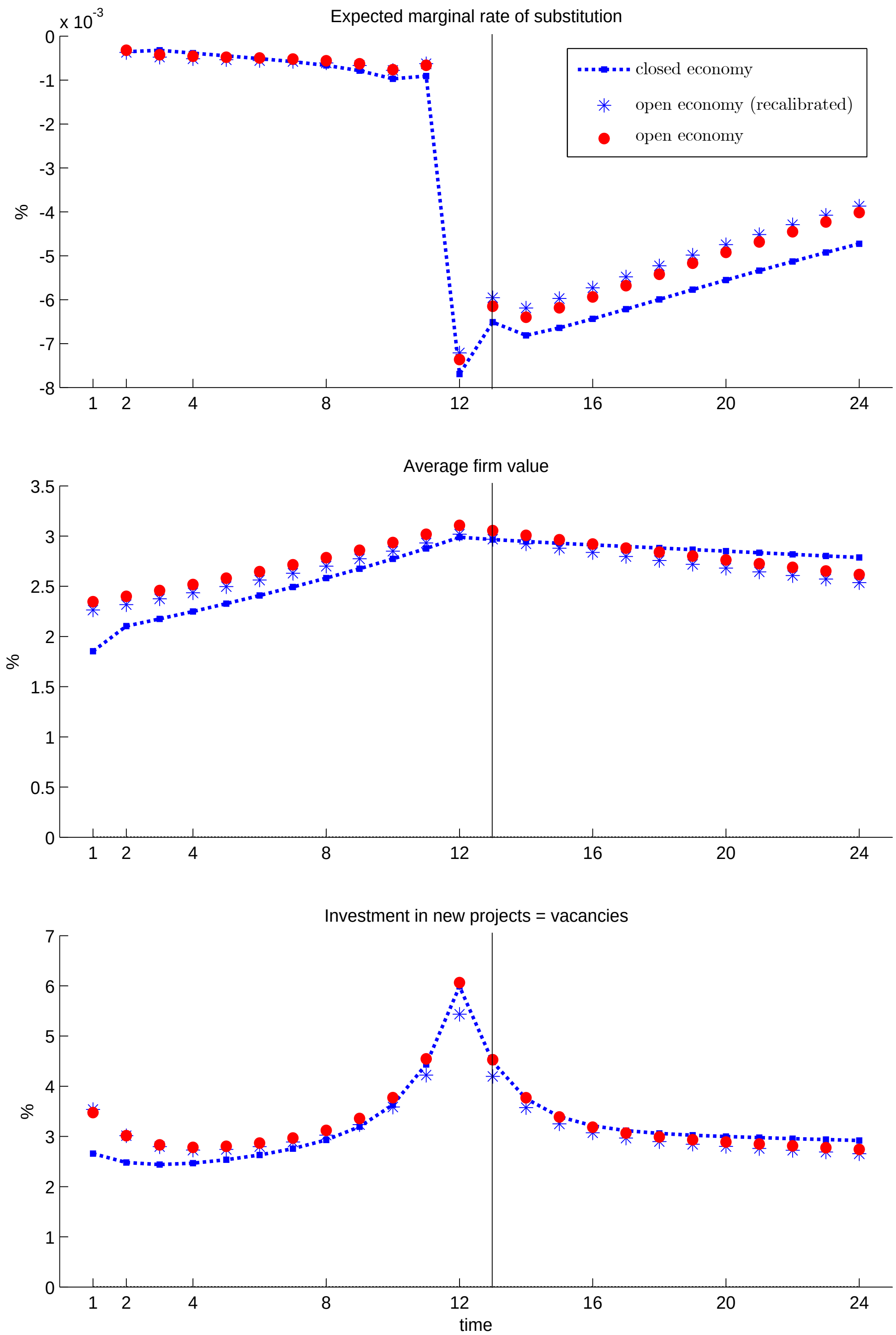
Notes: The panels plot the response of the indicated variable to a positive one-standard-deviation news shock; during the anticipation phase with stars and during the realization phase with squares.

Figure 7: Responses in a closed and open-economy RBC model II



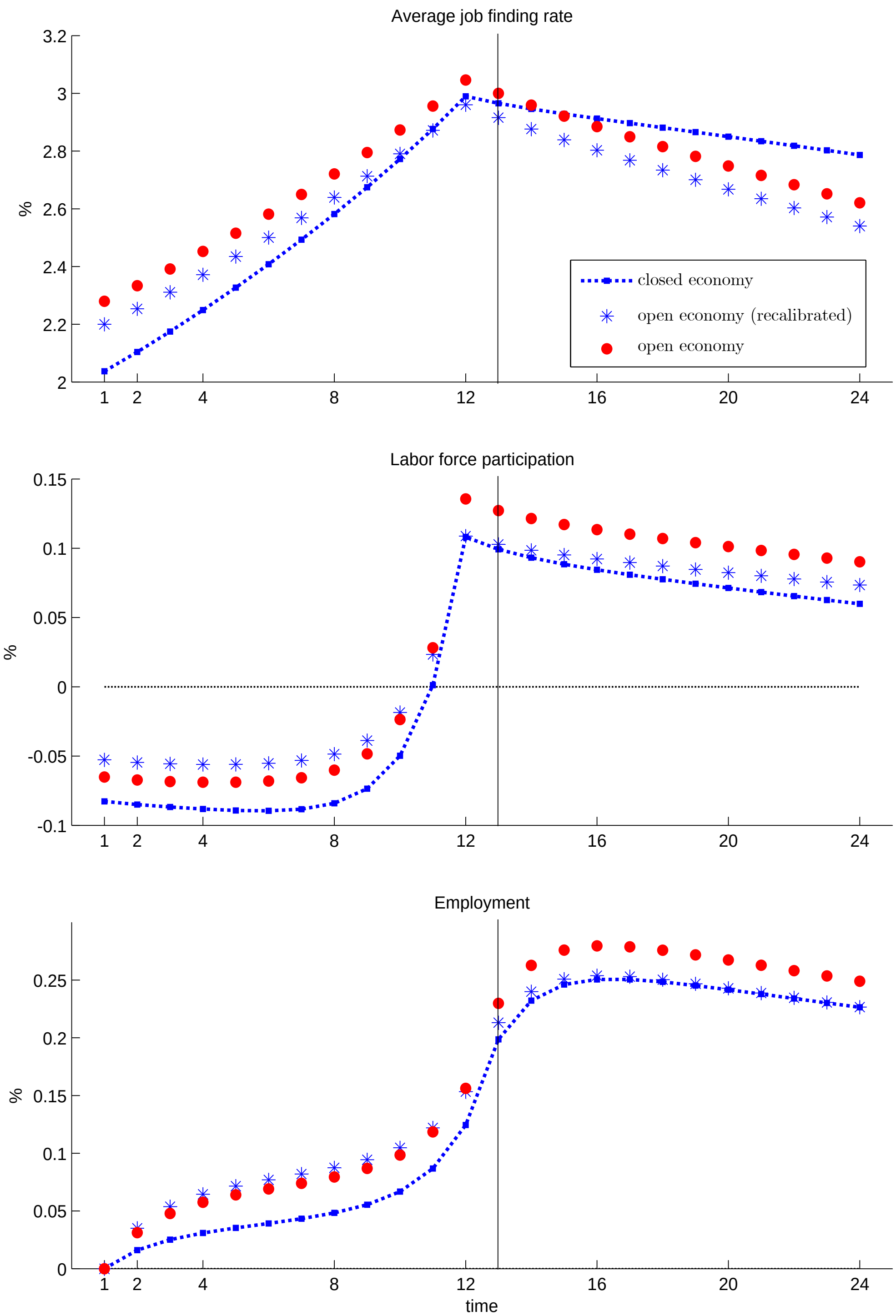
Notes: The panels plot the response of the indicated variable to a positive one-standard-deviation news shock; during the anticipation phase with stars and during the realization phase with squares.

Figure 8: Effect of recalibration I; $\gamma = 1.5$



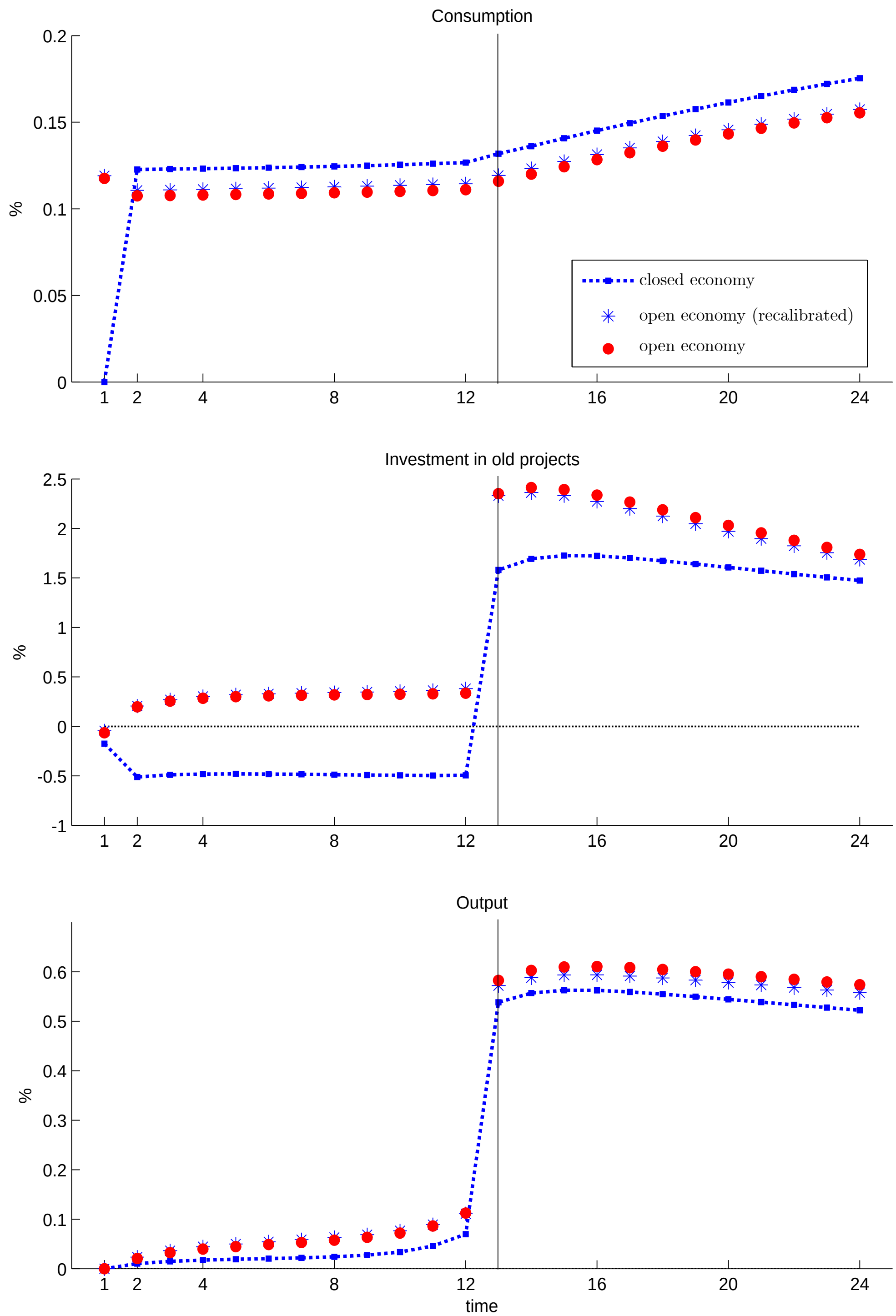
Notes: The panels plot the response of the indicated variable to a positive one-standard-deviation news shock; during the anticipation phase with stars and during the realization phase with squares.

Figure 9: Effect of recalibration II; $\gamma = 1.5$



Notes: The panels plot the response of the indicated variable to a positive one-standard-deviation news shock; during the anticipation phase with stars and during the realization phase with squares.

Figure 10: Effect of recalibration III; $\gamma = 1.5$



Notes: The panels plot the response of the indicated variable to a positive one-standard-deviation news shock; during the anticipation phase with stars and during the realization phase with squares.

Table 1: Calibration

	closed	open economy		target/source
factor dampening international trade		adjusting r	adjusting prices	
standard values				
discount factor, β	0.9966	=	=	
depreciation rate, δ	0.0084	=	=	
curvature production function, α	0.33	=	=	
persistence parameter, ρ	0.98	=	=	
volatility innovation, σ	0.0042	=	=	
match elasticity, μ	0.50	=	=	
match 1$^{\text{st}}$-order moments				
scaling matching function, $\bar{\mu}$	0.3917	=	=	$\tilde{\pi} = 45.4\%$
exogenous destruction, ρ_x	0.0274	=	=	$\frac{u}{u+n} = 5.7\%$
time endowment, l^*	1.5938	=	=	$\frac{u+n}{l^*} = 62.7\%$
scaling utility of leisure, ϕ	0.2150	0.2191	0.1726	$u + n = 1$
period entry cost, ψ	0.9930	0.9920	0.8667	$\pi = 33.8\%$
match 2$^{\text{nd}}$-order moments				
relative risk aversion, γ	1.5	=	=	range considered
curvature utility of leisure, κ	1.4283	1.3920	1.8482	$\frac{\sigma[(u+n)/l^*]}{\sigma[\ln y/n]} = 0.182$
share of entrepreneur, ω_e	0.0262	0.0262	0.0229	$\frac{\sigma[n/l^*]}{\sigma[\ln y/n]} = 0.437$
wage sensitivity, ω	0.7112	0.7299	0.7605	$\frac{\sigma[\ln w]}{\sigma[\ln y/n]} = 0.755$
penalty on borrowing, η_r	-	2.04e-5	1.56e-5	$\frac{\sigma[t/y]}{\sigma[\ln y]} = 0.281$
trade penalty, $\eta_c = \eta_i$	-	-	0.4306	$\frac{\sigma[t/y]}{\sigma[\ln y]} = 0.281$

Notes: The "=" sign indicates that the numbers are by construction equal to the number on the left. The "-" sign indicates that this parameter plays no role in this model. Prices are fixed in the economy with adjusting r and the nominal interest rate is almost constant in the model with adjusting prices.

Table 2: Summary statistics; $\gamma = 1.5$, full calibration

	data	closed	open	open
factor dampening international trade			adjusting r	adjusting prices
Used for calibration				
$u/(u+n)$	0.057	=	=	=
n/l^*	0.592	=	=	=
$\sigma\left[\frac{u+n}{l^*}\right]/\sigma\left[\ln\frac{y}{n}\right]$	0.182	=	=	=
$\sigma\left[\frac{n}{l^*}\right]/\sigma\left[\ln\frac{y}{n}\right]$	0.437	=	=	=
$\sigma\left[\ln w\right]/\sigma\left[\ln\frac{y}{n}\right]$	0.755	=	=	=
$\sigma\left[\ln t/y\right]/\sigma\left[\ln y\right]$	0.281	-	=	=
Standard RBC statistics for C, I, and Y				
$\sigma\left[\ln y\right]$	0.016	0.012	0.012	0.013
$\sigma\left[\ln y\right]/\sigma\left[\ln z\right]$	-	1.39	1.41	1.42
$\sigma\left[\ln i\right]/\sigma\left[\ln y\right]$	4.56	3.22	3.38	4.26
$\sigma\left[\ln c\right]/\sigma\left[\ln y\right]$	0.70	0.32	0.29	0.24
$\text{COR}(\ln c, \ln y)$	0.48	0.88	0.94	0.93
$\text{COR}(\ln i, \ln y)$	0.97	0.99	0.93	0.96
Statistics for other variables				
$\psi v/y$	-	0.016	0.016	0.014
$\sigma\left[\ln\frac{y}{n}\right]$	0.013	0.0069	0.0072	0.0070
$\sigma\left[\frac{n}{u}\right]/\sigma\left[\ln\frac{y}{n}\right]$	19.0	29.07	29.08	26.97
$\text{COR}\left[\frac{u}{u+n}, \ln y\right]$	-0.86	-0.85	-0.84	-0.86
$\text{COR}\left[\frac{u}{u+n}, \ln v\right]$	-0.93	-0.47	-0.45	-0.45

Notes: Monthly data from the model are transformed into quarterly data and then filtered using the HP-filter. Model statistics are based on one long sample of 60,000 observations. The "=" sign indicates that the numbers are by construction equal to the number on the left. The "-" sign indicates that this statistic plays no role in this model. Prices are fixed in the economy with adjusting r and the nominal interest rate is almost constant in the model with adjusting prices. The numbers in the row for $\psi v/y$ indicate steady state values.

Table 3: Robustness

	full Pigou cycle before or in 3$^{\text{rd}}$ month	6$^{\text{th}}$ month
Closed economy	$\gamma : [0.42, 0.45]$	$\gamma : [0.42, 0.52]$
	$\kappa : [2.69, 2.73]$	$\kappa : [2.60, 2.73]$
Open economy with adjusting r	$\gamma : [0.42, 0.48]$	$\gamma : [0.41, 0.52]$
	$\kappa : [2.56, 2.64]$	$\kappa : [2.51, 2.65]$
Open economy with adjusting prices	$\gamma : [0.35, 2.97]$	$\gamma : [0.35, 3.15]$
	$\kappa : [1.16, 2.89]$	$\kappa : [1.11, 2.89]$
	regular Pigou cycle before or in 3$^{\text{rd}}$ month	6$^{\text{th}}$ month
Closed economy	$\gamma : [0.42, 0.64]$	$\gamma : [0.42, 0.74]$
	$\kappa : [2.44, 2.73]$	$\kappa : [2.31, 2.73]$
Open economy with adjusting r	$\gamma : [0.42, 0.69]$	$\gamma : [0.41, 0.74]$
	$\kappa : [2.29, 2.64]$	$\kappa : [2.23, 2.65]$
Open economy with adjusting prices	$\gamma : [0.35, 2.97]$	$\gamma : [0.35, 3.15]$
	$\kappa : [1.16, 2.89]$	$\kappa : [1.11, 2.89]$

Notes: For values of γ in the indicated range the responses of consumption and total investment (for regular Pigou cycles) and the responses of consumption and *both* types of investment (full Pigou cycles) are jointly positive starting in the indicated period. Parameters are recalibrated for each value of γ considered. The value for κ at the upper bound of the given range corresponds to the value for γ at the bottom of the range.

Table 4: Summary statistics; $\gamma = 1.5$, partial calibration

	data	closed	open	open
factor dampening international trade			adjusting r	adjusting prices
Used for calibration				
$u/(u+n)$	0.057	=	=	=
n/l^*	0.592	=	=	=
$\sigma\left[\frac{u+n}{l^*}\right]/\sigma\left[\ln\frac{y}{n}\right]$	0.182	=	0.182	0.229
$\sigma\left[\frac{n}{l^*}\right]/\sigma\left[\ln\frac{y}{n}\right]$	0.437	=	0.455	0.495
$\sigma\left[\ln w\right]/\sigma\left[\ln\frac{y}{n}\right]$	0.755	=	0.737	0.699
$\sigma\left[\ln t/y\right]/\sigma\left[\ln y\right]$	0.281	-	=	=
Standard RBC statistics for C, I, **and** Y				
$\sigma\left[\ln y\right]$	0.016	0.012	0.013	0.013
$\sigma\left[\ln y\right]/\sigma\left[\ln z\right]$		1.39	1.42	1.46
$\sigma\left[\ln i\right]/\sigma\left[\ln y\right]$	4.56	3.22	3.38	4.26
$\sigma\left[\ln c\right]/\sigma\left[\ln y\right]$	0.70	0.32	0.29	0.23
$\text{COR}(\ln c, \ln y)$	0.48	0.88	0.94	0.92
$\text{COR}(\ln i, \ln y)$	0.97	0.99	0.93	0.96
Statistics for other variables				
$\psi v/y$	-	0.016	0.016	0.016
$\sigma\left[\ln\frac{y}{n}\right]$	0.013	0.0069	0.0071	0.0070
$\sigma\left[\frac{n}{u}\right]/\sigma\left[\ln\frac{y}{n}\right]$	19.0	29.07	31.79	28.95
$\text{COR}\left[\frac{u}{u+n}, \ln y\right]$	-0.86	-0.85	-0.85	-0.85
$\text{COR}\left[\frac{u}{u+n}, \ln v\right]$	-0.93	-0.47	-0.47	-0.39

Notes: Monthly data from the model are transformed into quarterly data and then filtered using the HP-filter. Model statistics are based on one long sample of 60,000 observations. The "=" sign indicates that the numbers are by construction equal to the number on the left. The "-" sign indicates that this statistic plays no role in this model. Prices are fixed in the economy with adjusting r and the nominal interest rate is almost constant in the model with adjusting prices. The numbers in the row for $\psi v/y$ indicate steady state values.

Table 5: Summary statistics; $\gamma = 0.45$, full calibration

	data	closed	open	open
factor dampening international trade			adjusting r	adjusting prices
Used for calibration				
$u/(u+n)$	0.057	=	=	=
n/l^*	0.592	=	=	=
$\sigma\left[\frac{u+n}{l^*}\right]/\sigma\left[\ln\frac{y}{n}\right]$	0.182	=	=	=
$\sigma\left[\frac{n}{l^*}\right]/\sigma\left[\ln\frac{y}{n}\right]$	0.437	=	=	=
$\sigma\left[\ln w\right]/\sigma\left[\ln\frac{y}{n}\right]$	0.755	=	=	=
$\sigma\left[\ln t/y\right]/\sigma\left[\ln y\right]$	0.281	-	=	=
Standard RBC statistics for C, I, and Y				
$\sigma\left[\ln y\right]$	0.016	0.012	0.013	0.013
$\sigma\left[\ln y\right]/\sigma\left[\ln z\right]$	-	1.41	1.43	1.44
$\sigma\left[\ln i\right]/\sigma\left[\ln y\right]$	4.56	3.73	3.87	4.67
$\sigma\left[\ln c\right]/\sigma\left[\ln y\right]$	0.70	0.29	0.29	0.26
$\text{COR}(\ln c, \ln y)$	0.48	0.44	0.49	0.54
$\text{COR}(\ln i, \ln y)$	0.97	0.98	0.91	0.96
Statistics for other variables				
$\psi v/y$	-	0.016	0.016	0.014
$\sigma\left[\ln\frac{y}{n}\right]$	0.013	0.0070	0.0072	0.0073
$\sigma\left[\frac{n}{u}\right]/\sigma\left[\ln\frac{y}{n}\right]$	19.0	29.07	29.66	25.90
$\text{COR}\left[\frac{u}{u+n}, \ln y\right]$	-0.86	-0.86	-0.86	-0.86
$\text{COR}\left[\frac{u}{u+n}, \ln v\right]$	-0.93	-0.48	-0.46	-0.46

Notes: Monthly data from the model are transformed into quarterly data and then filtered using the HP-filter. Model statistics are based on one long sample of 60,000 observations. The "=" sign indicates that the numbers are by construction equal to the number on the left. The "-" sign indicates that this statistic plays no role in this model. Prices are fixed in the economy with adjusting r and the nominal interest rate is almost constant in the model with adjusting prices. The numbers in the row for $\psi v/y$ indicate steady state values.