

FAIR PRICES & FAIR WAGES:  
IMPLICATIONS FOR MACROECONOMIC DYNAMICS  
IN CLOSED & OPEN ECONOMIES

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*Ođluma,*

*To my son Arda*

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# Chapter 1

## Introduction

*BUDDHISM: "Hurt not others in ways that you yourself would find harmful."*

*CONFUCIANISM: "Surely it is a maxim of loving kindness: Do not unto others what you would not have them do unto you."*

*TAOISM: "Regard your neighbor's gain as your own gain and your neighbor's loss as your own loss."*

*JUDAISM: "What is hateful to you, do not to your fellow men. That is the entire Law; all the rest is commentary."*

*CHRISTIANITY: "All things whatsoever ye would that men should do to you, do ye even so to them; for this is the Law and the Prophets."*

*ISLAM: "No one of you is a believer until he desires for his brother that which he desires for himself."*

*The Golden Rule<sup>1</sup>*

What is the relationship between output, employment, and inflation? To which extent and through which channels do economic policies affect these aggregates? How does economic integration affect these aggregates and the effectiveness of economic policies? These are some of the practically relevant questions that have been forming the research agenda of many economists. In this dissertation, I study a relatively small proportion of these questions. To this end, I use the New Keynesian model extended to allow for the facts that behavioral economics has assessed for price and wage formation. In particular, I incorporate reciprocal altruistic behavior to the New Keynesian model. The results I report in my dissertation suggest that this incorporation may have profound and far-reaching implications.

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<sup>1</sup>First Principles, Hausser (2006) pp. 356-418.

In this introductory chapter, first I briefly lay out the underlying motivations for (i) using the New Keynesian model as my general framework and (ii) its behavioral extension. In the section after, I provide a brief description of the microeconomic foundations of fair prices as the latter is relatively new to macroeconomics. Because the fair wage model I use builds on the efficiency wage theory, which has a long tradition in macroeconomics, it does not require an extra clarification (in addition to that provided in relevant chapters below).<sup>2</sup> In the last section, I offer a short road map of the major issues covered in my dissertation.

## 1.1 Behavioral Macroeconomics

Progress in macroeconomics over the past century has given rise to the dominance of a specific model: the New Keynesian model. Main elements of the New Keynesian model are explicit microeconomic foundations, general equilibrium, monopolistic competition, and staggered price setting.<sup>3</sup> The standard New Keynesian model can be represented by an IS curve, an LM curve, and a Phillips curve, and, in this sense, is akin to its intellectual forefathers from the (Old) Keynesian literature. But, because these IS-LM-Phillips curve relations are derived from utility/profit maximizing behavior of agents, and, thus, have rigorous microeconomic foundations, the New Keynesian model is also akin to the Real Business Cycle model.<sup>4</sup>

In the light of the findings of the New Keynesian literature, extending the New Keynesian model in one way or the other seems necessary<sup>5</sup>. But why behavioral economics?

In general, over the last three decades an increasing number of researchers trying to explain economic phenomena has been departing from the standard

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<sup>2</sup>For a textbook treatment of efficiency wages, see Chapter 9 of Blanchard and Fisher (1989) and Chapter 10 of Romer (1996).

<sup>3</sup>King and Wolman (1996) and Yun (1996) are early prototypes of the standard New Keynesian model. The book edited by Mankiw and Romer (1991), a two volume collection of papers written in 1980's, draws attention to the role of nominal and real rigidities, and forms to a great extent the intellectual foundations of the New Keynesian model. A similar collection emphasizing market imperfections is the book edited by Dixon and Rankin (1995).

<sup>4</sup>See Cooley (1994) for a collection of important contributions to the Real Business Cycle literature.

<sup>5</sup>Among many others, see, for example, Blanchard (2008), and Chari et al. (2008). See also the introductory sections of Chapters 2 through 5 in this dissertation



model of material payoff maximizing behavior towards models of behavior that attribute richer roles to psychological or sociological mechanisms. This departure is not a fad in the profession given the compelling evidence that human decisions are prone also to other factors that the standard models have abstracted from. For example, my subjective synopsis can name: Kahneman and Tversky (1979) on reference dependence; Akerlof (1982) on reciprocity in industrial relations; Shiller (1984) on fads and fashions in stock markets; Kahneman et al. (1986) on fairness considerations in monopoly pricing; Lux (1995) on herding in financial markets; Fehr and Gächter (2000) on cooperation and punishment in public goods.<sup>6</sup>

In particular, theories of reciprocal altruistic behavior and evidence from experimental markets provide a good explanation of stickiness that we observe in price and wage data (Okun 1981, Akerlof 1982, Kahneman et al. 1986, Fehr et al. 1993, Rabin 1993, and Renner and Tyran 2004). The intuitive explanation is as follows. For a stable relationship between the firm and its customers (workers), the new price (wage) offer of the firm should be justifiable with regard to the firm's attitude towards its customers (workers). For example, a higher price (lower wage) in response to a higher demand (drop in sales) is not justifiable behavior because it does not indicate any altruism. Hence, if the firm can show that it treats its costumers (workers) well (by not fully exploiting the monopoly power/by offering a wage higher than the market clearing wage), costumers (workers) in return continue to buy the good (to supply high effort).

Two tractable models consistent with the behavioral argument of wage and price stickiness are the fair price setting of Rotemberg (2005) and the fair wage setting of Danthine and Kurmann (2004). To model the price adjustment mechanism, I use Rotemberg's setting in Chapters 2, 3, and 6. To model the wage adjustment mechanism, I use the setting of Danthine and Kurmann in Chapters 3 through 6.

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<sup>6</sup>No need to say, it is behind the scope of this thesis to provide a comprehensive list of ideas and names of corresponding researchers in the area of behavioral economics. Thaler (1994) is a collection of his *Anomalies* columns in *Journal of Economic Perspectives*, and provides an extensive survey. A more abbreviated and compact survey is of Rabin (1998).

## 1.2 Microeconomic Foundations of Fair Prices

What proceeds provides a brief layout of a one-period model, and the link between the consumers fairness concerns and the probability of price adjustment. Consequently, it serves as a basis to my discussion about nominal rigidity in Chapters 2, 3, and 6. The material presented below is a brief summary of Rotemberg's (2005) analysis.

There is a unit mass of households. Each household produces its own differentiated good. The felicity function of household  $j$ , is given by

$$w^j = u(C^j) - v(\phi^j y^j), \quad (1.1)$$

where  $y^j$  denotes the output,  $\phi^j$  denotes a variable indicating costs and  $C^j$  is the Dixit-Stiglitz (1977) aggregator. The function  $u(\cdot)$  is concave and increasing, and the function  $v(\cdot)$  is convex and increasing. The aggregator is defined as  $C^j \equiv \left[ \int_0^1 c^j(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}}$ ,  $\theta > 1$ , where  $c^j(z)$  is the consumption of household  $j$  of good  $z$ ,  $\theta > 1$  is the elasticity of substitution. Expenditure minimization by households implies that the corresponding price index is given by

$$P = \left[ \int_0^1 (P^j)^{1-\theta} dj \right]^{\frac{1}{1-\theta}}, \quad (1.2)$$

and the demand for household  $j$ 's product is given by

$$y^j = \frac{E}{P} \left( \frac{P^j}{P} \right)^{-\theta}, \quad (1.3)$$

where  $E$  denotes the aggregate (nominal) expenditure. Further, household  $j$ 's total expenditure,  $E^j$ , equals its revenue from sales:

$$PC^j = E^j = P^j y^j. \quad (1.4)$$

Consumers expect altruistic behavior from their sellers towards them. In particular, consumers want seller  $i$  to set the price  $P^i$  so as to maximize

$$w^i + \varpi^i \int_{j \neq i} w_t^j \quad (1.5)$$

where  $0 < \varpi^i < 1$  is the parameter measuring the extend to which seller  $i$  is altruistic towards its customers. Using equations (1.1), (1.2), (1.3) and (1.4),

in (1.5), we can express the altruistic maximization problem of a seller as

$$\begin{aligned} \max_{P^i} u \left( \frac{P^i}{P} \frac{E}{P} \left( \frac{P^i}{P} \right)^{-\theta} \right) - v \left( \phi^i \frac{E}{P} \left( \frac{P^i}{P} \right)^{-\theta} \right) + \\ + \varpi^i \int_{j \neq i} \left[ u \left( E^j \left[ \int_0^1 (P^i)^{1-\theta} di \right]^{\frac{1}{\theta-1}} \right) - v(\phi^j y^j) \right]. \end{aligned}$$

The first order condition for this unconstrained maximization problem is

$$\begin{aligned} (1-\theta) \frac{E}{P} \frac{u'(C^i)}{P} \left( \frac{P^{i*}}{P} \right)^{-\theta} + \theta \frac{E}{P} \phi^i v'(\phi^i y^i) \left( \frac{P^{i*}}{P} \right)^{-\theta-1} + \\ - \varpi^i \int_{i \neq j} \frac{E^j}{P} \frac{u'(C^j)}{P} \left( \frac{P^{i*}}{P} \right)^{-\theta} = 0, \end{aligned}$$

where  $P^{i*}$  is the price that maximizes (1.5). In a symmetric equilibrium, all households have the same marginal utility of consumption,  $u'$ . Hence, the first order condition can be arranged to get

$$\frac{P^{i*}}{P} = \frac{\theta}{\theta + \varpi^i - 1} \frac{v'}{u'} \phi^i. \quad (1.6)$$

Notice that the term  $(\frac{v'}{u'} \phi^i)$  is nothing but the real marginal cost of production (cf. equation A 2.26 of Chapter 2). Two polar cases are worth to examine. As  $\varpi \rightarrow 0$ , the price approaches that implied under the standard monopolistic competition. More interestingly, as  $\varpi \rightarrow 1$ , the price approaches that implied under perfect competition.

Consumers do not know the true value of  $\varpi^i$  and  $\phi^i$ , but they receive random signals about the costs. Using these signals, they infer the value of  $\varpi^i$ . If they believe that  $\varpi^i$  is below some certain level, which implies firm  $i$  is not altruistic enough (the price is not fair), they stop buying. Rotemberg further provides the analysis of consumers' willingness to harm the firm that does not act altruistically. A direct effect of such a desire is a sharp fall in demand (boycotts), i.e., a large kink in the demand curve at a certain price level. For this reason, firms keep their prices below this price level, which, in turn induces price rigidity.

The inverse relationship between the relative price of firm  $i$  and the  $\varpi^i$  is apparent from equation (1.6). In a dynamic setting, a second plausible variable that can affect the consumers' inferences about  $\varpi^i$  is the level of inflation in the last period. It is plausible to assume that a price increase

is easier to pronounce by a firm because inflation can be blamed for the increase in costs. Such a statement of the firm does not need to be true, because consumers have imperfect information about firm's costs. Formally: the probability density function from which signals about costs are drawn governs also the probability that a firm keeps its price constant. Rotemberg suggest that an increase in inflation shifts the distribution such that drawing a positive inference about firm's altruism becomes more likely, which, in turn, implies that the probability that a firm keeps its price constant decreases. Denoting the letter probability by  $\gamma_t$  and inflation by  $\pi_t$ , the probability of price adjustment can be described, up to a log-linear approximation, by

$$\log \gamma_t = \omega_{rp} \log rp_t + \omega_\pi \log \pi_{t-1}, \quad (1.7)$$

where  $\omega_{rp} > 0$ ,  $\omega_\pi < 0$ ,  $rp_t \equiv P_t^{i^*}/P_t$ . Equation 1.7 shall turn out to be key equation in my analyses featuring fair prices. For this reason, I provide further clarification of this equation in the next two chapters.

### 1.3 An Overview of the Dissertation

The analyses in Chapters 2 and 3 are based on closed economy models. In these two chapters, I attempt to provide explanations for the persistent effects of monetary policy shocks on output and inflation, and the dynamic relationship between the latter two.

In Chapter 2, I study an economy where a contractionary (expansionary) monetary policy shock gives rise to a more (less) frequent price adjustment. To this end, I develop a model that allows for supply side effects of nominal shocks, and extend the price adjustment mechanism of Rotemberg (2005) accordingly. I then analyze the implications of the extended price adjustment mechanism for the dynamics of output and inflation in the aftermath of a monetary policy shock.

In Chapter 3, I explore the joint implications of fair prices and fair wages. The general framework that I use is based on Christiano et al. (2005). First, I analyze the comovements of employment, wages, and inflation with output, with a focus on the lead-lag relation between inflation and output. I then study the propagation of monetary policy shocks.

The analyses in Chapters 4 through 6 primarily concern issues related to international economics. As a general framework, I use a two-country model

in the tradition of Obstfeld and Rogoff (1995). There are, however, significant differences between the models as regards their details, e.g., assumptions regarding preferences, the production technology, international price settings, the structure of shocks, just to name a few.

In Chapters 4 and 5, I analyze the impact of an increase in international trade in financial assets on labor market volatility and on the effectiveness of fiscal policy, respectively. Unfortunately, notwithstanding numerous efforts, the impact of financial market integration is a highly controversial matter, and the matter remains essentially unclear. Therefore, my study in these two chapters is an offer of an alternative framework for thinking on these issues.

In Chapter 6, I again focus on the joint implications of fair prices and fair wages, but this time allowing for the real exchange rate movements and international propagation of shocks. I analyze the dynamic effects of monetary policy and technology shocks under different assumptions for market imperfections and completeness. My results with regard to market completeness contradict the findings of previous research, and therefore, suggest to reconsidering the claims of the relevant former studies.

In the last chapter, I offer some concluding remarks and my outlook on future research. All chapters are to a certain extent self contained (for the price of repeating myself a bit), and does not require to be read in certain order. To obtain a contrast of closed and open economy implications of fair prices and fair wages, Chapters 3 and 6 can be read in a row, but this not necessary as I provide a brief comparison in Chapter 6. I hope that the reader will gain some new insights.

## Chapter 2

# A New Cost Channel of Monetary Policy

Understanding the dynamics of output and inflation in the aftermath of a monetary policy shock is a key issue in macroeconomic research. Developing a deeper understanding of this issue requires a detailed analysis of the link between inflation and price adjustment by firms. The analysis of this link calls for a careful study of why firms adjust prices sluggishly.

Rigorous attempts to explain the sluggishness of prices are the theories of (i) imperfect information (Phelps 1970, Lucas 1972, Mankiw and Reis 2002), (ii) costly price adjustment and menu costs (Rotemberg 1982, Mankiw 1985, Akerlof and Yellen 1985), and (iii) costly information (Ball and Mankiw 1994). The theories developed by Taylor (1980), Rotemberg (1982), and Calvo (1983) have been widely applied in recent research as devices for modeling sticky prices in dynamic, general equilibrium frameworks.

These widely used theories of sluggish price adjustment cannot explain two stylized facts that have been documented by empirical researchers. First, Fabiani et al. (2006) report that implicit contracts between firms and their customers appear to be the main explanation of price stickiness in the euro area. Menu costs and costly information are found to be of minor importance. Implicit contracts imply that firms and their customers have long-term relations, and in order not to antagonize their customers firms reset prices only after cost shocks, but not after demand shocks.<sup>1</sup>

Second, the theories of Taylor (1980), Rotemberg (1982), and Calvo

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<sup>1</sup>For studies yielding similar results, see Blinder et al. (1998) for the US, Hall et al. (2000) for the UK, Amirault et al. (2004) for Canada, and Apel et al. (2005) for Sweden.

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(1983) imply a time-dependent pricing policy which, in turn, implies that the frequency of price adjustment is constant. Apel et al. (2005) and Fabiani et al. (2006), however, report that macroeconomic conditions affect the frequency of price adjustment. The view that the frequency of price adjustment should be taken as endogenous has also been suggested by Koniczny and Skrzypacz (2006) who report evidence that the intensity of consumer search for the best price affects the frequency of price adjustment.

In order to account for these two stylized facts, I analyze the effects of monetary policy on output and inflation in an extension of a model developed by Rotemberg (2005). Rotemberg's model is based upon behavioral economics, and it captures the connotations of both implicit contract theory and a variable frequency of price adjustment. Another appealing feature of Rotemberg's model is that it generalizes to positive long-run trend inflation.<sup>2</sup>

Rotemberg (2005) assumes that price increases are viewed by costumers as fair and justifiable only if these increases are triggered by cost increases. Otherwise customers get upset, and the relationship between the firm and its customers breaks down. Consumers have imperfect information about the cost of firms, and they receive random signals about costs. In Rotemberg's model, relative prices and inflation are signals about the fairness of price increases, and, in particular, inflation is a signal of cost increases. For this reason, the probability that firms can reset their price is a function of relative and general price level increases.

The main motivation for my extension of Rotemberg's model stems from the recent studies on the so-called cost channel of monetary policy transmission (See, for example, Barth and Ramey 2001, Ravenna and Walsh 2006, Chowdhury et al. 2006, and Gaiotti and Secchi 2006). These studies present empirical evidence on the presence of the cost channel. The cost channel implies that, apart from affecting the *demand* side of the economy, monetary policy shocks affect also the *supply* side because they affect firms' cost of financing working capital.

Building on the research on the cost channel of monetary policy, I assume that consumers perceive contractionary monetary changes as cost increases. Because consumers have imperfect information about the cost of firms, the interest rate is an easily-available, easy-to-monitor signal of cost-

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<sup>2</sup>Trend inflation is confirmed by economic data, and has important implications for macroeconomic dynamics. See, for example, Ball et al. (1988), Ascari (2004), and Cogley and Sbordone (2006) for implications of trend inflation in New Keynesian frameworks.

push shocks. Moreover, the interest rate contains important information about the overall state of the economy, which, in turn, is important because, as suggested by Rotemberg (2005), “*the frequency of price adjustment can depend on economy-wide variables observed by consumers*”. Because the cost channel of monetary policy I develop in this chapter differs from the traditional cost channel discussed in the earlier literature, I will henceforth call it *the new cost channel*. I will use the term *the working capital cost channel* when I refer to the traditional cost channel.

Using a small-scale, dynamic general equilibrium model, I show that the new cost channel has substantial implications for the propagation of monetary policy shocks. The responses of inflation and output to monetary policy shocks are more realistic in the model with the new cost channel than in the model without it. The response of inflation in my model is delayed and persistent. My model also implies a significant increase in the persistence of the effect of monetary policy shocks on output. Further, my model implies an increase in the persistence of the response of the nominal interest rate.

I organize the remainder of this chapter as follows. In Section 2.1, I lay out the dynamic stochastic general equilibrium model I used to derive my results. In Section 2.2, I report the results of numerical simulations. In Section 2.3, I report the results of the sensitivity analysis. In section 2.4, I conclude.

## 2.1 The Model Economy

The economy operates in discrete time, and monetary policy is the only source of uncertainty. The economy consists of households, firms, a financial intermediary, and a monetary authority. The numbers of households and firms are assumed to be large. For tractability, I assume a continuum of households, indexed by  $j$ , and firms, indexed by  $z$ , with  $j, z \in [0, 1]$ .

### 2.1.1 Households

The expected present value of lifetime utility of a representative household  $j$  is given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{(C_t^j)^{1-\sigma^{-1}} - 1}{1 - \sigma^{-1}} - \frac{(N_t^j)^{1+\phi}}{1 + \phi} \right], \quad (2.1)$$



with

$$C_t^j \equiv \left[ \int_0^1 c_t^j(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}}, \quad (2.2)$$

where  $0 < \beta < 1$  is the discount factor,  $0 < \sigma^{-1}$  is the coefficient of relative risk aversion (or, equivalently,  $\sigma$  is the intertemporal elasticity of substitution),  $0 < \phi$  is the inverse of the elasticity of labor supply with respect to real wages, and  $1 < \theta$  is the elasticity of substitution among differentiated goods.  $E_t$  is the mathematical expectation operator conditional on period  $t$  information,  $N_t^j$  is the quantity of labor supplied by household  $j$ , and  $c_t^j(z)$  denotes household  $j$ 's consumption of good  $z$ . Using the Dixit-Stiglitz (1977) aggregator given in (2.2), I derived the corresponding price index,  $P_t$ , defined as the price of one unit of the composite consumption good,  $C_t$ :

$$P_t = \left[ \int_0^1 P_t(z)^{1-\theta} dz \right]^{\frac{1}{1-\theta}}. \quad (2.3)$$

The demand of household  $j$  for good  $z$  is given by

$$c_t^j(z) = \left[ \frac{P_t(z)}{P_t} \right]^{-\theta} C_t^j, \quad (2.4)$$

where  $P_t(z)$  is the price of good  $z$ .

In order to maximize its utility function given in (2.1), the household  $j$  chooses  $C_t^j$ ,  $N_t^j$ , and the amount of nominal riskless one-period bonds  $B_t^j$  to carry over to the next period. The period- $t$  budget constraint is given by

$$\frac{R_t^{-1} B_t^j}{P_t} + C_t^j \leq \frac{B_{t-1}^j}{P_t} + \frac{W_t N_t^j}{P_t} + \Phi_t^j, \quad (2.5)$$

where  $R_t$  is the gross nominal returns on bond holdings,  $W_t$  is the nominal wage rate determined in a competitive labor market, and  $\Phi_t^j$  is the sum of the household's real profit income received from the financial intermediary and firms. Each household holds the same amount of shares of the financial intermediary and the same amount of shares of each firm.

The optimality conditions for the household's maximization problem are given by

$$(C_t^j)^{-\sigma^{-1}} = \lambda_t, \quad (2.6)$$

$$\frac{(N_t^j)^\phi}{(C_t^j)^{-\sigma^{-1}}} = \frac{W_t}{P_t}, \quad (2.7)$$

$$\frac{\lambda_t}{R_t P_t} = \beta E_t \frac{\lambda_{t+1}}{P_{t+1}}, \quad (2.8)$$

a transversality condition, and the binding version of the budget constraint given in (2.5). For future convenience, let  $\Lambda_{t,t+i}$  denote a stochastic discount factor for nominal payoffs between periods  $t$  and  $t+i$ . Then, using equations (2.6) and (2.8), I obtain

$$\Lambda_{t,t+i} \equiv \beta^i \left( \frac{C_{t+i}^j}{C_t^j} \right)^{-\sigma^{-1}} \frac{P_t}{P_{t+i}}. \quad (2.9)$$

### 2.1.2 Firms

Each firm operates in a monopolistically competitive goods market. The demand curve is given by

$$y_t(z) = \left[ \frac{P_t(z)}{P_t} \right]^{-\theta} C_t, \quad (2.10)$$

where  $y_t(z)$  is the good produced by firm  $z$  and  $C_t \equiv \int_0^1 C_t^j dj$  is total consumption.

The production function is given by

$$y_t(z) = N_t(z), \quad (2.11)$$

where  $N_t(z)$  is the labor input of firm  $z$ .

To model the working capital cost channel, I assume that the workers are paid before production takes place. Therefore, at the beginning of period  $t$ , each firm has to borrow an amount of  $W_t N_t(z)$  from the financial intermediary to finance its wage bill, and at the end of the period this amount has to be paid back with an interest of  $R_t - 1$ . Given the production function in (2.11), and the cost structure of the firm, cost minimization requires

$$mc_t = R_t w_t, \quad (2.12)$$

where  $mc_t$  is the real marginal cost of production and  $w_t \equiv W_t/P_t$ .

To model price stickiness, I use the price setting mechanism developed by Rotemberg (2005). The distinguishing feature of the setting suggested

by Rotemberg is that the probability that a firm can reset its price is an endogenous variable rather than an exogenous constant. Firms can change the price in every period with probability  $0 < 1 - \gamma_t < 1$ . The maximization problem of a typical firm can be expressed as

$$\max_{P_t(z)} E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \Gamma_{t,t+i} y_{t+i}(z) [P_t(z) - P_{t+i} m c_{t+i}(z)], \quad (2.13)$$

subject to

$$y_t(z) = \left[ \frac{P_t(z)}{P_t} \right]^{-\theta} C_t,$$

where the variable  $\Gamma_{t,t+i}$  denotes the probability that the firm cannot change the price between the periods  $t$  and  $t+i$  and defined as  $\Gamma_{t,t+i} \equiv \prod_{l=1}^i \gamma_{t+l}$ , with  $\Gamma_{t,t} \equiv 1$ . Firms set the price so as to maximize the expected present discounted value of profits. Using the demand curve to substitute out  $y_t(z)$  in (2.13) and maximizing it over  $P_t(z)$  gives

$$E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \Gamma_{t,t+i} y_{t+i}(z) \left[ P_t^*(z) - \frac{\theta}{\theta-1} P_{t+i} m c_{t+i} \right] = 0, \quad (2.14)$$

where  $P_t^*(z)$  is the optimal price. Equation (2.14) implies that if the firm can change its price in every period, then the optimal price of good  $z$  is simply a mark-up over marginal costs. But because the firm cannot set the price in every period, it takes into account also average future expected marginal revenues and average future expected marginal costs. These are the standard logical implications of staggered price adjustment mechanisms. Here, however, unlike time-dependent price-adjustment settings, the probability of price adjustment in the averaging factor depends on the state of the economy.<sup>3</sup> A detailed explanation of the link between the probability of price adjustment of a firm and the state of the economy shall be presented in the next subsection.

Using (2.14), the optimal relative price,  $rp_t \equiv P_t^*(z)/P_t$ , can be expressed as

$$rp_t = \frac{\theta}{\theta-1} \frac{E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \Gamma_{t,t+i} (P_{t+i}/P_t)^{1+\theta} C_{t+i} m c_{t+i}}{E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \Gamma_{t,t+i} (P_{t+i}/P_t)^{\theta} C_{t+i}}. \quad (2.15)$$

<sup>3</sup>Setting the probability of price adjustment,  $\gamma_t$ , constant reduces the price setting mechanism to that of Calvo (1983) and Yun (1996).

Because I assume symmetry across firms, implying that the firms that can reset their prices choose the same new price, I denote the relative price by  $rp_t$  rather than by  $rp_t(z)$ . The price index (2.3), therefore, can be written as

$$\gamma_t(\pi_t)^{\theta-1} + (1 - \gamma_t)(rp_t)^{1-\theta} = 1, \quad (2.16)$$

where  $\pi_t$  denotes the gross inflation rate.

### 2.1.3 The Frequency of Price Adjustment

Because the assumption of a variable frequency of price adjustment is one of the key features of the model in this chapter, it deserves special attention. As is widely known, models employing the price setting mechanism of Calvo (1983) assume that in any period of time a constant fraction of randomly selected firms cannot change their prices. This implies a constant time path for the frequency of price adjustment. But studies, e.g. by Konieczny and Skrzypacz (2005) and Nakamura and Steinsson (2008), show that there is a high correlation between the frequency of price changes and inflation. Thus, in a plausible general equilibrium model, a shock that affects inflation should also affect the frequency of price adjustment. Moreover, the Calvo mechanism gives rise to counterfactual results in the presence of positive trend inflation (Bakhshi et al. 2007).<sup>4</sup> The recent study of Konieczny and Skrzypacz (2006) provides empirical evidence that contradicts the constant frequency of price adjustment. Also, the findings of Apel et al. (2005) and Fabiani et al. (2006) suggest that the frequency of price adjustment is affected by macroeconomic conditions.

By building on the theory of implicit contracts, Rotemberg (2005) generalizes Calvo's (1983) model to incorporate a variable and endogenous frequency of price adjustment. The theory of implicit contracts implies that firms are reluctant to change prices because they have some sort of long term relationships with their customers, who do not like price increases. After an increase of the price of a firm, the relationship of the firm with its customers breaks down unless the customers believe that the increase in the price was triggered by cost increases, and, thus, fair.

Following Rotemberg (2005), I assume that the relative price,  $rp_t$ , and the inflation rate in the last period,  $\pi_{t-1}$ , are signals about the perceived

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<sup>4</sup>To remedy the shortcomings of the Calvo setting, Romer (1990) develops a model where firms facing cost of price adjustment optimally choose the frequency of price adjustment.

fairness of price increases, and, in particular,  $\pi_{t-1}$  is a signal of cost increases. Because, *ceteris paribus*, an increase in the relative price will imply that the absolute price is increased more relative to other prices,  $rp_t$  is a ‘negative’ signal of fairness. Because inflation implies an overall increase in costs,  $\pi_{t-1}$  is a ‘positive’ signal of fairness. In addition to  $rp_t$  and  $\pi_{t-1}$ , which are the variables affecting the frequency of price adjustment in Rotemberg (2005), I assume that the nominal interest rate,  $R_t$ , is also such a signal because consumers perceive nominal interest changes as cost changes. This assumption can be justified by considering that an increase in the nominal interest rate negatively affects the firm’s cost of financing working capital. Because of this cost-push effect, the increase in the nominal interest rate can be pointed to consumers as an increase in costs, i.e.,  $R_t$  is a ‘positive’ signal of fairness.<sup>5</sup> Recent findings of Choudhary et al. (2007) also support my extension of Rotemberg’s model. Choudhary et al. report that when faced with a temporary or expected rise in demand, around 85 % of price setters would leave their prices unchanged. When faced with an increase in the interest rate, however, about 42% of the price setters would increase the prices.

Moreover, as a signal of changes in costs, the nominal interest rate is easily available and easy to monitor. Consequently, as the nominal interest rate contains important information about the overall state of the economy, the nominal interest rate act as a proxy for cost-change-signaling variables that are absent in the model.

Accordingly, firms adjust their prices only when they believe that the price increase will not bring about a customer resistance, i.e., a sharp fall in demand.<sup>6</sup> Thus, the random signals that govern the fairness evaluation of a price increase also govern the probability of the price adjustment:

$$\log \gamma_t = \omega_{rp} \log rp_t + \omega_{\pi} \log \pi_{t-1} + \omega_R \log R_t. \quad (2.17)$$

As regards the signs of the parameters,  $\omega_{rp}$  is positive because, *ceteris paribus*,

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<sup>5</sup>A counter argument to this justification can be as follows. An increase in the nominal interest rate is a signal of tighter monetary policy, and thus will lead to a decrease in inflation. For this reason consumers may perceive price increases after an increase in the nominal interest rate as unfair. I have also simulated a model in which an increase in the nominal interest rate gives rise to a less frequent price adjustment. As results of that simulation (not presented) have been counterfactual, my assumption that consumers perceive nominal interest changes as cost changes appears empirically more plausible than the counter argument above.

<sup>6</sup>Price decreases, on the other hand, are excluded from the analysis by assuming that the steady state level of inflation is sufficiently large which, in turn, makes the price decreases nonoptimal.

if the increase in the price of good  $z$  is higher than the increase in the consumer price index, then customer of firm  $z$  can perceive this unfair, and thus the reset probability  $1 - \gamma_t$  decreases. Because higher inflation will imply higher costs, and because price increases triggered by cost increases are perceived fair,  $\omega_\pi$  is negative, and thus the reset probability  $1 - \gamma_t$  increases in inflation.<sup>7</sup> Finally, the parameter  $\omega_R$  is negative because of the cost-push effect of nominal interest rate increases.

### 2.1.4 The Financial Intermediary and The Monetary Authority

The financial intermediary operates costlessly, borrows an amount of  $M_t$  from the monetary authority at the rate  $R_t - 1$ , and lends the amount  $W_t \int_0^1 N_t(z) dz$  to the firms at the rate  $R_t - 1$ . This implies that the profit of the financial intermediary is zero. I assume the monetary authority transfers its interest income  $W_t \int_0^1 N_t(z) dz (R_t - 1)$  to the financial intermediary which in turn distributes it to its shareholders.

In order to close the model, I assume that the monetary authority conducts its policy according to a reaction function given by

$$\log R_t = \rho_0 + \rho_\pi \log \pi_t + \rho_L \log R_{t-1} + \varepsilon_t^R, \quad (2.18)$$

where  $\rho_0$  is a constant, and  $\varepsilon_t^R$  is an unanticipated shock to monetary policy. The latter is also assumed to be white-noise.

### 2.1.5 Aggregation

Because I study a symmetric equilibrium, I can drop the indices of  $j$ 's and  $z$ 's from all equations but equation (2.10). The reason for excluding equation (2.10) is that the so-called *inefficient price dispersion*. To view this issue, integrate both sides of the equation (2.10) over  $z$ . The result is the resource constraint

$$Y_t = s_t C_t, \quad (2.19)$$

where  $Y_t \equiv \int_0^1 y_t(z) dz$ , and  $s_t \equiv \int_0^1 \left( \frac{P_t(z)}{P_t} \right)^{-\theta} dz$ . Because, by Jensen's inequality,  $s_t$  is bounded below by 1, aggregate production may differ from

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<sup>7</sup>The idea of that the reset probability increases in inflation is emphasized also in Bakhshi et al. (2007).

aggregate consumption (Schmitt-Grohé and Uribe 2004). Thus the price dispersion generated by the assumed price setting mechanism is a costly distortion. Applying the same reasoning used to derive equation (2.16),  $s_t$  can be expressed as

$$s_t = (1 - \gamma_t)rp_t^{-\theta} + \gamma_t\pi_t^\theta s_{t-1}. \quad (2.20)$$

Market clearing conditions for bonds, labor, and loans markets are given by

$$\int_0^1 B_t^j dj = 0, \quad \int_0^1 N_t(z) dz = \int_0^1 N_t^j dj, \quad \text{and } M_t = W_t N_t.$$

### 2.1.6 Calibration and Solution of the Model

I log-linearized the equations of the model, and then solved and simulated the calibrated model using the algorithm developed by Klein (2000) and McCallum (2001).<sup>8</sup> To log-linearize, I chose a positive level of steady-state inflation so that the variations in the frequency of price adjustment have an effect on the propagations of shocks. To see this point, note that the coefficient of  $\gamma_t$  in the log-linearized version of equation (2.15) and that of equation (2.16) are, respectively,  $\gamma\beta\pi^\theta - \gamma\beta\pi^{\theta-1}$  and  $\frac{\pi^{1-\theta}-1}{(1-\gamma)(\theta-1)}$ .<sup>9</sup> Thus setting inflation to zero, i.e.,  $\pi = 1$ , reduces these coefficients to zero.

I calibrate the parameters of my model as summarized in Table 2.1. The calibration of the parameters characterizing preferences is based on Ravenna and Walsh (2006), and is standard in the literature.<sup>10</sup> Setting one period to equal a quarter of a year, I set the discount factor  $\beta = 1.041^{-1/4}$  so that the annual rate of interest is 4.1%. I set  $\sigma^{-1} = 1.5$  implying a higher risk aversion than logarithmic utility. I set the inverse of the labor supply elasticity,  $\phi$ , to 1. I set  $\theta = 11$ , implying a markup rate of 10%.

<sup>8</sup>In the appendix to this chapter, I present a detailed derivation of several equations of the model, the solution for the steady state, and the log-linearization of equilibrium conditions.

<sup>9</sup>For notational convenience, I drop the time index of a variable to denote its steady state value.

<sup>10</sup>In order to visualize the effects of varying parameter values, I shall conduct sensitivity analysis in the next section.

Table 2.1: *Calibrated Parameters*

<i>Preferences</i>	
Discount factor:	$\beta = 1.041^{-1/4}$
Intertemporal elasticity of substitution:	$\sigma = 2/3$
Labor supply elasticity	$\phi^{-1} = 1$
Demand elasticity:	$\theta = 11$
<i>Inflation, Price Rigidity and Frequency of Price Adjustments</i>	
Steady-state value of reset probability:	$1 - \gamma = 0.25$
Steady-state value of gross inflation:	$\pi = 1.05^{1/4}$
Elasticity of $\gamma_t$ w.r.t.	
a)optimal relative price:	$\omega_{rp} = 2.5$
b)past inflation:	$\omega_{\pi} = -15$
c)nominal interest rate	$\omega_R = -10$
<i>Monetary Policy</i>	
Interest Rate Smoothing	$\rho_L = 0.9$
Reaction to Inflation	$\rho_{\pi} = 0.9$

The parameters characterizing the price adjustment mechanism are calibrated following Rotemberg (2005). I set  $\pi$  equal to  $1.05^{1/4}$ , so that the annual inflation is 5%, and  $rp$  equal to 1.05. When steady state inflation is zero, steady state values of  $rp_t$  and  $s_t$  are equal to 1 irrespective of the steady state value of  $\gamma_t$ . Given the values of  $\theta$ ,  $\pi$  and  $rp$ , equation (2.16) implies  $\gamma = 0.75$  which, in turn, indicates that, on average, firms adjust their prices once a year. I set  $\omega_{rp} = 2.5$  and  $\omega_{\pi} = -15$ . I set the parameter  $\omega_R$ , governing the effect of the new cost channel, equal to  $-10$ .

For the parameter values of the monetary authority's reaction function, I set  $\rho_{\pi} = 0.9$  and  $\rho_L = 0.9$ . These two values are also based on Rotemberg (2005).

## 2.2 Effects of Monetary Policy Shocks

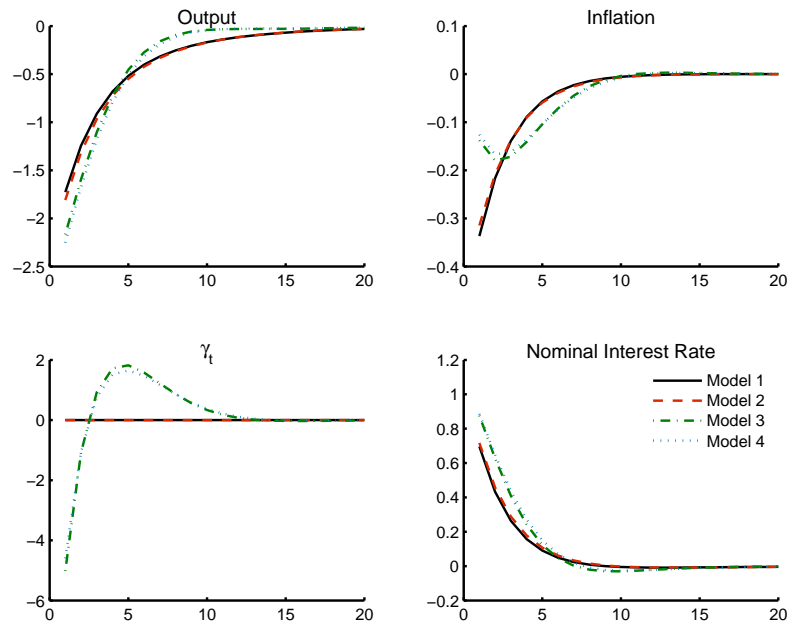
### 2.2.1 A Comparison of Four Alternative Models

Before analyzing the effects of monetary policy shocks in my model, it will be convenient to highlight per se implications of the working capital cost channel and the variable frequency of price adjustment for the propagation



of monetary policy shocks. To this end, I consider four distinct versions of my model. The first one is a standard New Keynesian model, the structure of which is equivalent to that of the baseline model, except that it features Calvo (1983) type price staggering and no working capital cost channel. The second one extends the first one to allow for the working capital cost channel. The third one replaces Calvo-type price staggering in the first one with Rotemberg's (2005) pricing. And the fourth one extends the third one to allow for the working capital cost channel. Note that in the last two models, I considered the pure Rotemberg setting, and thus, abstracted from the new cost channel, the implications of which I shall present in Subsection 2.2.2. All four models considered feature trend inflation.

**Figure 2.1:** *A Contractionary Monetary Shock in Four Alternative Models*



*Note:* The horizontal axis measures quarters. The vertical axis measures logarithmic/percentage deviations from the steady state. Model 1: New Keynesian Model with Calvo pricing. Model 2: Model 1 allowing for the working capital cost channel. Model 3: Model 1 with Rotemberg pricing. Model 4: Model 3 allowing for the working capital cost channel.

Figure 2.1 presents the impulse response functions for the four distinct models. The impulse response functions describe the dynamics of four variables—output, inflation,  $\gamma_t$ , and the nominal interest rate—in the aftermath

of a one percentage point positive shock to the nominal interest rate. Comparing the impulse response functions for Models 1 and 3 to those for Models 2 and 4 highlights the role played by the working capital cost channel on the dynamics of inflation and output in the aftermath of contractionary monetary policy shock. The impulse response functions illustrate the result that the working capital cost channel does not significantly affect the responses of output, inflation,  $\gamma_t$ , and nominal interest rate. Furthermore, this result obtains irrespective of Calvo or Rotemberg type price setting mechanism. For example, the absolute difference in the initial output responses in the first two models –featuring Calvo pricing– is 8.20 basis points, whereas the corresponding statistic in the latter two models –featuring Rotemberg pricing– is 8.58 basis points. Thus, the working capital cost channel alone does not play a critical role for the dynamics of output and inflation, a result also emphasized by Christiano, Eichenbaum and Evans (2005).

As regards the role of the variable frequency of price adjustment for the propagation of monetary policy shocks, my results are qualitatively similar to those reported in Rotemberg (2005). Comparing the impulse response functions for Models 1 and 2 to those for Models 3 and 4 shows that Rotemberg-type pricing produces a delayed response of inflation as shown in the data (Christiano, Eichenbaum and Evans 1999). Since in the models with Rotemberg pricing, the impact effect of a shock on inflation is less than those in the models with Calvo pricing, the impact effect on output is larger in the models with Rotemberg pricing.

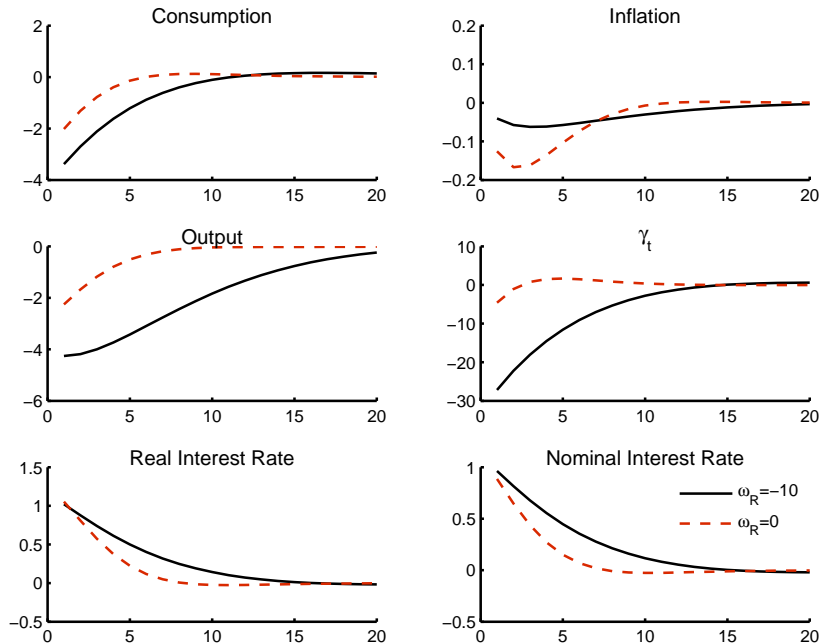
### 2.2.2 Implications of the New Cost Channel

Figure 2.2 depicts impulse response functions for the baseline model and for Rotemberg’s (2005) model. Note that the difference between the baseline model and Rotemberg model is that the former extends the latter by introducing the new cost channel. As can be seen from Figure 2.2, this extension significantly alters the dynamics of model variables.

The response of inflation generated by the baseline model (solid line) is more delayed than the response of inflation generated by the Rotemberg model (dashed line). Measuring the persistence of responses, for example, by half-life, we can observe that the inflation response is more persistent in the baseline model. The baseline model generates also less volatile inflation. The reason for this is that allowing for the new cost channel causes a significant downward shift in the response of  $\gamma_t$ . This arises because the coefficient of  $\gamma_t$  in the linearized version of equation (2.16) is always negative due to  $\pi > 1$

and  $\theta > 1$ . Even though the response of optimal relative price also shifts downwards in my model (not shown in Figure 2.2), the decrease in optimal relative price falls short of the decrease in  $\gamma_t$ . A larger response of  $\gamma_t$ , in turn, implies a muted response of inflation. The intuitive reason for this is that, recall, in the baseline model an increase in the nominal interest rate is a signal of a cost push shock. This induces more frequent price adjustment. The increase in the frequency of price adjustment (drop in  $\gamma_t$ ) dampens the disinflationary effect of a contractionary monetary policy shock. In short, the stronger the (negative) response of  $\gamma_t$  the weaker the (negative) response of inflation. The muted response of inflation, in turn, gives rise to a higher increase in the real interest rate through two channels. The first channel is the well known Fisher condition:  $r_t = R_t/E_t\pi_{t+1}$ , where  $r_t$  denotes the real interest rate. The second channel is the reaction function of the monetary authority,  $\log R_t = 0.9 \log \pi_t + 0.9 \log R_{t-1}$ . Thus, the reduced and stretched inflation response increases the response of the real interest rate directly through the Fisher condition and indirectly through the reaction function of the monetary authority. This indirect effect explains in part the magnified responses of  $\gamma_t$ .

Figure 2.2: *Rotemberg v.s. New Cost Channel*



Note: Solid (dashed) lines show responses in the baseline (Rotemberg) model.

The increased response of real interest rate implies a more persistent consumption and output effects. The difference between the responses of output and consumption stems from price dispersion, and comparing the consumption and output responses for the two models highlights that accounting for price dispersion has nontrivial consequences only in the extended model. The assumption of the new cost channel implies a significant increase in the response of output with respect to that of consumption due to the increase in the response of the price dispersion.

To illustrate further the implications of the assumption of the new cost channel, I assumed  $\gamma_R = -13$  and  $\theta = 15$ , and simulated the effects of a monetary tightening for this particular case as well as for the benchmark case. Figure 2.3 depicts the impulse response functions for both this specific calibration (solid line) and the benchmark calibration,  $\gamma_R = -10$ ,  $\theta = 11$ , (dashed line). Note that setting  $\theta = 15$  implies a more competitive goods market and a steady state level of 0.7266 for  $\gamma_t$ . A more competitive goods market and a greater  $\gamma_R$  (in absolute value) shift the response of output downwards, and generate a hump-shaped output response. As regards inflation, its response is reduced, and the delay of the peak of the inflation response is now six quarters, whereas for the benchmark calibration it is four quarters. By switching from the benchmark calibration to the new one, neither the consumption response nor the nominal interest rate response are altered significantly.

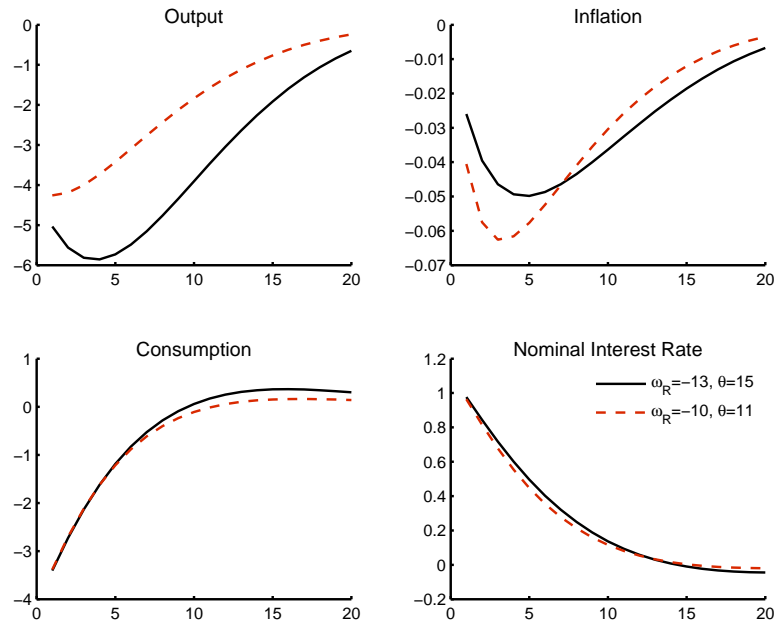


Figure 2.3: Responses under Alternative Parameterizations of  $\omega_R$  and  $\theta$

In sum, my results suggest that the new cost channel can generate output and inflation responses to monetary policy shocks that closely resemble those found in vector autoregressive (VAR) studies assessing the effects of monetary policy shocks (See, for example, Leeper et al. 1996, Bernanke and Mihov 1998, Rotemberg and Woodford 1998, and Christiano et al. 1999).

## 2.3 Sensitivity Analysis

I now analyze the sensitivity of my results to various changes in the calibration of the parameters  $\pi$ ,  $\omega_{rp}$ ,  $\omega_\pi$ ,  $\omega_R$ ,  $\sigma$ ,  $\phi$  and  $\theta$ . Note that any variation in the steady-state of inflation implies a variation in the steady-state of  $\gamma_t$ . Thus, by analyzing the sensitivity of my results with respect to the steady state inflation, I implicitly analyze the sensitivity of my results with respect to the degree of price stickiness as well. Table 2.2 summarizes the set of intervals of these parameters for which I conduct the sensitivity analysis.

**Table 2.2:** *Range of Parameters Varying*

<i>Parameter</i>		<i>Range</i>
Steady state inflation	$\pi$	$1.05^{1/4} : 1.50^{1/4}$
Elasticity of $\gamma_t$ w.r.t.		
optimal relative price	$\omega_{rp}$	0 : 3
lagged inflation	$\omega_\pi$	-25 : 0
nominal interest rate	$\omega_R$	-20 : 0
Intertemporal elasticity of substitution	$\sigma$	0.5 : 2
Inverse of labor supply elasticity	$\phi$	0 : 2
Demand elasticity	$\theta$	5 : 25

In order to summarize the results of the sensitivity analysis, I use three dimensional graphs. The graphs illustrate how the variation in a parameter alters the impulse response functions. The alternative values of the parameter in question are shown on the northwest-southeast axis of the graphs.

Figure 2.4 displays the responses of output and inflation for  $\pi \in [1.05^{1/4}, 1.50^{1/4}]$  (first row),  $\omega_{rp} \in [0, 3]$  (second row),  $\omega_\pi \in [-25, 0]$  (third row), and  $\omega_R \in [-20, 0]$  (last row). Given  $rp = 1.05$  and  $\theta = 11$ , a 5% annual inflation implies  $\gamma = 0.7485$ , whereas a 50% annual inflation implies  $\gamma = 0.1803$ . The graphs in the first row shows that the response of inflation shifts downwards with the increase in  $\pi$ , which, in turn, decreases

the persistence of the output response. This implies that the Phillips-curve gets steeper with the increase in steady-state inflation. Moreover, the delay of the peak of the inflation response decreases from 4 quarters to 1 quarter when annual inflation increases from 5% to 50%. In other words, the delay is 4 quarters when prices are, on average, reset every 4 quarters, and the delay is 1 quarter when prices are, on average, reset every quarter. The second row of graphs shows that the increase in  $\omega_{rp}$  brings about a stronger output response and a more muted inflation response. The third row of graphs shows that the results are robust to the choice of  $\omega_{\pi}$ , and illustrates that  $\omega_{\pi} > 0$  is necessary for a delayed peak in inflation response. The graphs in the last row confirm the results of Subsection 2.2.2. As the response of inflation magnifies, the persistence of the output response decreases with the decrease in  $\omega_R$ .

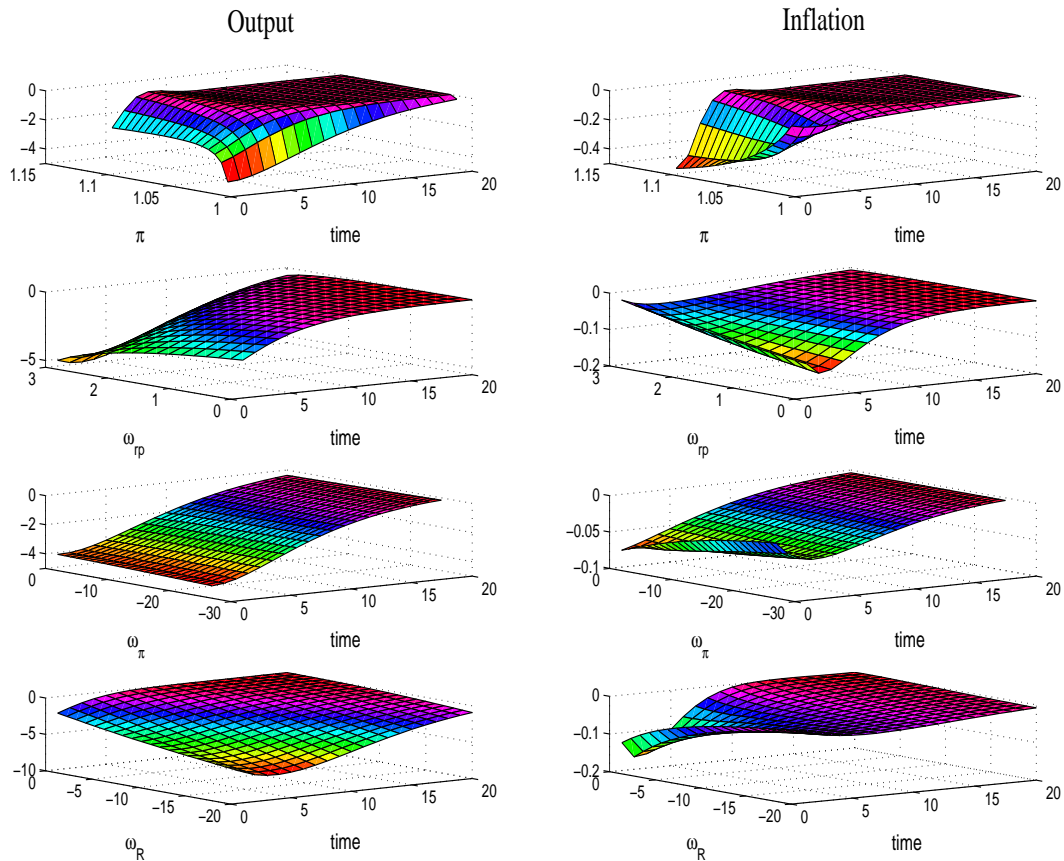
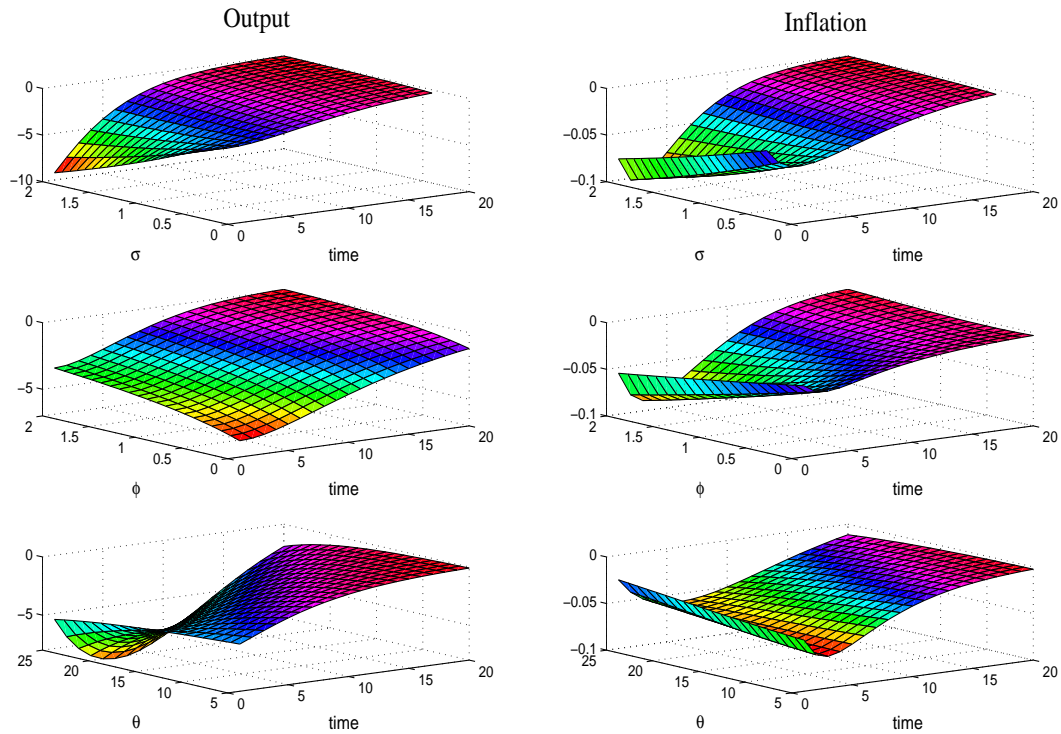


Figure 2.4: Sensitivity analysis for alternative values of  $\pi$ ,  $\omega_{rp}$ ,  $\omega_{\pi}$ , and  $\omega_R$



**Figure 2.5:** *Sensitivity analysis for alternative values of values of  $\sigma$ ,  $\phi$  and  $\theta$*

Figure 2.5 presents results of the sensitivity analysis with regard to the preference parameters. Variations in the parameters do not alter the patterns of the responses significantly except for those expected. For example, the volatility of output increases with the decrease in the coefficient of relative risk aversion,  $\sigma^{-1}$  as shown by the graphs in the first row. The reason is that when households become less risk averse, they require also less consumption smoothing, which, in turn, translates itself to high volatility of output. The second row of graphs shows that increasing the inverse of the labor supply elasticity dampens (magnifies) the output (inflation) response. This occurs because a decrease in the labor supply elasticity induces less sensitive households to wage changes. Thus, for a given level of output, firms has to pay higher wages which translates itself to higher inflation. In other words, the Phillips-curve becomes steeper. The graphs in the last row replicates the result of of the previous section; a more competitive goods market increases the output response because of the increase in the response of the price dispersion. A change in the competitiveness of the goods market induced by the variation in the elasticity of substitution,  $\theta$ , does not affect the response of consumption (not shown in Figure 2.5). Thus, the results reported in Section 2.2 are robust with respect to the calibration of preferences as well.

## 2.4 Conclusions

I incorporated the cost channel of monetary policy, the variable frequency of price adjustment, and trend inflation into a small scale, dynamic, general equilibrium model. First, I found that allowing for the working capital cost channel alone does not significantly alter output and inflation effects of monetary policy shocks, as has also been emphasized by Christiano et al. (2005). Second, I showed that assuming the new cost channel, which implies that the frequency of price adjustment increases in the nominal interest rate, can account both for the persistence of the output response and for the muted and delayed inflation response to monetary policy shocks found in several VAR studies (e.g., Leeper et al. 1996 and Bernanke and Mihov 1998).

The reason for this striking result is that in my model, a contractionary (expansionary) nominal shock gives rise to a more (less) frequent price adjustment, which, in turn, dampens the disinflationary (inflationary) effect a nominal shock, and, thus, magnifies the output effect. Therefore, it would be interesting, in the tradition of Ball (1994 and 1995), to see the implications of the new cost channel for announced and/or permanent policy changes.

My theoretical analysis should also stimulate empirical research. Despite well-documented evidences of the working capital cost channel and implicit contracts, the relevance of their combination, the new cost channel, requires micro- and macro-evidences, which, in turn calls for econometric, experimental, or survey-type studies.



## Appendix to Chapter 2

This appendix contains derivations of the expressions and results that are reported in the main text but require some further explanations to obtain. After presenting the equilibrium conditions of my model in their non-linear form, I solve for the steady states of the stationary variables. Note that because of the assumed trend inflation, all the nominal variables, except for the nominal interest rate, are nonstationary. Hence, prior to solving, I normalize the nominal variables to make the problem stationary. Then, I log-linearize the equilibrium conditions around a steady state with trend inflation.

### A 2.1 Solving for the Dynamics in the Baseline Model

The consumption index  $C_t^j$  is a constant-elasticity-of-substitution aggregator:

$$C_t^j \equiv \left[ \int_0^1 c_t^j(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}}. \quad (\text{A } 2.1)$$

Given the price charged by firm  $z$  for its product,  $P_t(z)$ , corresponding consumption-based money price index (or the consumer price index),  $P_t$ , defines the minimum cost of a unit of the aggregate defined by (A 2.1). Thus, I can define the expenditure minimization problem of a consumer by

$$\min_{c_t(z)^j} \int_0^1 P_t(z) c_t^j(z) dz \quad \text{subject to} \quad C_t^j = 1.$$

The first order condition to this problem is

$$P_t(z) = \nu_t (c_t^j(z))^{-1/\theta} (C_t^j)^{-1/\theta}, \quad (\text{A } 2.2)$$

where  $\nu_t$  is the Lagrange multiplier on the constraint. Multiplying both sides of (A 2.2) by  $c_t(z)$ , integrating over  $z$ , and using the definition of  $C_t^j$  given by (A 2.1) imply

$$\int_0^1 P_t(z) c_t^j(z) dz = \nu_t \left[ \int_0^1 c_t^j(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}}. \quad (\text{A } 2.3)$$

Note that total expenditure of household  $j$  should be equal to the value of aggregate consumption of household  $j$ , i.e.,  $\int_0^1 P_t(z) c_t^j(z) dz = P_t C_t^j$ . This condition together with (A 2.3) implies

$$P_t = \nu_t. \quad (\text{A } 2.4)$$

Substituting (A 2.4) into (A 2.2) gives the demand schedule of household  $j$  for product  $z$ :

$$c_t^j(z) = \left[ \frac{P_t(z)}{P_t} \right]^{-\theta} C_t^j. \quad (\text{A 2.5})$$

Integrate (A 2.5) over  $j$ , to get the demand curve that firm  $z$  faces:

$$y_t(z) = \left[ \frac{P_t(z)}{P_t} \right]^{-\theta} C_t, \quad (\text{A 2.6})$$

where  $y_t(z) \equiv \int_0^1 c_t^j(z) dj$  and  $C_t \equiv \int_0^1 C_t^j dj$ . Integrating (A 2.6) over  $z$  gives the resource constraint:

$$Y_t = s_t C_t, \quad (\text{A 2.7})$$

where  $Y_t \equiv \int_0^1 y_t(z) dz$ , and

$$s_t P_t^{-\theta} \equiv \int_0^1 (P_t(z))^{-\theta} dz. \quad (\text{A 2.8})$$

Finally, using (A 2.4) and (A 2.5) in (A 2.2) gives the consumer price index:

$$P_t^{1-\theta} = \left[ \int_0^1 P_t(z)^{1-\theta} dz \right]. \quad (\text{A 2.9})$$

The assumed price adjustment setting in the model implies that in period  $t$  a fraction of  $1 - \gamma_t$  of firms can adjust prices. Thus, letting  $P_t^*(z)$  denote the adjusted price, (A 2.9) can be expressed as

$$\begin{aligned} P_t^{1-\theta} &= (1 - \gamma_t) P_t^*(z)^{1-\theta} + \\ &+ \gamma_t \left( (1 - \gamma_{t-1}) P_{t-1}^*(z)^{1-\theta} + \gamma_{t-1} \left( (1 - \gamma_{t-2}) P_{t-2}^*(z)^{1-\theta} + \dots \right) \right) \\ &= (1 - \gamma_t) P_t^*(z)^{1-\theta} + \gamma_t P_{t-1}^{1-\theta}. \end{aligned}$$

Dividing this expression through by  $P_t$ , I obtain

$$1 = \gamma_t \pi_{t-1}^{\theta-1} + (1 - \gamma_t) r p_t^{1-\theta}. \quad (\text{A 2.10})$$

Applying the same logic used in steps from (A 2.9) to (A 2.10) to (A 2.8), I can write

$$s_t P_t^{-\theta} = (1 - \gamma_t) P_t(z)^{-\theta} +$$

$$\begin{aligned}
& +\gamma_t \left( (1 - \gamma_{t-1})P_{t-1}(z)^{-\theta} + \gamma_{t-1} \left( (1 - \gamma_{t-2})P_{t-2}(z)^{-\theta} + \dots \right) \right) \\
& = (1 - \gamma_t)P_t(z)^{-\theta} + \gamma_t P_{t-1}^{-\theta} s_{t-1},
\end{aligned}$$

which, in turn, can be arranged to obtain:

$$s_t = (1 - \gamma_t)rp_t^{-\theta} + \gamma_t \pi_t^\theta s_{t-1}. \quad (\text{A 2.11})$$

The rest of the derivations of the non-linear model are described in the main text of this chapter.

A stationary equilibrium of the economy presented in Section 2.1 consists of (i) a set of stationary processes  $C_t, N_t, y_t, w_t, mc_t, R_t, \lambda_t, rp_t, \pi_t, s_t, \gamma_t$  that satisfies the conditions (A 2.7), (A 2.10), (A 2.11), (2.6), (2.7), (2.8), (2.11), (2.12), (2.15), (2.17), and (2.18); and (ii) the condition that goods market, labor market and financial markets clear. Thus, I have system of eleven equations in eleven variables. For convenience, I present these eleven equations in their aggregated form below once again:

$$C_t^{-\sigma^{-1}} = \lambda_t, \quad (\text{A 2.12})$$

$$\frac{N_t^\phi}{C_t^{-\sigma^{-1}}} = w_t, \quad (\text{A 2.13})$$

$$\frac{\lambda_t}{R_t P_t} = \beta E_t \frac{\lambda_{t+1}}{P_{t+1}}, \quad (\text{A 2.14})$$

$$Y_t = N_t, \quad (\text{A 2.15})$$

$$mc_t = R_t w_t, \quad (\text{A 2.16})$$

$$rp_t = \frac{\theta}{\theta - 1} \frac{E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \Gamma_{t,t+i} (P_{t+i}/P_t)^{1+\theta} C_{t+i} mc_{t+i}}{E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \Gamma_{t,t+i} (P_{t+i}/P_t)^\theta C_{t+i}}, \quad (\text{A 2.17})$$

$$Y_t = s_t C_t, \quad (\text{A 2.18})$$

$$1 = \gamma_t \pi_{t-1}^{\theta-1} + (1 - \gamma_t) rp_t^{1-\theta} \quad (\text{A 2.19})$$

$$s_t = (1 - \gamma_t) rp_t^{-\theta} + \gamma_t \pi_t^\theta s_{t-1}, \quad (\text{A 2.20})$$

$$\log \gamma_t = \omega_{rp} \log rp_t + \omega_\pi \log \pi_{t-1} + \omega_R \log R_t, \quad (\text{A 2.21})$$

$$\log R_t = \rho_0 + \rho_\pi \log \pi_t + \rho_L \log R_{t-1} + \varepsilon_t^R. \quad (\text{A 2.22})$$

## A 2.2 (Nonstochastic) Steady State Relations

I assume a positive steady state inflation, i.e.  $\pi > 1$ . This assumption together with (the steady-state version of) (A 2.14) implies

$$R = \pi/\beta. \quad (\text{A 2.23})$$

The assumption of a positive steady state inflation, however, is not enough to pin down the values of  $\gamma$  and  $rp$ . Hence, one needs to assign a value to either  $\gamma$  or  $rp$  to obtain a value for the other (for a given value of  $\theta$ ). In this chapter, following Rotemberg (2005), I assign a value to  $rp$ . Then using (A 2.19), I obtain

$$\gamma = \frac{1 - rp^{1-\theta}}{\pi^{\theta-1} - rp^{1-\theta}}. \quad (\text{A 2.24})$$

Notice that a logically consistent price adjustment probability, i.e.,  $0 < 1 - \gamma < 1$ , requires that  $1 < rp < 2^{1/(\theta-1)}$  and  $\pi rp > 1$ . Using (A 2.20), I obtain

$$s = \frac{(1 - \gamma)rp^{-\theta}}{1 - \gamma\pi^\theta}. \quad (\text{A 2.25})$$

Finally, (A 2.17) implies that in steady state, the following relation holds:

$$rp = \frac{\theta}{\theta - 1} \frac{\sum_{i=0}^{\infty} (\beta\gamma\pi^\theta)^i}{\sum_{i=0}^{\infty} (\beta\gamma\pi^{\theta-1})^i} mc.$$

Let me define two new parameters  $\lambda_1 \equiv \beta\gamma\pi^\theta$  and  $\lambda_2 \equiv \beta\gamma\pi^{\theta-1}$ . Because for the assumed values of  $\beta$ ,  $\gamma$ ,  $\pi$ , and  $\theta$  (cf. Table 2.1), both  $\lambda_1$  and  $\lambda_2$  are less than one, I can write

$$mc = \frac{\theta - 1}{\theta} \frac{1 - \lambda_1}{1 - \lambda_2} rp. \quad (\text{A 2.26})$$

Using equations (A 2.13), (A 2.15), (A 2.16), and (A 2.18), I get an expression describing the steady state level of output,  $Y = \left(\frac{mc}{R}\right)^{\frac{\sigma}{1+\sigma\phi}} s^{\frac{1}{1+\sigma\phi}}$ . By making use of the previously stated steady state equations, this last expression can be written as

$$Y = \left(\frac{\beta}{\pi}\right)^{\frac{\sigma}{1+\sigma\phi}} \left(\frac{\theta - 1}{\theta}\right)^{\frac{\sigma}{1+\sigma\phi}} \left(\frac{(1 - \lambda_1)(1 - \gamma)}{(1 - \lambda_2)(1 - \gamma\pi^\theta)}\right)^{\frac{1}{1+\sigma\phi}} rp^{\frac{\sigma-\theta}{1+\sigma\phi}}. \quad (\text{A 2.27})$$

Notice that the first term is the effect of the working capital cost channel. Second term is the effect of monopolistic competition. Third term is the joint effect of trend inflation and sticky prices. The final term is the effect of sticky prices alone. Given our parameter restrictions, the first three effects are distortionary. If  $\sigma < \theta$ , then the final effect is also distortionary.

### A 2.3 Log-Linearization and Log-linearized Equilibrium Conditions

I continue now with the log-linearization of the system of equations given by (A 2.12)–(A 2.22). I assume that the equilibrium remains near a steady state around which I am log-linearizing. Consequently, the properties of the equilibrium dynamics can be approximated by first order deviations from the equilibrium.

Let me begin with the first equation of the equilibrium conditions: (A 2.12). Taking a first order Taylor approximation around the steady state gives

$$-\sigma C^{-\sigma^{-1}} \tilde{C}_t = \lambda \tilde{\lambda}_t,$$

where a tilde over variable denotes its log-deviation from steady state, (e.g.,  $\tilde{X}_t \equiv \log X_t - \log X$ ).<sup>11</sup> Because in steady state  $C^{-\sigma^{-1}} = \lambda$ , I can simplify the last expression to obtain

$$-\sigma \tilde{C}_t = \tilde{\lambda}_t.$$

I apply this simple approximation method to the system of equations given above. But to economize on space, I describe below the log-linearization of one more equation extensively, and present all other equations in their log-linear form.

The next equation that I describe its log-linearization is a relatively complex equation: (A 2.17), which describes the determinants of the optimal relative price. Before starting with linearizing the entire equation let us have a closer look on

$$\sum_{j=0}^{\infty} \beta^j \Gamma_{t,t+1}$$

which can be expressed as

$$1 + \beta \gamma_{t+1} + \beta^2 \gamma_{t+1} \gamma_{t+2} + \beta^3 \gamma_{t+1} \gamma_{t+2} \gamma_{t+3} \dots$$

<sup>11</sup>An incomplete but practically useful explanation of the log-linearization method is as follows. Let  $f(X_{1,t}, \dots, X_{m,t}) = g(Z_{1,t}, \dots, Z_{n,t})$ . We can write this relation as  $\log(f(\exp^{\log X_{1,t}}, \dots, \exp^{\log X_{m,t}})) = \log(g(\exp^{\log Z_{1,t}}, \dots, \exp^{\log Z_{n,t}}))$ .

Take the first order Taylor approximation around the steady state to get

$$\begin{aligned} \log f(X_1, \dots, X_m) + \frac{(f_1(X_1, \dots, X_m) X_1 (\log X_{1,t} - \log X_1) + \dots + f_m(X_1, \dots, X_m) X_m (\log X_{m,t} - \log X_m))}{f(X_1, \dots, X_m)} &\approx \\ \log g(Z_1, \dots, Z_n) + \frac{(g_1(Z_1, \dots, Z_n) Z_1 (\log Z_{1,t} - \log Z_1) + \dots + g_n(Z_1, \dots, Z_n) Z_n (\log Z_{n,t} - \log Z_n))}{f(Z_1, \dots, Z_n)}. & \end{aligned}$$

Using the steady state relation ( $f(X_1, \dots, X_m) = g(Z_1, \dots, Z_n)$ ) to simplify the last expression, we can write

$$\sum_{i=1}^m f_i(X_1, \dots, X_m) X_i \tilde{X}_{i,t} \approx \sum_{i=1}^n g_i(Z_1, \dots, Z_n) Z_i \tilde{Z}_{i,t}.$$

Differentiating this gives

$$\begin{aligned}
& 0 + \beta\gamma\tilde{\gamma}_{t+1} + (\beta\gamma)^2\tilde{\gamma}_{t+1} + (\beta\gamma)^3\tilde{\gamma}_{t+1} + \dots \\
& + 0 + 0 + (\beta\gamma)^2\tilde{\gamma}_{t+2} + (\beta\gamma)^3\tilde{\gamma}_{t+2} + \dots \\
& + 0 + 0 + 0 + (\beta\gamma)^3\tilde{\gamma}_{t+3} + \dots \\
& \vdots
\end{aligned}$$

Note that the first line is equal to  $\tilde{\gamma}_{t+1} \sum_{j=1}^{\infty} (\gamma\beta)^j$  which, in turn, equals  $\frac{(\gamma\beta)^1}{1-\gamma\beta}\tilde{\gamma}_{t+1}$ . In the same fashion, second line equals  $\frac{(\gamma\beta)^2}{1-\gamma\beta}\tilde{\gamma}_{t+2}$ , third line equals  $\frac{(\gamma\beta)^3}{1-\gamma\beta}\tilde{\gamma}_{t+3}$ , fourth line... Hence, we can express the above sum as

$$\sum_{j=1}^{\infty} \frac{(\gamma\beta)^j}{1-\gamma\beta} \tilde{\gamma}_{t+j}.$$

Now rearrange our original optimal price equation as

$$\begin{aligned}
LHS & \equiv rp_t E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \Gamma_{t,t+i} (P_{t+i}/P_t)^\theta C_{t+i} \\
& = \frac{\theta}{\theta-1} E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \Gamma_{t,t+i} (P_{t+i}/P_t)^{1+\theta} C_{t+i} m c_{t+i} \equiv RHS.
\end{aligned}$$

Note that  $\frac{P_{t+i}}{P_t} = \frac{P_{t+1}}{P_t} \frac{P_{t+2}}{P_{t+1}} \dots \frac{P_{t+i}}{P_{t+i-1}} = \pi_{t+1} \pi_{t+2} \dots \pi_{t+i} = \prod_{s=1}^i \pi_{t+s}$ . Let me start with the *LHS*. Using the definitions of  $\Lambda_{t,t+i}$  and  $\Gamma_{t,t+i}$  rewrite *LHS* as:

$$LHS = rp_t C_t^{1-\sigma^{-1}} + E_t \sum_{i=1}^{\infty} \beta^i \left( \prod_{l=1}^i \gamma_{t+l} \pi_{t+l}^{\theta-1} \right) C_{t+i}^{1-\sigma^{-1}}.$$

Differentiating this expression gives

$$\alpha_1 \left( \tilde{r} p_t + \frac{1-\sigma^{-1}}{(1-\lambda_2)^{-1}} \tilde{C}_t + E_t \sum_{i=1}^{\infty} \lambda_2^i \left( \tilde{\gamma}_{t+i} + (\theta-1) \tilde{\pi}_{t+i} + \frac{1-\sigma^{-1}}{(1-\lambda_2)^{-1}} \tilde{C}_{t+i} \right) \right),$$

where  $\alpha_1 \equiv \frac{rp C_t^{1-\sigma^{-1}}}{1-\lambda_2}$ . In the same fashion, differentiating *RHS* gives

$$\alpha_2 \left( \frac{\tilde{m} c_t + (1-\sigma^{-1}) \tilde{C}_t}{(1-\lambda_1)^{-1}} + E_t \sum_{i=1}^{\infty} \lambda_1^i \left( \tilde{\gamma}_{t+i} + \theta \tilde{\pi}_{t+i} + \frac{\tilde{m} c_{t+i} + (1-\sigma^{-1}) \tilde{C}_{t+i}}{(1-\lambda_1)^{-1}} \right) \right),$$

where  $\alpha_2 \equiv \frac{\theta mc C^{1-\sigma^{-1}}}{(\theta-1)(1-\lambda_1)}$ . Note that in the discussion of the steady state above, I stated  $rp = \frac{\theta}{\theta-1} \frac{1-\lambda_2}{1-\lambda_1} mc$ . Thus  $\alpha_1 = \alpha_2$ . Setting  $dLHS = dRHS$  again, and a bit of algebraic manipulation gives

$$\begin{aligned} \tilde{r}p_t &= E_t \sum_{i=0}^{\infty} \lambda_1^i (1 - \lambda_1) \tilde{m}c_{t+i} + \\ &+ E_t \sum_{i=0}^{\infty} \left( \lambda_1^i (1 - \lambda_1) - \lambda_2^i (1 - \lambda_2) \right) (1 - \sigma^{-1}) \tilde{C}_{t+i} + \\ &+ E_t \sum_{i=1}^{\infty} \lambda_1^i \left( \tilde{\gamma}_{t+i} + \theta \tilde{\pi}_{t+i} \right) - E_t \sum_{i=1}^{\infty} \lambda_2^i \left( \tilde{\gamma}_{t+i} + (\theta - 1) \tilde{\pi}_{t+i} \right). \quad (\text{A 2.28}) \end{aligned}$$

Now lead (A 2.28) one period, take period  $t$  expectations, and use the law of iterated expectations to get:

$$\begin{aligned} E_t \tilde{r}p_{t+1} &= E_t \sum_{i=0}^{\infty} \lambda_1^i (1 - \lambda_1) \tilde{m}c_{t+i+1} + \\ &+ E_t \sum_{i=0}^{\infty} \left( \lambda_1^i (1 - \lambda_1) - \lambda_2^i (1 - \lambda_2) \right) (1 - \sigma^{-1}) \tilde{C}_{t+i+1} + \\ &+ E_t \sum_{i=1}^{\infty} \lambda_1^i \left( \tilde{\gamma}_{t+i+1} + \theta \tilde{\pi}_{t+i+1} \right) - E_t \sum_{i=1}^{\infty} \lambda_2^i \left( \tilde{\gamma}_{t+i+1} + (\theta - 1) \tilde{\pi}_{t+i+1} \right). \quad (\text{A 2.29}) \end{aligned}$$

Lead (A 2.28) two periods, take period  $t$  expectations, and use the law of iterated expectations to get:

$$\begin{aligned} E_t \tilde{r}p_{t+2} &= E_t \sum_{i=0}^{\infty} \lambda_1^i (1 - \lambda_1) \tilde{m}c_{t+i+2} + \\ &+ E_t \sum_{i=0}^{\infty} \left( \lambda_1^i (1 - \lambda_1) - \lambda_2^i (1 - \lambda_2) \right) (1 - \sigma^{-1}) \tilde{C}_{t+i+2} + \\ &+ E_t \sum_{i=1}^{\infty} \lambda_1^i \left( \tilde{\gamma}_{t+i+2} + \theta \tilde{\pi}_{t+i+2} \right) - E_t \sum_{i=1}^{\infty} \lambda_2^i \left( \tilde{\gamma}_{t+i+2} + (\theta - 1) \tilde{\pi}_{t+i+2} \right). \quad (\text{A 2.30}) \end{aligned}$$

Multiply (A 2.29) through by  $\lambda_1$ , and subtract the result from (A 2.28) to get:

$$\tilde{r}p_t - \lambda_1 E_t \tilde{r}p_{t+1} = (1 - \lambda_1) (\tilde{m}c_t + (1 - \sigma^{-1}) \tilde{C}_t +$$

$$\begin{aligned}
& +E_t\lambda_1\left(\tilde{\gamma}_{t+1} + \theta\tilde{\pi}_{t+1}\right) - (1 - \sigma^{-1})E_t\sum_{i=0}^{\infty}\lambda_2^i(\tilde{C}_{t+i} - \lambda_1\tilde{C}_{t+i+1})+ \\
& -E_t\sum_{i=1}^{\infty}\lambda_2^i\left(\tilde{\gamma}_{t+i} - \lambda_1\tilde{\gamma}_{t+i+1} + (\theta - 1)(\tilde{\pi}_{t+i} - \lambda_1\tilde{\pi}_{t+i+1})\right). \quad (\text{A } 2.31)
\end{aligned}$$

Multiply (A 2.29) through by  $\lambda_2$ , and subtract the result from (A 2.28) to get:

$$\begin{aligned}
\tilde{r}p_t - \lambda_2 E_t \tilde{r}p_{t+1} &= -(1 - \lambda_2)(1 - \sigma^{-1})\tilde{C}_t - E_t\lambda_2\left(\tilde{\gamma}_{t+1} + (\theta - 1)\tilde{\pi}_{t+1}\right) \\
& + (1 - \sigma^{-1})E_t\sum_{i=0}^{\infty}\lambda_1^i(\tilde{C}_{t+i} - \lambda_2\tilde{C}_{t+i+1})+ \\
& + E_t\sum_{i=1}^{\infty}\lambda_1^i\left(\tilde{\gamma}_{t+i} - \lambda_2\tilde{\gamma}_{t+i+1} + \theta(\tilde{\pi}_{t+i} - \lambda_2\tilde{\pi}_{t+i+1})\right). \quad (\text{A } 2.32)
\end{aligned}$$

Multiply (A 2.30) through by  $\lambda_1\lambda_2$ , and subtract the result from (A 2.28) to get:

$$\begin{aligned}
\tilde{r}p_t - \lambda_1\lambda_2 E_t \tilde{r}p_{t+2} &= E_t\sum_{i=0}^{\infty}\lambda_1^i(1 - \lambda_1)(\tilde{m}c_{t+i} - \lambda_1\lambda_2\tilde{m}c_{t+i+2})+ \\
& + E_t\sum_{i=0}^{\infty}\left(\lambda_1^i(1 - \lambda_1) - \lambda_2^i(1 - \lambda_2)\right)(1 - \sigma^{-1})(\tilde{C}_{t+i} - \lambda_1\lambda_2\tilde{C}_{t+i+2})+ \\
& + E_t\sum_{i=1}^{\infty}\lambda_1^i\left(\tilde{\gamma}_{t+i} + \theta\tilde{\pi}_{t+i} - \lambda_1\lambda_2\tilde{\gamma}_{t+i+2} - \theta\lambda_1\lambda_2\tilde{\pi}_{t+i+2}\right)+ \\
& - E_t\sum_{i=1}^{\infty}\lambda_2^i\left(\tilde{\gamma}_{t+i} + (\theta - 1)\tilde{\pi}_{t+i} - \lambda_1\lambda_2\tilde{\gamma}_{t+i+2} - (\theta - 1)\lambda_1\lambda_2\tilde{\pi}_{t+i+2}\right). \quad (\text{A } 2.33)
\end{aligned}$$

Two more steps left: First, add (A 2.31) to (A 2.32); then from the result, subtract (A 2.33) in order to obtain the final equation describing the dynamics of the optimal relative price:

$$\begin{aligned}
\tilde{r}p_t &= E_t\left[(\lambda_1 + \lambda_2)\tilde{r}p_{t+1} - (\lambda_1\lambda_2)\tilde{r}p_{t+2} + \right. \\
& + (\theta(\lambda_1 - \lambda_2) + \lambda_2)\tilde{\pi}_{t+1} - (\lambda_1\lambda_2)\tilde{\pi}_{t+2} + \\
& + (1 - \lambda_1)\tilde{m}c_t - \lambda_2(1 - \lambda_1)\tilde{m}c_{t+1} + \\
& \left. + (\lambda_2 - \lambda_1)(1 - \sigma^{-1})\tilde{C}_t + (\lambda_1 - \lambda_2)(1 - \sigma^{-1})\tilde{C}_{t+1} + \right.
\end{aligned}$$



$$+(\lambda_1 - \lambda_2)\tilde{\gamma}_{t+1}]. \quad (\text{A } 2.34)$$

In addition to (A 2.34), the other log-linearized equations used to derive the results are given by

$$\text{optimal consumption: } \tilde{C}_t = \tilde{\lambda}_t, \quad (\text{A } 2.35)$$

$$\text{labor supply: } \phi\tilde{N}_t + \frac{1}{\sigma}\tilde{C}_t = \tilde{w}_t, \quad (\text{A } 2.36)$$

$$\text{Euler equation: } \tilde{\lambda}_t - E_t\tilde{\lambda}_{t+1} = \tilde{R}_t - E_t\tilde{\pi}_{t+1}, \quad (\text{A } 2.37)$$

$$\text{production function: } \tilde{Y}_t = \tilde{N}_t, \quad (\text{A } 2.38)$$

$$\text{real marginal costs: } \tilde{m}c_t = \tilde{w}_t + \tilde{R}_t, \quad (\text{A } 2.39)$$

$$\text{resource constraint: } \tilde{Y}_t = \tilde{s}_t + \tilde{C}_t, \quad (\text{A } 2.40)$$

$$\text{inflation: } \tilde{\pi}_t = (\gamma^{-1}\pi^{1-\theta} - 1)\tilde{r}p_t + \frac{\pi^{1-\theta} - 1}{(1-\gamma)(\theta-1)}\tilde{\gamma}_t, \quad (\text{A } 2.41)$$

$$\text{price dispersion: } \tilde{s}_t = \theta(\gamma\pi^\theta - 1)\tilde{X}_t + \frac{\gamma(\pi^\theta - 1)}{1-\gamma}\tilde{\gamma}_t + \theta\gamma\pi^\theta\tilde{\pi}_t + \gamma\pi^\theta\tilde{s}_{t-1}, \quad (\text{A } 2.42)$$

$$\text{probability of price adjustment: } \tilde{\gamma}_t = \omega_{rp}\tilde{r}p_t + \omega_\pi\tilde{\pi}_{t-1} + \omega_R\tilde{R}_t, \quad (\text{A } 2.43)$$

$$\text{monetary policy: } \tilde{R}_t = \rho_0 + \rho_\pi\tilde{\pi}_t + \rho_L\tilde{R}_{t-1} + \varepsilon_t^R. \quad (\text{A } 2.44)$$

Note that if steady state inflation is zero,  $\pi = 1$ , the coefficients of  $\tilde{\gamma}_t$  are zero in (A 2.34), (A 2.42) and (A 2.41), i.e., variations in  $\gamma_t$  do not have any effect on the dynamics of the economy. Equations (A 2.34), (A 2.43), and (A 2.41) constitute the Phillips-curve block of the model.

Given the system of equations (A 2.34)–(A 2.44) and corresponding parameter values, one can use Blanchard and Kahn (1980) (local) conditions to check the existence and uniqueness of a solution for this system. As mentioned above, to solve and simulate the model, I used the computer algorithm developed by Klein (2000) and McCallum (2001), but one can use other algorithms, such as those developed by Anderson and Moore (1985), Juillard (1996) and his team, Uhlig (1997), or King and Watson (1998). The codes I used to generate my results are, of course, available upon a request.

## Chapter 3

# Fair Wages, Fair Prices & Sluggish Inflation

In models of monetary business cycles, mechanisms of sluggish adjustment of prices and/or wages play a central role for explaining the propagation of monetary policy shocks. As mechanisms of sluggish price/wage adjustment, the models of Taylor (1980), Rotemberg (1982), and Calvo (1983) have been widely used by researchers studying monetary policy. Because none of these mechanisms can account for the observed lag-lead relation between inflation and output, indexation schemes, as in the model of Christiano, Eichenbaum and Evans (2005), or sticky information as in the model of Mankiw and Reis (2002) have attracted growing attention.

Empirical evidence of price stickiness supports neither indexation schemes nor sticky information. For example, Fabiani et al. (2006), summarizing the results of survey studies conducted by the Inflation Persistence Network (IPN) of the European Central Bank in the Euro Area, conclude that long-term relationships between customers and firms are the most relevant explanation of price stickiness, and that there is no supporting evidence for indexation and sticky information.<sup>1</sup> In analogy to the case of price setting, empirical research on wage setting has shown that long-term relationships in labor markets are an important determinant of wage stickiness (Blinder and Choi 1990, Campbell and Kamlani 1997, Bewley 1999). The motivation put forward by Akerlof (2007, p.27) is also worth quoting:

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<sup>1</sup>Several other survey-type studies on price setting behavior of firms document results similar to that of the IPN studies. See Blinder et al. (1998) for the US, Hall et al. (2000) for the UK, Amirault et al. (2004) for Canada, and Apel et al. (2005) for Sweden.

...evidence suggests that wage earners and customers have views on what wages and prices should be. The reflection of such views in utility functions produce trade-offs between inflation and unemployment. Those trade-offs have significant implications for economic policy.

Consistent with the evidence, the current chapter presents a dynamic stochastic general equilibrium model (DSGE) with fair wages and fair prices, and analyzes the propagation of monetary policy shocks. As Ball and Romer (1990) and Chari et al. (2000) have shown that sticky prices alone cannot generate large output effects of monetary shocks, the focus of the sticky-price literature has been mainly on explaining the large output-effects of monetary shocks by incorporating real rigidities. Following the suggestion of Gali and Gertler (1999) that real rigidities may also be needed to account for inflation dynamics, I focus to explain the sluggish adjustment of inflation to monetary shocks. My results show that the model can explain the observed lag-lead relation between inflation and output. Following a monetary impulse, output peaks after three quarters and inflation peaks after four quarters. Subjecting the model both to monetary and technology shocks results in a lead-lag correlation between output and inflation which closely matches that in US data.

The fair-wage block of my model builds on the recent contributions of Collard and de la Croix (2000) and Danthine and Kurmann (2004), both of which, in turn, resort to the “gift-exchange” efficiency wages theory tracing back to Akerlof (1982). According to the gift-exchange efficiency wages theory, workers are willing to provide effort beyond some reference level of effort if they feel that their firm treats them well. Firms, in turn, seek to motivate workers by offering a wage above the market-clearing wage. The optimizing behavior of workers and firms results in structural unemployment. Collard and de la Croix extend the efficiency wage theory in a flexible price DSGE framework by allowing effort to depend on past wages. This intertemporal link in wage setting renders the adjustment of wages sluggish. Danthine and Kurmann incorporate this intertemporal link into a sticky price DSGE model. The model by Danthine and Kurmann, however, differs from my model as, in their model, prices are set à la Calvo (1983), and money holdings are motivated via a cash in advance constraint on consumption and investment.

The fair-price block of my model builds on the recent contribution of Rotemberg (2005). Rotemberg assumes that price increases are viewed by customers as fair and justifiable only if these increases are triggered by cost increases. Otherwise customers get upset, and the relationship between the firm and its customers breaks down. Thus, fear of customer anger gives rise

to a sluggish adjustment of prices. In addition to the evidence coming from survey studies, there is a large number of studies in applied economics that supports this view. For example, Zbaracki et al. (2004) find that of the overall costs of price adjustment, 74% is associated with customer relations (customer cost), 22% with managerial costs, and 4% with menu costs.<sup>2</sup> In Rotemberg's model, consumers have imperfect information about the cost of firms, but they receive random signals about costs. Rotemberg specifies a setting where relative prices and past inflation are signals about the fairness of price increases, and, in particular, past inflation is a signal of cost increases. For this reason, the probability that firms can reset its price is a function of the relative price and past inflation.

Fair wages and fair prices are the two key features of my model. Several researchers have studied the implications of similar specifications. Two early antecedents of my analysis are the works of Phelps and Winter (1970) and Okun (1981). Phelps and Winter provide a formal model of monopolistic competition with customer markets where, due to the imperfect diffusion of information on prices, customers remain with their current sellers. Okun suggests that inflation inertia stems from the long-term relationships ("invisible handshakes") in labor and customer markets. Ball and Romer (1990) show that a combination of imperfect competition and menu costs with imperfect information in customer markets or with efficiency wages can generate large effects of nominal shocks. The current chapter, however, provides the first study that incorporates the combination of fair-wages and fair-prices into a DSGE framework.

The remainder of this chapter is organized as follows. The next two sections lay down the model and its calibration. The section after details and discusses the results of the simulated model. The last section summarizes and offers some concluding remarks.

### 3.1 The Model Economy

The economy operates in discrete time, and consists of households, perfectly competitive firms, monopolistically competitive firms, and a monetary authority. The numbers of households and firms are assumed to be large. For tractability, I assume a continuum of households, indexed by  $j$ , and monop-

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<sup>2</sup>Zbaracki et al. (2004) also argue that the main reason behind such high managerial costs is the customer costs.

olistically competitive firms, indexed by  $z$ , with  $j, z \in [0, 1]$ .

### 3.1.1 Households

In each household  $j$ , a proportion  $0 < N_t^j < 1$  of its members is employed, while the rest is unemployed as a consequence of efficiency wages. On the individual level, following Alexopoulos (2004) and Danthine and Kurmann (2004), employment is randomly allocated across the members of each household, and the proportion  $N_t^j$  is the same across households (i.e.  $N_t^j = N_t$ ). Consumption is equally redistributed across the members of a household. As a result, households' members are both ex-ante and ex-post identical.

Household  $j$  inelastically supplies a unit of labor, and decides on the sequences of consumption,  $C_t^j$ , nominal money balances  $M_t^j$ , effort  $e_t^j$ , and nominal bond holdings  $B_t^j$ . The expected present value of lifetime utility of a representative household  $j$  is given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ \log(C_t^j - hC_{t-1}^j) + \frac{\chi}{1 - \sigma_m} \left( \frac{M_t^j}{P_t} \right)^{1 - \sigma_m} - N_t^j \mathcal{G}(e_t^j) \right], \quad (3.1)$$

where  $0 < \beta < 1$  is the discount factor,  $0 \leq h < 1$  is a measure of the degree of (internal) habit formation, and  $0 < \chi$  and  $0 < \sigma_m$  are money demand parameters.<sup>3</sup>  $E_t$  is the mathematical expectation operator conditional on period  $t$  information,  $P_t$  is a nominal price index,  $\mathcal{G}(e_t^j)$  is an *effort function* determining the disutility that the household  $j$  derives from effort. Following Danthine and Kurmann (2004), the form for the effort function is given by

$$\mathcal{G}(e_t^j) = [e_t^j - (\phi_0 + \phi_1 \log w_t^j + \phi_2 \ln N_t + \phi_3 \log w_t + \phi_4 \log w_{t-1}^j)]^2, \quad (3.2)$$

where  $w_t^j$  ( $w_t$ ) denotes household  $j$ 's (aggregate) real wage rate.<sup>4</sup> The terms in parenthesis determine the norm that household  $j$  resorts to by providing effort. Accordingly, if the household provides more effort than the reference level, i.e. the norm, its utility decreases because households do not like providing effort. On the other hand, if the household provides less effort than the reference level, its utility decreases again because of fairness concerns,

<sup>3</sup>For better comparability of my results with the results of Christiano et al. (2005), I assumed internal habit formation rather than external habit formation. The model in Chapter 4 features external habit formation.

<sup>4</sup>See Danthine and Kurmann (2004) and the references therein for a discussion on the form of the effort function.

i.e. household does not want to provide lower effort in exchange for higher compensation, analogous to gift exchange behavior (Akerlof 1982). The reference level of effort is assumed to be increasing in  $w_t^j$ , and decreasing in  $N_t$ ,  $w_t$ , and  $w_{t-1}^j$ . The assumptions for these sign restrictions are as follows. The parameter  $\phi_0$  is an arbitrary constant. A positive change in the real wage of household  $j$  motivates the household to work harder, i.e.  $\phi_1 > 0$ ,  $\phi_4 < 0$ . The change in (rather than only the level of) compensation being also a determinant of effort is a key assumption in my setting as in the settings of Collard and de la Croix (2000) and Danthine and Kurmann (2004). Furthermore, in his extensive survey of questionnaire and interview studies on the origins of wage rigidity Bewley (2002) shows that change in wages is an important determinant effort. A higher aggregate level of employment discourages household  $j$  because it would be easier for her to find a new job if she gets unemployed because of providing low effort,  $\phi_2 < 0$ . Finally a higher aggregate real wage decreases the relative real wage of the household, which, in turn, is perceived to be unfair by household  $j$ , and decreases the level of effort,  $\phi_3 < 0$ .

The period- $t$  budget constraint is given by

$$\frac{R_t^{-1}B_t^j + M_t^j}{P_t} + C_t^j = \frac{B_{t-1}^j + M_{t-1}^j + T_t^j}{P_t} + w_t^j N_t^j + \Phi_t^j, \quad (3.3)$$

where  $R_t$  is the gross nominal returns on bond holdings,  $T_t^j$  is the lump-sum transfers from the monetary authority, and  $\Phi_t^j$  is the sum of the household's real profit income.

Letting  $\lambda_t$  denote the Lagrange multiplier associated with the budget constraint, the first order conditions for the household  $j$  can be written as

$$(C_t^j - hC_{t-1}^j)^{-1} - h\beta (E_t C_{t+1}^j - hC_t^j)^{-1} = \lambda_t, \quad (3.4)$$

$$\chi \left( \frac{M_t^j}{P_t} \right)^{-\sigma_m} = \lambda_t - \beta E_t \left[ \frac{\lambda_{t+1}}{\pi_{t+1}} \right], \quad (3.5)$$

$$e_t^j = \phi_0 + \phi_1 \log w_t^j + \phi_2 \log N_t + \phi_3 \log w_t + \phi_4 \log w_{t-1}^j, \quad (3.6)$$

$$\lambda_t = R_t \beta E_t \left[ \frac{\lambda_{t+1}}{\pi_{t+1}} \right], \quad (3.7)$$

where  $\pi_t$  denotes gross inflation,  $\pi_t = P_t/P_{t-1}$ . Additionally, I assume that the usual transversality condition holds.

### 3.1.2 Firms

There are two types of sectors on the production side: a final goods sector and an intermediate goods sector. The final goods sector is perfectly competitive, and the intermediate goods sector is monopolistically competitive.

#### Final Goods Sector

The production technology for final goods is given by

$$Y_t \equiv \left[ \int_0^1 y_t(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}}, \quad (3.8)$$

where  $1 < \theta$  is the elasticity of substitution among differentiated intermediate goods,  $Y_t$  is the final good, and  $y_t(z)$  is an intermediate good. Because the final goods sector is perfectly competitive, final goods producers maximize their profits by taking the price of their good and the price of their input, denoted by  $P_t(z)$ , as given. The profit maximization problem of a typical final good firm can be written as

$$\max_{y_t(z)} P_t \left[ \int_0^1 y_t(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}} - \int_0^1 P_t(z) y_t(z) dz.$$

The first order condition for this problem yields the usual demand schedule for good  $z$ :

$$y_t(z) = \left[ \frac{P_t(z)}{P_t} \right]^{-\theta} Y_t. \quad (3.9)$$

The zero profit condition, together with equation (3.9), implies

$$P_t = \left[ \int_0^1 P_t(z)^{1-\theta} dz \right]^{\frac{1}{1-\theta}}. \quad (3.10)$$

#### Intermediate Goods Sector

Each firm in the intermediate goods sector consists of a production unit and a pricing unit. The production unit minimizes the cost of production, and the pricing unit maximizes the profits of the firm. The production technology for intermediate goods is given by

$$y_t(z) = A_t e_t(z) N_t(z), \quad (3.11)$$

where  $e_t(z)N_t(z)$  is the effective labor service rented from the households, and  $A_t$  is an aggregate technology shock to productivity.<sup>5</sup> The law of motion of the technology shock is governed by

$$\log A_t = \rho_A \log A_{t-1} + \epsilon_t^A, \quad (3.12)$$

where  $\epsilon_t^A$  is an independently and identically distributed innovation with mean zero and standard deviation  $\sigma_{\epsilon^A}$ .

When minimizing the cost of production, the production unit faces two constraints: The production should sustain the demand and the effort should sustain the norm. Formally, we have

$$\begin{aligned} & \min_{N_t(z), w_t(z), e_t(z)} w_t(z)N_t(z) \\ & \text{subject to } y_t(z) \leq A_t e_t(z)N_t(z) \quad \text{and} \\ & e_t(z) = \phi_0 + \phi_1 \log w_t(z) + \phi_2 \log N_t + \phi_3 \log w_t + \phi_4 \log w_{t-1}. \end{aligned}$$

In the second constraint, following Danthine and Kurmann (2004), I replaced  $w_{t-1}(z)$  with  $w_{t-1}$  (cf. equation (3.2)). In this way, cost minimization becomes a static problem, implying that firms do not account for the consequences of offering a higher wage today for the future effort of households (Collard and de la Croix (2000)).

Letting  $mc_t(z)$  denote the Lagrange multiplier associated with the demand constraint, the first order conditions for the production unit can be written as

$$w_t(z) = mc_t(z) \frac{y_t(z)}{N_t(z)}, \quad (3.13)$$

$$N_t(z) = mc_t(z) \frac{y_t(z)}{e_t(z)} \frac{\phi_1}{w_t(z)}. \quad (3.14)$$

The Lagrange multiplier  $mc_t(z)$  is identical to marginal cost, which equals average cost due to the constant returns to scale form of the production technology. Substituting equation (3.13) into (3.14) implies the Solow (1979) condition

$$e_t(z) = \phi_1. \quad (3.15)$$

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<sup>5</sup>In the appendix to this chapter, I extend my model to allow for investment dynamics. Simulation results for the extended model show that this extension does not bring about a significant change in my main results.



The Solow condition induces the elasticity of effort with respect to the real wage rate to be 1. That is, the optimal real wage rate should be set such that a variation in the real wage rate does not affect the wage-effort ratio. Hence, under the Solow condition, the optimal real wage rate implied by 3.13 minimizes the cost of effective labor.

When maximizing the profits, the pricing unit can choose a price different from marginal cost as a result of monopolistically competitive environment. When doing so, the pricing unit faces the demand constraint given by equation (3.9). Moreover, as in Rotemberg (2005), the pricing unit can change the price in every period with probability  $0 < 1 - \gamma_t < 1$ . The maximization problem of the pricing unit can be expressed as

$$\begin{aligned} \max_{P_t(z)} E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \Gamma_{t,t+i} y_{t+i}(z) [P_t(z) - P_{t+i} m c_{t+i}(z)], \\ \text{s.t. } y_t(z) = \left[ \frac{P_t(z)}{P_t} \right]^{-\theta} Y_t. \end{aligned}$$

The variable  $\Lambda_{t,t+i}$  denotes the stochastic discount factor for nominal payoffs between periods  $t$  and  $t+i$  and defined as  $\Lambda_{t,t+i} \equiv \beta^i \pi_{t,t+i}^{-1} \left( \frac{\lambda_{t+i}}{\lambda_t} \right)$ , with  $\pi_{t,t+i} \equiv P_{t+i}/P_t$ . The variable  $\Gamma_{t,t+i}$  denotes the probability that the pricing unit cannot change the price between the periods  $t$  and  $t+i$  and defined as  $\Gamma_{t,t+i} \equiv \prod_{l=1}^i \gamma_{t+l}$ , with  $\Gamma_{t,t} \equiv 1$ . Using the demand curve to substitute out  $y_t(z)$  in the objective function of the pricing unit and maximizing it over  $P_t(z)$  gives

$$E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \Gamma_{t,t+i} y_{t+i}(z) \left[ P_t^*(z) - \frac{\theta}{\theta-1} P_{t+i} m c_{t+i}(z) \right] = 0, \quad (3.16)$$

where  $P_t^*(z)$  is the optimal price. Equation (3.16) illustrates the standard implication of staggered price adjustment mechanisms that the optimal price maximizes the profits when average future expected marginal revenues equal average future expected marginal costs. As in Chapter 2, the probability of price adjustment in the averaging factor is an *endogenous variable*, i.e., price adjustment of an intermediate firm depends on the state of the economy.<sup>6</sup>

<sup>6</sup>Setting the probability of price adjustment,  $\gamma_t$ , constant reduces the price setting mechanism to that of Calvo (1983) and Yun (1996).

What follows briefly rationalizes the idea behind the fair pricing that gives rise to endogenous price adjustment.<sup>7,8</sup> Following Rotemberg (2005), I assume that firms in the intermediate goods sector are reluctant to change prices because they have some sort of long term relationships with their customers, who do not like price increases. After an increase in the price of a firm in the intermediate sector, the relationship of that firm with its customers breaks down unless the customers believe that the increase in the price was triggered by cost increases, and, thus, fair. Furthermore, there is sufficiently large trend inflation, which, in turn, makes price decreases non-optimal.

Customers do not have perfect information about the cost changes of the firms in the intermediate goods sector, and evaluate the fairness of the firms by the signals they receive. As in Rotemberg (2005), the relative price, denoted by  $rp_t \equiv P_t^*(z)/P_t$  and lagged inflation,  $\pi_{t-1}$ , are signals about the perceived fairness of price increases.<sup>9</sup> Because, ceteris paribus, an increase in the relative price will imply that the absolute price is increased more relative to other prices,  $rp_t$  is a ‘negative’ signal of fairness. Because, ceteris paribus, higher inflation implies an overall increase in costs,  $\pi_{t-1}$  is a ‘positive’ signal of fairness.

Accordingly, firms adjust their prices only when they believe that the price increase will not bring about customer resistance, i.e., a sharp fall in demand. Thus, the random signals that govern the fairness evaluation of a price increase also govern the probability of the price adjustment:

$$\log \gamma_t = \omega_{rp} \log rp_t + \omega_\pi \log \pi_{t-1}. \quad (3.17)$$

As regards the signs of the parameters, an increase in the relative price will decrease the reset probability, thus,  $\omega_{rp}$  is positive. As higher inflation will imply more frequent price adjustments,  $\omega_\pi$  is negative, so that the reset probability rises with higher inflation.

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<sup>7</sup>My discussion shall be brief because the setting of the fair pricing that gives rise to endogenous price adjustment is principally the same as in Chapter 2. The mere difference to Chapter 2 is that the fair-price setting in this chapter does not assume the new cost channel, and, thus, it is identical to the setting developed by Rotemberg (2005).

<sup>8</sup>For a detailed discussion on the microeconomics of fair-price specification, see Rotemberg (2005) or my introductory chapter of this dissertation.

<sup>9</sup>Because all new price setters will set the same price,  $rp_t$  does not have any firm index (Yun (1996)).

### 3.1.3 The Monetary Authority

The lump-sum transfers from the monetary authority are financed by newly printed money:

$$\int_0^1 T_t^j dj = M_t - M_{t-1}, \quad (3.18)$$

where  $M_t$  is the money supply which grows at a gross rate of  $m_t$ , namely

$$M_t = m_t M_{t-1}. \quad (3.19)$$

The law of motion of the growth rate of money is governed by

$$\log m_t = \log \pi^{1-\rho_m} + \rho_m \log m_{t-1} + \epsilon_t^m, \quad (3.20)$$

where  $\epsilon_t^m$  is serially uncorrelated mean zero innovation.<sup>10</sup> Equation (3.20) ensures that, in the steady state, the (gross) growth rate of money supply equals (gross) inflation.

### 3.1.4 Aggregation

I assume symmetry across households and across firms. Symmetry across firms implies that the firms that can reset their prices choose the same new price. Therefore, the price index (3.10) can be expressed as

$$1 = \gamma_t \pi_{t-1}^{\theta-1} + (1 - \gamma_t) r p_t^{1-\theta}. \quad (3.21)$$

Defining a new variable as  $s_t \equiv \int_0^1 \left( \frac{P_t(z)}{P_t} \right)^{-\theta} dz$  and applying the same reasoning used to derive equation (3.21),  $s_t$  can be expressed as

$$s_t = (1 - \gamma_t) r p_t^{-\theta} + \gamma_t \pi_t^\theta s_{t-1}. \quad (3.22)$$

Integrating both sides of equation (3.9) over  $z$  implies

$$Y_t^i = s_t Y_t,$$

where  $Y_t^i \equiv \int_0^1 y_t(z) dz$ . Thus, aggregate production differs from aggregate real purchases by an amount of  $s_t$ . A natural interpretation of  $s_t$  is that it is

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<sup>10</sup>I assume that the monetary authority conducts its policy by a money supply rule rather than by an interest rate rule because this assumption allows for a direct comparison of my results with those of Danthine and Kurmann(2004) and Christiano et al. (2005). Moreover, I have also explored the implications of an interest rate rule in the model of this chapter. The effect is little or no change in my results.

the price dispersion generated by the assumed price setting mechanism. The price dispersion is a costly distortion because, by Jensen's inequality,  $s_t$  is bounded below by 1 (Schmitt-Grohé and Uribe 2004).

The market clearing conditions for the markets of final goods, bonds, labor, and money are given by

$$\int_0^1 (C_t^j) dj = Y_t, \quad \int_0^1 B_t^j dj = 0, \quad \int_0^1 N_t(z) dz = \int_0^1 N_t^j dj, \quad \text{and} \\ \int_0^1 M_t^j dj = M_t.$$

## 3.2 Calibration of the Model

The benchmark calibration of the model is summarized in Table 3.1. For the parameters  $\beta$  and  $\theta$ , I assume values that are consistent with those used in the business-cycle literature. Setting one period to equal a quarter of a year, I set the discount factor  $\beta = 1.03^{-1/4}$  so that the annual real interest rate in steady-state is 3%. I set  $\theta = 10$ , implying a markup rate of 11%.

For the parameters  $h$  and  $\sigma_m$ , I draw on the work of Christiano et al. (2005). For the degree of habit formation,  $h$ , Christiano et al. report estimates between 0.52 and 0.71. I assumed a value of  $h = 0.62$ . For the value of  $\sigma_m$ , Christiano et al. report estimates between 10.12 and 11.09. I assumed  $\sigma_m = 10.85$ .

To set the parameters of the effort function, I derived the fair wage function by substituting the Solow condition (equation 3.15) into the optimal effort supply condition (equation 3.6):

$$\log w_t = \eta_1 \log N_t + \eta_2 \log w_{t-1}, \quad (3.23)$$

where  $\eta_1 \equiv -\phi_2/(\phi_1 + \phi_3)$  and  $\eta_2 \equiv -\phi_4/(\phi_1 + \phi_3)$ . Drawing on the estimates of Danthine and Kurmann (2004), I set  $\eta_1 = 0.03$  and  $\eta_2 = 0.99$ .

I assume a positive level of steady-state inflation so that in the log-linearized model, the variations in the frequency of price adjustment have an effect on the propagation of shocks.<sup>11</sup> I set  $\pi = 1.04^{1/4}$ , so that the annual

<sup>11</sup>The coefficient of  $\gamma_t$  in the log-linearized version of equation (3.16) and that of equation (3.21) are, respectively,  $\gamma\beta\pi^\theta - \gamma\beta\pi^{\theta-1}$  and  $\frac{\pi^{1-\theta}-1}{(1-\gamma)(\theta-1)}$ . Thus setting  $\pi = 1$  reduces these coefficients to zero. Besides, trend inflation is confirmed by economic data, and has important implications for macroeconomic dynamics. See, for example, Ball et al. (1988), Ascari (2004), and Cogley and Sbordone (2006) for implications of trend inflation in New Keynesian frameworks.

Table 3.1: *Calibrated Parameters*

Discount factor:	$\beta = 1.03^{-1/4}$
Semi elasticity of money demand:	$\sigma_m = 10.85$
Degree of habit formation:	$h = 0.62$
Elasticity of real wage w.r.t.	
a)employment:	$\eta_1 \equiv -\phi_2/(\phi_1 + \phi_3) = 0.03$
b)past real wage:	$\eta_2 \equiv -\phi_4/(\phi_1 + \phi_3) = 0.99$
Demand elasticity:	$\theta = 10$
Steady-state value of reset probability:	$1 - \gamma = 0.25$
Steady-state value of gross inflation:	$\pi = 1.04^{1/4}$
Elasticity of $\gamma_t$ w.r.t.	
a)optimal relative price:	$\omega_{rp} = 1.5$
b)past inflation:	$\omega_\pi = -15$
Serial correlation of the money growth rate:	$\rho_m = 0.60$
Serial correlation of the technology process:	$\rho_A = 0.96$
Standard deviation of the monetary innovation:	$\sigma_{\epsilon^\mu} = 0.0060$
Standard deviation of the technology innovation:	$\sigma_{\epsilon^A} = 0.0064$

inflation is 4% in steady state, which is approximately equal to the postwar average inflation rate in many industrialized countries. I set  $\gamma = 3/4$ , implying that, on average, firms adjust their prices once a year in the steady state. An average frequency of the price adjustment of four quarters is roughly consistent with the findings of Nakamura and Steinsson (2008).

The setting of the parameters that characterize the probability of price adjustment are based on the papers of Rotemberg (2005) and Nakamura and Steinsson (2008). Nakamura and Steinsson report that inflation and frequency of price adjustment are highly correlated with a coefficient of 0.81. Rotemberg assigns  $\omega_p = 2.5$  and  $\omega_\pi = -15$ . Applying these values in my model, however, results in a correlation of 0.37 between inflation and reset probability. Therefore, I lowered  $\omega_p$  to 1.5 and kept  $\omega_\pi = -15$ . Applying these values in my model generates a correlation of 0.72 between inflation and reset probability.

Finally, I set the persistence parameters of the shock processes,  $(\rho_m, \rho_A)$ , to (0.6, 0.96) and the standard deviations of innovations,  $(\sigma_{\epsilon^\mu}, \sigma_{\epsilon^A})$ , to (0.0060, 0.0064). These values in my model result in a variance decomposition of output and inflation where around 70% of output fluctuations and 54% of inflation fluctuations are due to technology shocks. Such a variance decomposition is in line with the empirical evidence reported in the literature (See, for example, Christiano et al. 2003; Altig et al. 2005).

### 3.3 Simulation Results

This section assesses the implications of fair wages, fair prices, and their interaction for the dynamics of key variables in the log-linearized version of the baseline model. To check the performance of my model, I shall report also the simulation results of three variants of the baseline model. The first variant is a model that features a price setting mechanism formulated by Calvo (1983). In the model featuring Calvo-type price setting,  $\log \gamma_t = \log \gamma$  replaces equation (3.17) of the baseline model. The second variant is a model that features a Walrasian labor market. In the model featuring a Walrasian labor market, optimal labor supply condition given by  $N_t^j = w_t^j [(C_t^j - hC_{t-1}^j)^{-1} - h\beta(C_{t+1}^j - hC_t^j)^{-1}]$  replaces the optimal effort supply condition of the baseline model. Finally, the third variant is a model that features Calvo-type price setting and a Walrasian labor market. Because I shall refer to these variants repeatedly, I suggest using the following shorthand: No-fair-prices (No-FP) for the first variant, no-fair-wages (No-FW) for the second variant and no-fair-prices/wages (No-FPW) for the third variant.

#### 3.3.1 Selected Second Moments

As a first performance check of my model, I calculate four theoretical and empirical moments. These four moments are

- (i) the correlation of the change in inflation with detrended output;
- (ii) the ratio of the standard deviation of quarterly change in output to that of the yearly change in output;
- (iii) the correlation of detrended real wages with detrended hours worked;
- (iv) the correlation of detrended real wages with detrended output.

The reason for choosing to present these statistics is that they illustrate crucial features of business cycles that standard models of monetary business cycles fail to reproduce (Mankiw and Reis 2006).

Table 3.2 compares the theoretical moments of the baseline model and of its variants with the empirical ones of US data. The data are quarterly from 1959:1 to 2006:4, and downloadable from the Bureau of Economic Analysis and Bureau of Labor Statistics.<sup>12</sup> The empirical moments imply that

<sup>12</sup>All series are for the non-farm business sector. Output and hours worked are converted into per-capita terms using a measure of the US population over age 16. Inflation is the log-change in the implicit price deflator. The real wage rate is measured by the nominal compensation deflated by the implicit price deflator. Detrended variables are constructed with the Hodrick-Prescott (HP) filter.

Table 3.2: Selected Moments

	US data	Baseline	No-FP	No-FW	No-FPW	No Habit
$\rho(\pi_{t+2} - \pi_{t-2}, y_t)$	0.42	0.50	0.28	0.10	-0.23	0.54
$\sigma(y_t - y_{t-1})/\sigma(y_t - y_{t-4})$	0.39	0.33	0.35	0.39	0.38	0.50
$\rho(w_t, n_t)$	-0.07	0.16	0.16	0.77	0.79	0.17
$\rho(w_t, y_t)$	0.11	0.08	0.06	0.87	0.89	0.15

Note:  $\rho(\pi_{t+2} - \pi_{t-2}, y_t)$  denotes the correlation of the change in inflation with detrended output,  $\sigma(y_t - y_{t-1})/\sigma(y_t - y_{t-4})$  denotes the ratio of the standard deviation of quarterly change in output to that of the yearly change in output,  $\rho(w_t, n_t)$  denotes the correlation of detrended real wages with detrended hours worked, and  $\rho(w_t, y_t)$  denotes the correlation of detrended real wages with detrended output.

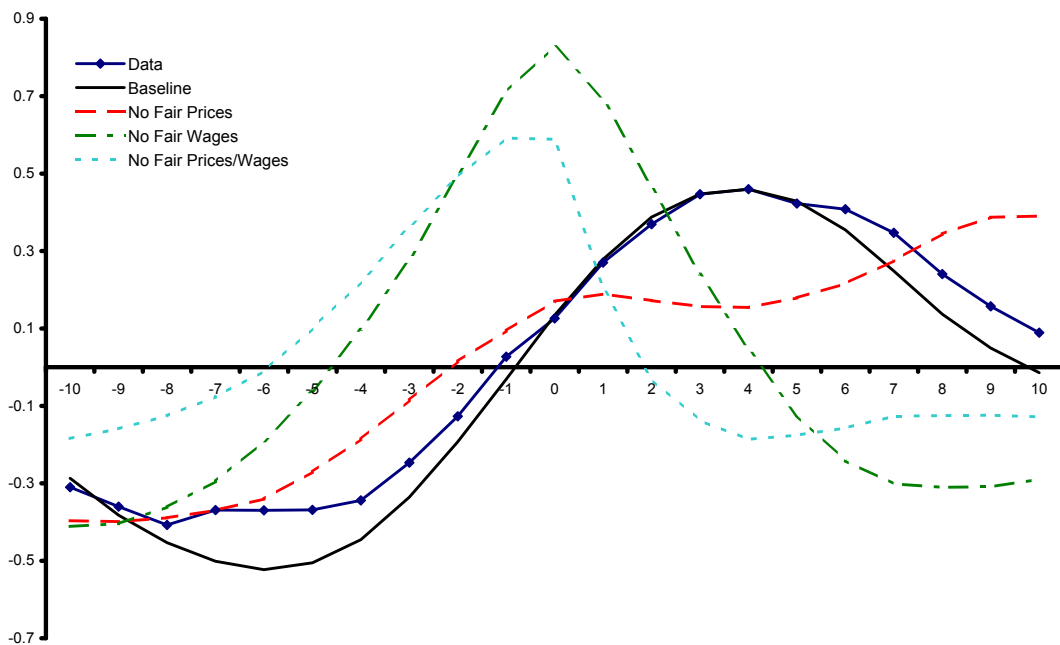
- (i) inflation is procyclical;
- (ii) output gradually responds to shocks as the statistic is less than one half;<sup>13</sup>
- (iii) real wages and employment are weakly correlated;
- (iv) real wages and output are weakly correlated.

Note that the baseline model features four frictions: monopolistic competition, habit formation, fair wages, and fair prices. The latter two are the key specifications of the baseline model. It appears from Table 3.2 that of these two key specifications, fair wages plays the most important role in moving the model in the right direction to account for the procyclicality of inflation and for the weak correlation of real wages. The models featuring a Walrasian labor market (columns under No-FW and No-FPW) generate much too low inflation-output correlation and much too high real wage-employment correlation and real wage-output correlation. Removing habit formation from the baseline model (the column under No Habit) not only clears away the gradual response of output, but also worsens the other statistics slightly. When we compare the no-fair-price model with no-fair-wage model, it seems that the fair-price specification is not very important for output inflation dynamics. Figure 3.1, however, shows that this is not the case.

Figure 3.1 depicts the cross-correlations of the output with the leads and lags of inflation. The line marked with a diamond sign corresponds to the correlations in the US output and inflation data from 1959:1 to 2006:4, both

<sup>13</sup>If output evolved as a random walk, the ratio of the standard deviation of quarterly change in output to that of the yearly change in output would be one half.

HP-filtered. The cross-correlation functions for the US data illustrate that output co-moves positively with future inflation and negatively with lagged inflation. Furthermore, inflation follows output with a lag of 4 quarters (Gali and Gertler 1999, Den Haan and Sumner 2004, Wang and Wen 2007). While only the models featuring fair wages (solid line and dashed line) can generate data where output co-moves positively with future inflation and negatively with lagged inflation, only the baseline model can account for the shape of the actual cross correlation function. The baseline model errs mainly in accounting for the exact degrees of correlations. The cross correlation functions for models of No-FW (dot-dashed line) and No-FPW (dotted line) are far too different than that implied by the actual data.



*Note: The figure plots the cross-correlations of the output with the leads and lags of inflation. The horizontal axis measures  $k$  (leads/lags). The vertical axis measures the cross-correlations.*

**Figure 3.1:** *Dynamic cross-correlations:  $output(t)$ ,  $inflation(t+k)$*

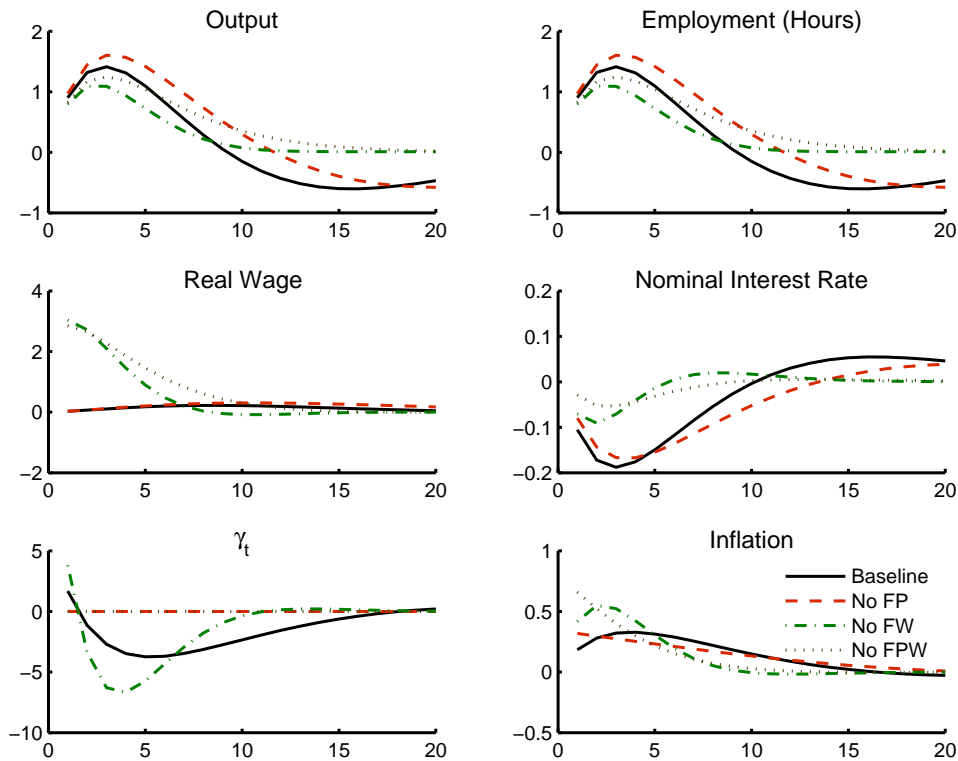
Thus, in my model, fair-wage and fair-price specifications are necessary to account for some key features of the data. We can now assess the implications of fair-wage and fair-price specifications for the transmission of monetary policy shocks.



### 3.3.2 Transmission of Monetary Policy Shocks

To study the transmission of monetary policy shocks I calculate the impulse response functions with the impulse being a unit standard-deviation shock to the money growth rate. Figure 3.2 depicts the impulse response functions

**Figure 3.2:** *Impulse Response Functions for a Monetary Shock*



*Note: The figure plots the responses of key variables to a unit standard-deviation positive shock to money growth rate. The horizontal axis measures quarters. The vertical axis measures logarithmic/percentage deviations from the steady state.*

for the baseline model (solid line), for the No-FP model (dashed line), for the No-FW model (dot-dashed line), and for the No-FPW model (dotted line).

In the two models featuring a Walrasian labor market (No-FW and No-FPW), the persistence of output responses (measured, for example, by the half life of the output response) is considerably lower than the two models featuring fair wages (baseline and No-FP). The intuition behind this result is that in models featuring a Walrasian labor market the adjustment in the labor market takes place both in hours-worked and in the real wage rate, and

the impact effect of the monetary impulse on the real wage rate is around three times as large as the impact effect on hours-worked. Consequently, the impact effect on inflation is large, and dies rapidly out, which, in turn, result in the low persistence of the output response. Another implication of the models featuring a Walrasian labor market is that in these models the liquidity effect is much weaker than in the models featuring fair wages.<sup>14</sup>

In the two models featuring the fair-price setting (baseline and No-FW), the persistence of output responses is lower than the two models featuring Calvo price setting. To understand this result note that in the models featuring the fair-price setting customer resistance to price increases decreases with past inflation. Hence, the inflationary effect of the monetary shock gives rise to an increase in the frequency of price adjustment after the first quarter. The increase in the frequency of price adjustment feeds back inflation, which, in turn, decreases the output persistence.

As regards the lead-lag relation between inflation and output, only the baseline model displays one quarter delay between the peaks of the output and inflation responses. In the models featuring Calvo price setting (No-FP and No-FPW), output counterfactually lags inflation. Removing the fair-wage setting from the baseline model brings about the result that both the inflation response and the output response reach their peaks in the second quarter. Thus, the gradual adjustment of the real wage gives rise to inflation inertia. But this inertia in inflation caused by the fair-wage specification is not enough to generate a realistic inflation response. To this end, we need also the fair-price specification so that the inflation response displays a hump-shaped pattern and also lags the output response.

To sum up, the two key specifications of the baseline model, namely fair-wage and fair-price settings, are also the keys to generate realistic output-inflation dynamics in the aftermath of a monetary shock.

### 3.3.3 Robustness Checks

Are the results presented so far robust to the calibration of my key specifications? In terms of some basic statistics, Table 3.3 presents a detailed answer to this question. These basic statistics include, in addition to the

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<sup>14</sup>The liquidity effect is the decrease in the nominal interest rate following an expansion of monetary aggregates. Standard New Keynesian models fail to generate the liquidity effect (Keen 2004).

Table 3.3: Robustness Checks

	Benchmark Calibration	Calibration of Fair-Wage Setting						Calibration of Fair-Price Setting		
		$\eta_1$			$\eta_2$			$(\omega_{rp}, \omega_\pi)$		
		0.02	0.05	0.075	0.6	0.8	0.9	(0.18, -5)	(0.63, -10)	(2.65, -20)
$\rho(\pi_{t+2} - \pi_{t-2}, y_t)$	0.50	0.47	0.53	0.55	0.31	0.37	0.43	0.35	0.41	0.62
$\sigma(y_t - y_{t-1})/\sigma(y_t - y_{t-4})$	0.33	0.33	0.34	0.34	0.35	0.35	0.34	0.35	0.34	0.32
$\rho(w_t, n_t)$	0.16	0.16	0.16	0.17	0.93	0.74	0.50	0.16	0.16	0.16
$\rho(w_t, y_t)$	0.08	0.08	0.08	0.08	0.89	0.67	0.42	0.06	0.07	0.09
Output Multiplier	5.17	6.75	3.42	2.24	20.55	14.92	10.43	8.23	6.68	3.48
Inflation Multiplier	2.86	2.80	2.91	2.93	2.41	2.56	2.70	2.70	2.76	3.13
Lag( $\pi, y$ )	1	1	1	1	0	1	1	-1	0	3

selected moments of Table 3.2, *output multiplier*, *inflation multiplier* and the lag-lead relation between inflation and output. Output multiplier (inflation multiplier) measures the sum of the output (inflation) responses to a monetary shock over 15 quarters. The lag-lead relation between inflation and output is represented by a statistic denoted as  $lag(\pi, y)$  which measures the difference between the delays in the peaks of the responses of output and inflation to a monetary shock. A negative lag implies inflation leads output. By choosing numerical values for the calibration of the fair wage function (equation (3.23)) I consider three cases that cover also the lower and upper estimates of Çenesiz and Pierdzioch (2008):  $\eta_1 \in \{0.02, 0.05, 0.075\}$  and  $\eta_2 \in \{0.6, 0.8, 0.9\}$ . By choosing numerical values for the calibration of the function that governs the probability of price adjustment (equation (3.17)), I consider three cases, and in each case, as in the benchmark calibration, the parameters of the function are adjusted such that the implied correlation between inflation and the reset probability is 0.72:  $(\omega_{rp}, \omega_\pi) = (0.18, -5)$ ,  $(\omega_{rp}, \omega_\pi) = (0.63, -10)$ , and  $(\omega_{rp}, \omega_\pi) = (2.65, -20)$ .

From Table 3.3, it is notable that the gradual response of output to shocks is robust to the calibration of the fair-wage and fair-price settings. The reason for this is that in my model, gradual response of output is mainly driven by the assumption of habit formation in consumption.

From the columns under  $\eta_1$ , it turns out that the lower values of  $\eta_1$  give rise to an increase in inflation inertia, which, in turn, increases the persistence of the output response. Given that the model implies proportional output and employment responses, a lower value of  $\eta_1$  implies that the real wage is less contingent on aggregate demand changes, and, thus, more rigid. Accordingly, lower values of  $\eta_1$  indicates less volatile inflation.

As regards the calibration of  $\eta_2$ , the responses of output to a monetary shock become more persistent when the current real wage rate depends less on its past value. Given that  $\eta_1$  is fixed at its benchmark value of 0.03, lowering  $\eta_2$  causes added rigidity in the adjustment of real wages. This, in turn, decelerates the adjustment of marginal cost and inflation, and increases the resistance of customers to price increases, both of which give rise to increased persistence of the output response. But for lower values of  $\eta_2$ , the real wage rate and employment and the real wage rate and output are no more weakly correlated. Moreover, for  $\eta_2 = 0.6$ , a lag between the peaks of inflation and output response ceases to exist.

Turning to the columns regarding the calibration of fair-price setting,

the second moments are in general not very sensitive to the elasticities of  $\gamma_t$ . Furthermore, it is easily observable that increasing the elasticities of  $\gamma_t$  results in a decrease of the output persistence. The main reason for the decrease in the output persistence is that increasing the elasticities of  $\gamma_t$  brings about a more frequent price adjustment. Increasing the frequency of price adjustment renders the output effect of monetary shocks low. But a realistic lead-lag relation between inflation and output obtains only when these parameters exceed some threshold values.

### 3.4 Conclusions

I have presented a DSGE model featuring fair wages and fair prices as key settings, and analyzed their implications. I have shown that the fair-price setting combined with the fair-wage setting that allows for an intertemporal link in real wages can generate a delayed inflation response that is hump-shaped and lags the output response. Thus, the results suggest that the model can explain the observed lead-lag relation between inflation and output.

Because of their profound implications, fair wages and fair prices require much more research both on macro and micro levels. As is pointed out by Akerlof (2007), a rigorous microfoundation of each setting will explain many puzzling facts that researcher and policy makers try to understand. On the macro level, incorporating fair prices with other forms of fair wages or in general with other forms of labor-market frictions is likely to yield significant insights. Incorporating fair wages with other forms of state depending price setting, such as the one developed by Dotsey, King and Wolman (1999), may also have interesting implications for the way aggregate shocks propagate.

## Appendix to Chapter 3: Allowing for Investment Dynamics

In this appendix, I present the results for another variant of my model: the baseline model extended to allow for investment and investment specific features. As the reader may wonder how investment and the related specifications are modeled, I first provide a brief explanation of the steps I have undertaken by extending my model. Then, by means of impulse-response and cross-correlation functions, I show that allowing for investment dynamics does not bring about a significant change in the results reported in the main text.

### A 3.1 Adding Investment to the Baseline Model

I assume that households own the capital stock. The dynamics of the capital stock  $K_t^j$  of household  $j$  are given by

$$K_{t+1}^j = (1 - \delta)K_t^j + \left(1 - \mathcal{S}\left(\frac{I_t^j}{I_{t-1}^j}\right)\right) I_t^j, \quad (\text{A 3.1})$$

where  $0 < \delta < 1$  is the rate of depreciation,  $\mathcal{S}(\cdot)$  is a function determining investment adjustment costs,  $I_t^j$  denotes investment. Utilizing a fraction of  $u_t^j$  of capital stock entails  $\mathcal{A}(u_t^j)K_t^j$  units of cost. Both functions,  $\mathcal{A}(\cdot)$  and  $\mathcal{S}(\cdot)$ , are increasing and convex. Furthermore, I assume  $\mathcal{A}(u) = \mathcal{S}(1) = \mathcal{S}'(1) = 0$ , so that the steady state of the model does not depend on variable capacity utilization and investment adjustment costs. The reason of incorporating these two settings into my model is as follows. As is widely known, in the absence of capital adjustment costs, investment (consumption) become too volatile (smooth) in response to shocks. Hence, the cost of capital adjustment smooths investment. It is also known that nominal stickiness alone does not generate realistic output persistence in response to monetary shocks (Ball and Romer 1990 and Chari et al. 2000). Christiano et al. (2005) and Dotsey and King (2006) show that introducing variable capital utilization into a New Keynesian model overcomes the critique of Chari et al. (2000). I followed Christiano et al. (2005) in characterizing these two settings.

The period- $t$  budget constraint is given by

$$\frac{R_t^{-1}B_t^j + M_t^j}{P_t} + C_t^j + I_t^j + \mathcal{A}(u_t^j)K_t^j = \frac{B_{t-1}^j + M_{t-1}^j + T_t^j}{P_t} + r_t u_t^j K_t^j + w_t^j N_t^j + \Phi_t^j, \quad (\text{A 3.2})$$

where  $r_t u_t^j K_t^j$  is the income from renting capital services.

Let  $\mu_t$  denote the Lagrange multiplier associated with the capital accumulation constraint for households' utility maximization problem (cf. equation 3.1). The first order conditions with respect to  $K_{t+1}^j$ ,  $u_t^j$ , investment  $I_t^j$  are given by

$$\mu_t = \beta E_t [\lambda_{t+1} (r_{t+1} u_{t+1}^j + \mathcal{A}(u_{t+1}^j))] + \beta(1 - \delta) E_t [\mu_{t+1}], \quad (\text{A } 3.3)$$

$$\mathcal{A}'(u_t^j) = r_t, \quad (\text{A } 3.4)$$

$$\begin{aligned} \lambda_t = \mu_t & \left( 1 - \mathcal{S} \left( \frac{I_t^j}{I_{t-1}^j} \right) - \frac{I_t^j}{I_{t-1}^j} \mathcal{S}' \left( \frac{I_t^j}{I_{t-1}^j} \right) \right) + \\ & + \beta E_t \left[ \mu_{t+1} \left( \frac{I_{t+1}^j}{I_t^j} \right)^2 \mathcal{S}' \left( \frac{I_{t+1}^j}{I_t^j} \right) \right]. \end{aligned} \quad (\text{A } 3.5)$$

The production technology for intermediate goods is given by

$$y_t(z) = A_t K_t(z)^\alpha (e_t(z) N_t(z))^{1-\alpha}, \quad (\text{A } 3.6)$$

where  $\alpha$  is the share of capital,  $K_t(z)$  is the capital services rented from the households. The rental rate of capital,  $r_t$ , is determined in an economy wide spot market.<sup>15</sup> Cost minimization problem of firms can be stated as

$$\min_{K_t(z), N_t(z), w_t(z), e_t(z)} r_t K_t(z) + w_t(z) N_t(z)$$

$$\text{s.t. } y_t(z) \leq K_t(z)^\alpha (e_t(z) N_t(z))^{1-\alpha},$$

$$e_t^z = \phi_0 + \phi_1 \log w_t(z) + \phi_2 \log N_t + \phi_3 \log w_t + \phi_4 \log w_{t-1}.$$

Letting  $mc_t(z)$  denote the Lagrange multiplier associated with the demand constraint, the first order conditions for the production unit can be written as

$$r_t = \alpha mc_t(z) \frac{y_t(z)}{K_t(z)}, \quad (\text{A } 3.7)$$

$$w_t(z) = (1 - \alpha) mc_t(z) \frac{y_t(z)}{N_t(z)}, \quad (\text{A } 3.8)$$

<sup>15</sup>This is a standard assumption in the New Keynesian literature, meaning that capital is homogenous across firms (See, for example, King and Watson 1996 and Yun 1996).

$$N_t(z) = (1 - \alpha)mc_t(z) \frac{y_t(z)}{e_t(z)} \frac{\phi_1}{w_t(z)}. \quad (\text{A } 3.9)$$

The last two conditions and (A 3.6) replace equations (3.11), (3.13) and (3.14) of the baseline model. Thus, in the extended model, we have 6 additional variables,  $K_t(z)$ ,  $K_{t+1}^j$ ,  $u_t^j$ ,  $I_t^j$ ,  $r_t$ , and  $\mu_{t+1}$  and 6 additional conditions, (A 3.1), (A 3.3), (A 3.4), (A 3.5), (A 3.7), and

$$\int_0^1 K_t(z)dz = \int_0^1 u_t^j K_t^j dj. \quad (\text{A } 3.10)$$

The last one is the market clearing condition for capital services. My extension of the baseline model requires also a modification in the resource constraint:

$$\int_0^1 y_t(z)dz = s_t \int_0^1 (C_t^j + I_t^j + \mathcal{A}(u_t^j)K_t^j) dj \quad (\text{A } 3.11)$$

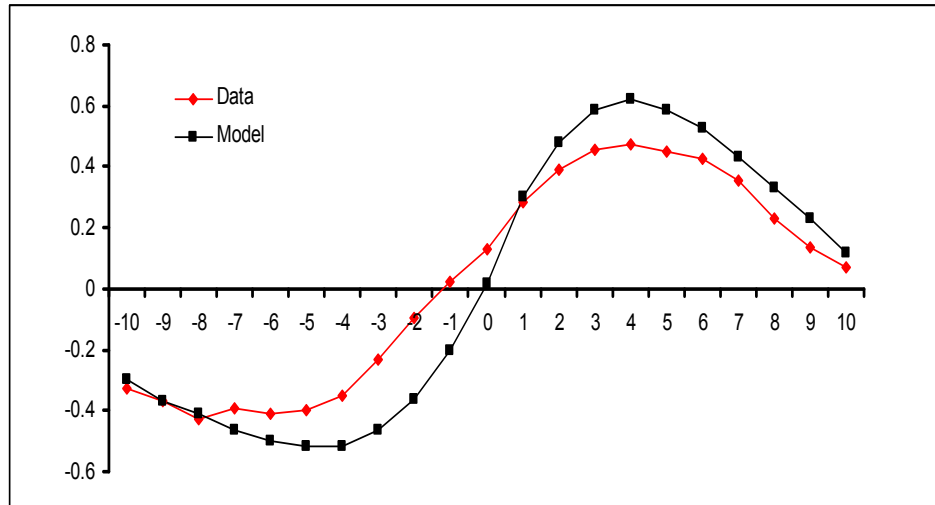
Corresponding parameters of the extended model are calibrated as follows. I set  $\alpha = 1/3$ , implying a capital share of 33%. I set  $\delta = 0.0241$ , implying an annual rate of depreciation 10%. These are the standard values used in the business-cycle literature. Calibration of the elasticity of capital utilization,  $\mathcal{A}''(u)/\mathcal{A}'(u)$ , and the parameter governing the degree of investment adjustment costs,  $\mathcal{S}''(1)$ , are based on Christiano et al. (2005):  $\mathcal{A}''(u)/\mathcal{A}'(u) = 0.01$  and  $\mathcal{S}''(1) = 1.89$ .

### A 3.2 Simulation Results for the Extended Model

Figure A 3.1 depicts the cross-correlations of the output with the leads and lags of inflation. The line marked with a diamond sign corresponds to the correlations in the US output and inflation data from 1959:1 to 2006:4, both HP-filtered. As does the baseline model, my extended model (line marked with a square sign) resemble the shape of the cross-correlation function implied by data.

Figure A 3.2 presents the impulse response functions of the extended model and its variants for a monetary shock. The variants are chosen as in the main text. A brief description of the impulse response functions for my extended model is as follows. First, all key variables respond in a hump-shaped fashion to a monetary impulse. Second, the increase in consumption falls short of that in investment. Third employment closely tracks output. Fourth, the real wage response is small and positive. Fifth, both models imply a liquidity effect. Sixth, inflation follows output with a lag of two quarters.



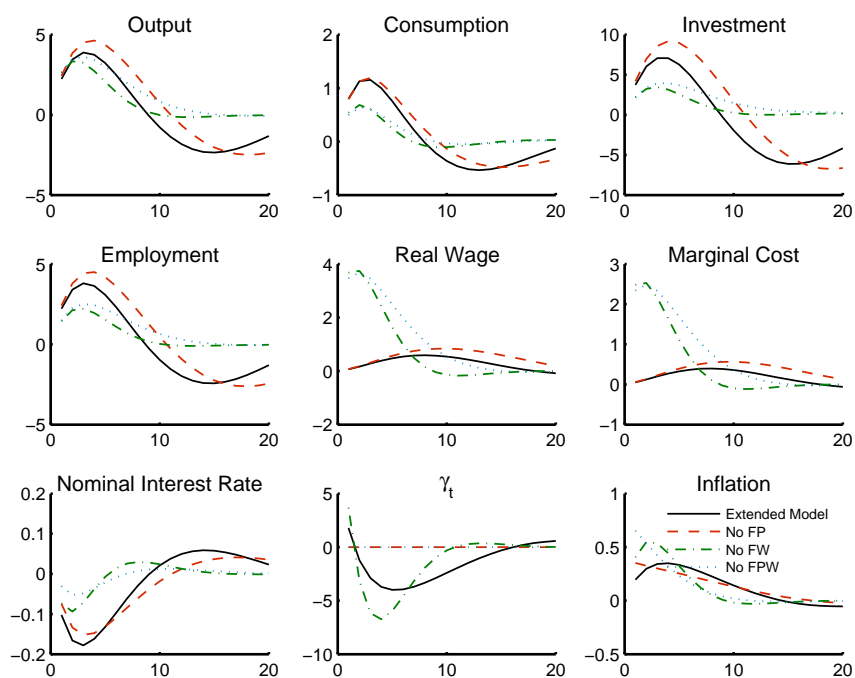
Figure A 3.1: *Dynamic cross-correlations: output( $t$ ), inflation( $t+k$ )*

Note: The figure plots the cross-correlations of the output with the leads and lags of inflation. The horizontal axis measures  $k$  (leads/lags). The vertical axis measures the cross-correlations.

The implications of the variants of the extended model is rather similar to that of the baseline model (cf. Figure 3.2). The fair-wage setting dampens the responses of the real wage rate, marginal cost, and inflation, and magnifies the responses of output, consumption, investment, employment, and the nominal interest rate. The fair-price setting smooths the responses of the macroeconomic aggregates.

Hence, it is a plausible conclusion that the main results of Chapter 3 hold also under a more general framework.

Figure A 3.2: Impulse Response Functions for a Monetary Shock



Note: The figure plots the responses of key variables to a unit standard-deviation positive shock to money growth rate. The horizontal axis measures quarters. The vertical axis measures logarithmic/percentage deviations from the steady state.

## Chapter 4

# Capital Mobility & Labor Market Volatility

A question widely discussed among academics and politicians is whether the increase in capital mobility that has taken place since the mid-1980s has given rise to more labor market volatility and job uncertainty (Scheve and Slaughter 2004).<sup>1</sup> This question is of central importance because the burden of adjustment that labor has to bear in the wake of macroeconomic fluctuations should increase when capital is internationally highly mobile while labor is not. In consequence, the recent increases in capital mobility may have resulted in an asymmetric distribution of the benefits and losses from globalization among mobile capital and immobile labor. Inflexibilities and frictions in labor markets that are beleaguered by structural unemployment have the power to reinforce this asymmetric distribution of the benefits and losses from globalization. In consequence, the potentially complex interaction of capital mobility and labor market frictions is likely to be one key determinant of the extent to which people are willing to accept the economic and social changes brought about by the globalization of the world's economy.

I use a dynamic stochastic general equilibrium (DSGE) model to analyze whether and, if so, to which extent capital mobility increases labor market volatility. My DSGE model builds on the two-country general equilibrium models developed by Obstfeld and Rogoff (1995) and Betts and Devereux (2000, 2001), which have become the prototype models for analyzing macroeconomic dynamics in open economies. Their models feature a Walrasian labor market in which wages adjust rapidly, households are always on their labor supply schedule, and structural unemployment is absent. To account for the

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<sup>1</sup>The material in this chapter is based on my joint work "Capital Mobility and Labor Market Volatility" with Christian Pierdzioch, mimeo, (2007).

stylized facts of real-world labor markets, I develop an extended model that features a non-Walrasian labor market. My extended model can explain the existence of structural unemployment, the empirically observed volatilities of employment and real wages relative to output, the low correlation between real wages and employment, and the high variability of employment relative to that of real wages.

In order to model a non-Walrasian labor market, I extend my DSGE model to incorporate fair wages. The analysis of the implications of fair wages for the properties of DSGE models has a long tradition in macroeconomic research (Danthine and Donaldson 1990). My approach to introduce efficiency wages into my DSGE model builds on the recent contributions of Collard and de la Croix (2000) and Danthine and Kurmann (2004). They have extended dynamic general equilibrium models to incorporate the so-called "gift exchange" efficiency-wage theory that traces back to Akerlof (1982). The "gift exchange" efficiency-wage theory stipulates that workers dislike effort. Workers are willing to provide effort beyond some reference level of effort (the gift of workers) if they feel that their firm treats them well. Firms, in turn, seek to motivate workers by offering a wage above the market-clearing wage (the gift of the firm). The optimizing behavior of workers and firms results in structural unemployment.

I report that, in a model featuring fair wages, capital mobility magnifies the response of employment and the real wage in the immediate aftermath of productivity shocks and monetary shocks. At the same time capital mobility dampens the medium run effects of productivity shocks and monetary shocks on employment and the real wage. As a result, the overall effect of capital mobility on the volatility of employment and the real wage, and on their cyclical properties is moderate. My results regarding the effects of capital mobility on the volatilities of key macroeconomic variables is reminiscent of a famous result derived by Cole and Obstfeld (1991), who shows that allocations in an endowment economy may be identical under complete markets and financial autarchy.

My results are consistent with recent empirical evidence reported by Razin and Rose (1994), who have found no significant empirical link between financial openness and macroeconomic volatility. In contrast, using a search-theoretic model, Azariades and Pissarides (2007) have reported that capital mobility may result in more labor market volatility. Buch and Pierdzioch (2005) and Buch et al. (2005) have reported that the link between capital mobility and macroeconomic volatility in OECD countries has changed over

time and may depend on the nature of shocks hitting an economy. Similarly, Kose et al. (2003) have found that capital mobility may be associated with an increase in the ratio of consumption volatility to income volatility, but that this effect turns negative if the volume of gross capital flows crosses a particular threshold. Recent empirical evidence, thus, yields the result that capital mobility need not necessarily increase macroeconomic volatility. This result is consistent with the observation that in the United States and other Western countries business-cycle volatility and employment volatility have tended to decrease since the mid 1980s (Stock and Watson 2002, Carlino et al. 2003).

I organize the remainder of this chapter as follows. In Section 4.1, I lay out the DSGE model I used to derive my results. The basic structure of my model resembles the structures of the models developed by Obstfeld and Rogoff (1995) and Betts and Devereux (2000, 2001), so that my discussion can be relatively brief. In Section 4.2, I report the results of numerical simulations of my model. In Section 4.3, I offer some concluding remarks.

## 4.1 The Model

The world consists of two countries. Both countries are populated by a continuum of infinitely lived households. Households form rational expectations. Domestic and foreign households have identical preferences. Households are internationally immobile. Households own the firms of the country in which they reside. Firms sell the differentiated goods they produce in a monopolistically competitive goods market. Some firms set the prices of their goods in the currency of the country in which they reside. Other firms set the prices of their goods in the currency of their customers. I call the latter a pricing-to-market (PTM) price-setting strategy (Betts and Devereux 2000, 2001). In addition to households and firms, every country is populated by a government.

### 4.1.1 Households

Each household consists of a large number of household members of total measure unity. Some members of households are unemployed, while the others are employed. Following Alexopoulos (2004) and Danthine and Kurmann (2004), employment is randomly allocated across workers. The proportion

of unemployed household members is the same across households. Households make all intertemporal decisions, and redistribute consumption equally among their members. Each household inelastically supplies one unit of time for work, and has preferences defined over consumption, real balances, and effort. The expected discounted lifetime utility of a representative household is given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ \log(C_t^j - X_t^j) + \frac{\chi}{1 - \sigma_m} \left( \frac{M_t^j}{P_t} \right)^{1 - \sigma_m} - N_t^j \mathcal{G}(e_t^j) \right], \quad (4.1)$$

with  $j$  being the household index and  $0 < \beta < 1$ ,  $\chi > 0$ , and  $\sigma_m > 0$ .  $E_t$  denotes the conditional expectations operator,  $N_t$  denotes the proportion of household members working,  $\mathcal{G}(e_t)$  denotes the disutility of effort,  $M_t/P_t$  denotes real money holdings, and  $C_t$  denotes a real consumption index.

This consumption index,  $C_t = \left[ \int_0^1 c_t(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}}$ , is defined as a constant-elasticity-of-substitution index of differentiated goods,  $c_t(z)$ ,  $z \in [0, 1]$ , where the elasticity of substitution is given by  $\theta > 1$ . The consumer price index,  $P_t$ , is defined as the minimum expenditure required to buy one unit of  $C_t$ . The consumer price index is defined as

$$P_t = \left[ \int_0^n p_t(z)^{1-\theta} dz + \int_n^{n+(1-n)\xi} q_t(z^*)^{1-\theta} dz + \int_{n+(1-n)\xi}^1 (S_t p^*(z^*))^{1-\theta} dz \right]^{\frac{1}{1-\theta}}, \quad (4.2)$$

where  $n \in (0, 1)$  denotes the size of the domestic country,  $p_t(z)$  denotes the domestic currency price of a domestically produced good,  $q_t(z^*)$  denotes the domestic currency price of a foreign PTM good,  $S_t$  denotes the nominal exchange rate, and  $p_t^*(z^*)$  denotes the foreign currency price of a foreign non-PTM good. The parameter  $\xi$  denotes the proportion of firms that follow a PTM strategy. The domestic demand for good  $z$  for consumption purposes is given by

$$c_t(z) = (p_t(z)/P_t)^{-\theta} C_t. \quad (4.3)$$

Households do not only derive utility from consuming the consumption index,  $C_t^j$ , but also derive disutility from the variable  $X_t^j$ . This variable captures a "catching-up with the Joneses" effect in households' preferences. It is defined as

$$X_t^j = h C_{t-1}^A, \quad (4.4)$$

where  $0 < h < 1$ , and  $C_t^A$  = denotes aggregate (per capita) consumption. An increase in the level of aggregate consumption results in a decrease in the level of utility a household attains, and in an increase in the marginal utility a household derives from consumption, implying that households try to "catch up with the Joneses".

The disutility a household derives from effort is determined by an effort function,  $\mathcal{G}(e_t^j)$ . Four considerations matter for the specification of the effort function (Collard and de la Croix 2000, Danthine and Kurmann 2004). First, if a firm pays a higher real wage, households are motivated and work harder. For this reason, their reference level of effort is an increasing function of the individual households' current real wage,  $w_t^j$ . Second, if the aggregate level of employment is high, households realize that they can easily find a new employment opportunity in case they lose their job. Hence, the reference level of effort is a decreasing function of the aggregate level of employment,  $N_t$ . Third, if the real wage received by a household does not change when the aggregate real wage increases, individual households' relative compensation decreases. Because households perceive this to be unfair, they decrease the level of effort they provide. This implies that the reference level of effort is a decreasing function of the aggregate real wage,  $w_t$ . Fourth, if households observe changes in real wages from one period to the next, they adjust their reference level of effort. This captures the empirical finding reported by Bewley (1998) that changes in wages rather than wage levels are an important determinant of effort. Accordingly, the reference level of effort is a decreasing function of an individual households' past wage,  $w_{t-1}^j$ . Taken together, these four considerations imply that the effort function is of a form

$$\mathcal{G}(e_t^j) = [e_t^j - (\phi_0 + \phi_1 \log w_t^j + \phi_2 \log N_t + \phi_3 \log w_t + \phi_4 \log w_{t-1}^j)]^2, \quad (4.5)$$

where  $\phi_1 > 1$ ,  $\phi_2 < 0$ ,  $\phi_3 < 0$ , and  $\phi_4 < 0$ .

#### 4.1.2 Budget Constraint and First-Order Conditions

Households maximize their expected discounted lifetime utility subject to their budget constraint. According to households budget constraint, the total income received by households consists of the yield on their holdings in bonds, the profit income yielded by their ownership of domestic firms, their labor income, and their income from renting capital to domestic firms. Given their total income, households determine their optimal consumption, effort, investment, and next period's capital stock. Households also decide on their preferred holdings in domestic money and bonds. The individual households'

budget constraint is given by

$$D_t^j = R_{t-1}D_{t-1}^j + M_{t-1}^j - M_t^j + w_t^j N_t^j P_t + R_t^k k_t^j P_t + \\ - C_t^j P_t - I_t^j P_t - AC_t^j P_t + \Phi_t^j P_t + T_t P_t, \quad (4.6)$$

where  $D_t$  denotes the quantity of domestic nominal riskless one-period bonds,  $R_t$  denotes the gross nominal interest rate on bonds,  $R_t^k$  denotes the real rental rate of capital,  $T_t$  denotes real lump-sum transfers received from the government,  $I_t$  denotes real investment,  $AC_t$  is the real adjustment cost households incur when adjusting their capital stock, and  $\Phi_t$  denotes the real profit income the household receives from domestic firms. The law of motion of households' capital stock,  $k_t^j$ , is given by

$$I_t^j = k_{t+1}^j - (1 - \delta)k_t^j, \quad (4.7)$$

where  $0 < \delta < 1$  denotes the depreciation rate. The investment good,  $I_t$ , is constructed in the same way as the consumption index, i.e.  $I_t = \left[ \int_0^1 i_t(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}}$ . Thus, the domestic demand for good  $z$  for investment purposes,  $i_t(z)$ , can be expressed by

$$i_t(z) = (p_t(z)/P_t)^{-\theta} I_t. \quad (4.8)$$

The adjustment cost households incur when adjusting their capital stock are given by

$$AC_t^j = \frac{\psi (k_{t+1}^j - k_t^j)^2}{2 k_t^j}, \quad (4.9)$$

where  $\psi \geq 0$ .

The first-order conditions that describe the solution to an individual households' utility-maximization problem are given by

$$C_t^j - X_t^j = \lambda_t P_t, \quad (4.10)$$

$$\chi \left( \frac{M_t^j}{P_t} \right)^{-\sigma_m} = \lambda_t P_t - \beta P_t E_t \lambda_{t+1}, \quad (4.11)$$

$$\lambda_t = \beta R_t E_t \lambda_{t+1}, \quad (4.12)$$

$$e_t^j = \phi_0 + \phi_1 \log w_t^j + \phi_2 \log N_t + \phi_3 \log w_t + \phi_4 \log w_{t-1}^j, \quad (4.13)$$

$$\lambda_t P_t + \beta(1 - \delta) E_t \lambda_{t+1} P_{t+1} + \beta E_t R_{t+1}^k \lambda_{t+1} P_{t+1} + \\ + \frac{\psi}{2} \beta E_t \lambda_{t+1} P_{t+1} \frac{(k_{t+2}^j)^2 - (k_{t+1}^j)^2}{(k_{t+1}^j)^2} = \psi \lambda_t P_t \frac{k_{t+1}^j - k_t^j}{k_t^j} \quad (4.14)$$



where  $\lambda_t$  denotes the Lagrange multiplier on the households' budget constraint.

### 4.1.3 Financial Markets

As regards the structure of international financial markets, I consider two polar cases. First, I consider the case of a world economy in which agents can trade in integrated financial markets for riskless one-period nominal bonds. For simplicity, I assume that domestic households invest in a home-currency denominated nominal bond, and that foreign households invest in a foreign-currency denominated nominal bond and a home-currency denominated nominal bond. This assumption implies that, in the case of an integrated international bond market, the condition of uncovered interest-rate parity holds. Second, I consider the case of a world economy in which markets for trade in international assets do not exist (Cole and Obstfeld 1991, Heathcote and Perri 2002). In this case, home households invest in a home-currency denominated nominal bond, and foreign households invest in a foreign-currency denominated nominal bond. The market-clearing condition for the home-currency denominated nominal bond in the case of an integrated international bond market is given by

$$\int_j D_t^j dj + \int_j D_t^{j*} dj = 0 \quad (4.15)$$

and the market-clearing conditions in the case of financial autarchy are given by

$$\int_j D_t^j dj = 0 \quad (4.16)$$

and

$$\int_j F_t^{j*} dj = 0 \quad (4.17)$$

where  $F_t^{j*}$  denotes the foreign-currency denominated bond.

### 4.1.4 Firms

Each firm consists of a production and a price-setting unit. The production unit produces the good,  $z$ , according to the production function

$$y_t(z) = A_t k_t(z)^\alpha [e_t(z) N_t(z)]^{1-\alpha}, \quad (4.18)$$

where  $A_t$  denotes an aggregate productivity shock. Given the level of effort provided by households, the production unit determines the real wage and chooses the level of capital and employment in order to minimize total production costs. Following Danthine and Kurmann (2004), I assume that the production unit replaces the individual households' past wage,  $w_{t-1}^j$ , with the aggregate past wage  $w_{t-1}$  in the effort function when minimizing total production costs. Because firms treat as exogenous when minimizing total production costs, this assumption implies that they do not account for the consequences of offering a higher wage today for the future effort of households. In technical terms, this assumption implies that the production unit solves a static wage-setting problem. Hence, the production unit does not have to store information on the distribution of past wages of its employees. In economic terms, this assumption implies that, in a symmetric equilibrium, all firms will pay identical wages. Using in the effort function, the first-order conditions for the cost-minimization problem are given by

$$w_t(z) = (1 - \alpha)mc_t(z) \frac{y_t(z)}{n_t(z)}, \quad (4.19)$$

$$n_t(z) = (1 - \alpha)mc_t(z) \frac{\phi_1 y_t(z)}{e_t(z)w_t(z)}, \quad (4.20)$$

$$R_t^k(z) = \alpha mc_t(z) \frac{y_t(z)}{k_t(z)}, \quad (4.21)$$

where  $mc_t(z)$  denotes the real marginal cost of production. The first-order conditions imply  $e_t(z) = \phi_1$ , a condition known as the Solow (1979) condition.

Because of monopolistic competition in the goods market, the price-setting unit can set the price of the good produced by the production unit in order to maximize profits. I let  $q_t^*(z)$  denote the foreign-currency price of a domestic PTM good, and  $y_t^D(z)$  and  $y_t^F(z)$  denote the demand at home and abroad. The demand functions are given by

$$y_t^D(z) = (p_t(z)/P_t)^{-\theta} Q_t, \quad (4.22)$$

$$y_t^F(z) = (q_t^*(z)/P_t^*)^{-\theta} Q_t^*, \quad (4.23)$$

$Q_t = n(C_t + I_t + AC_t)$  and  $Q_t^* = (1 - n)(C_t^* + I_t^* + AC_t^*)$ . The price-setting unit sets the price of the good subject to a discrete time version of the price-setting mechanism developed by Calvo (1983). With probability  $0 < \gamma < 1$ , the price-setting unit cannot revise the price of its good in any given period of time. Therefore, the price-setting unit of a PTM firm sets the current domestic-currency and foreign-currency prices of the product,  $p_t(z)$

and  $q_t^*(z)$ , so as to maximize the expected discounted present value profits. The solutions to this maximization problem are

$$p_t(z) = \frac{\theta}{\theta - 1} \frac{E_t \sum_{s=t}^{\infty} \gamma^{s-t} R_{t,s} (Q_s / P_s^{-\theta}) m c_s(z)}{E_t \sum_{s=t}^{\infty} \gamma^{s-t} R_{t,s} (Q_s / P_s^{1-\theta})}, \quad (4.24)$$

$$q_t^*(z) = \frac{\theta}{\theta - 1} \frac{E_t \sum_{s=t}^{\infty} \gamma^{s-t} R_{t,s} (Q_s^* / P_s^{*\theta}) m c_s(z)}{E_t \sum_{s=t}^{\infty} \gamma^{s-t} R_{t,s} (Q_s^* / P_s^{*1-\theta}) S_s}, \quad (4.25)$$

where  $R_{t,s} \equiv \prod_{j=s}^t R_t^{-1}$  is the market discount factor. Similar expressions can be derived for the profit-maximizing prices,  $q_t(z^*)$  and  $p_t^*(z^*)$ , set by the price-setting units of foreign PTM firms, and for the profit-maximizing price set by the price-setting units of non-PTM firms. The latter set a single domestic currency denominated price for both the domestic and foreign goods market.

#### 4.1.5 The Government Sector

The government sector consists of a single central bank and a fiscal authority. The central bank controls the money supply. The budget constraint of the fiscal authority is given by

$$P_t T_t = M_t - M_{t-1}. \quad (4.26)$$

#### 4.1.6 Solution and Calibration of the Model

I log-linearized my model around a symmetric flexible-price steady state in which bond holdings in the domestic and foreign country are zero. I then simulated the calibrated model using the algorithm developed by McCallum (1998) and Klein (2000). The calibrated parameter values are summarized in Table 4.1.

I calibrate the model to match quarterly data. I assume that the domestic and foreign countries are of equal size ( $n = 0.5$ ). With regard to households' preferences, I assume  $\beta = 0.99$ , implying an annual real interest rate of approximately 4.1 percent. I followed Sutherland (1996) and Senay (1998) in assuming  $\sigma_m = 9$ , an assumption consistent with the calibration used by Hairault and Portier (1993). As regards the parameter that captures the "catching-up with the Joneses" effect in households' preferences, I use the numerical values used by Ljungqvist and Uhlig (2000) and set  $h = 0.8$ .

Table 4.1: *Calibrated Parameters*

Country size	$n = 0.5$
Discount factor:	$\beta = 1.04^{-1/4}$
Semi elasticity of money demand:	$\sigma_m = 9$
Degree of habit formation;	$h = 0.8$
Elasticity of real wage w.r.t.	
a)employment:	$\eta_1 \equiv -\phi_2/(\phi_1 + \phi_3) = 0.03$
b)past real wage:	$\eta_2 \equiv -\phi_4/(\phi_1 + \phi_3) = 0.99$
Demand elasticity:	$\theta = 11$
Capital share:	$\alpha = 0.36$
Reset probability:	$1 - \gamma = 0.25$
Capital adjustment costs:	$\psi = 21.5$
Proportion of PTM firms	$\xi = 0.95$
Risk premium	$\Psi = 0.004$

With regard to the elasticity of substitution between differentiated goods, I assume  $\theta = 11$ , which is common in the literature. The value I chose for  $\theta$  implies a steady-state markup of prices over marginal costs of 10 percent. As regards the depreciation rate, I assume  $\delta = 0.024$ , implying an annual depreciation rate of 10 percent. The capital share parameter in the production function assumes the value  $\alpha = 0.36$ . These are typical estimates of U.S. data. I calibrate the Calvo-pricing parameter such that the average delay between price adjustments is four periods ( $\gamma = 0.75$ ), a value roughly the same as the one in Danthine and Kurmann (2004). I resort to the empirical estimates that have recently been reported by Bergin (2006) to calibrate the adjustment costs households' incur when adjusting their capital stock. Accordingly, I assume  $\psi = 21.5$ . Following again Bergin (2006), I assume that the proportion of firms that follow a PTM price-setting strategy is relatively large. I set  $\xi = 0.95$ .

In order to calibrate the parameters of the effort function, I first derive the fair-wage function. The fair-wage function obtains when the Solow condition,  $e_t = \phi_1$ , is used in the effort function. Apart from a constant, the fair-wage function, in a symmetric equilibrium, is given by

$$\log w_t = \eta_1 \log N_t + \eta_2 \log w_{t-1}, \quad (4.27)$$

where  $\eta_1 = -\phi_2/(\phi_1 + \phi_3)$  and  $\eta_2 = -\phi_4/(\phi_1 + \phi_3)$ . Danthine and Kurmann (2004) have reported the estimates  $\eta_1 = 0.03$  and  $\eta_2 = 0.99$  for the United States. Because the parameters of the fair-wage function are key parameters

of my model, I shall present in Section 4.2 simulation results that I obtain when I use alternative numerical values for the parameters of the fair-wage function to calibrate my model.

With regard to the stochastic processes that describe the dynamics of domestic and foreign productivity, I follow Backus et al. (1992) in specifying the following bivariate autoregressive model:

$$\begin{pmatrix} \hat{A}_t \\ \hat{A}_t^* \end{pmatrix} = \begin{pmatrix} 0.906 & 0.088 \\ 0.088 & 0.906 \end{pmatrix} \begin{pmatrix} \hat{A}_{t-1} \\ \hat{A}_{t-1}^* \end{pmatrix} + \begin{pmatrix} \varepsilon_t^{\hat{A}} \\ \varepsilon_t^{\hat{A}^*} \end{pmatrix}, \quad (4.28)$$

where a hat over a variable denotes deviations from the steady state. The standard deviations of the disturbance terms are given by  $\sigma_{\varepsilon^{\hat{A}}} = \sigma_{\varepsilon^{\hat{A}^*}} = 0.00852$ . The coefficient of correlation between the disturbance terms is 0.258.

Similar to Chari et al. (2002), I calibrate the stochastic processes that describe the dynamics of domestic and foreign monetary shocks

$$\begin{pmatrix} \hat{M}_t \\ \hat{M}_t^* \end{pmatrix} = \begin{pmatrix} 0.68 & 0 \\ 0 & 0.68 \end{pmatrix} \begin{pmatrix} \hat{M}_{t-1} \\ \hat{M}_{t-1}^* \end{pmatrix} + \begin{pmatrix} \varepsilon_t^{\hat{M}} \\ \varepsilon_t^{\hat{M}^*} \end{pmatrix}. \quad (4.29)$$

The standard deviations of the disturbance terms are given by  $\sigma_{\varepsilon^{\hat{M}}} = \sigma_{\varepsilon^{\hat{M}^*}} = 0.009$  as in Kollmann (2001). The coefficient of correlation between the disturbance terms is 0.3, which is in between the correlations used by Kollmann (2001) and Chari et al. (2002).

Finally, I use a risk premium to ensure the stationarity of the steady state in the case of integrated international bond markets. If I had not added a risk premium, productivity shocks and monetary shocks would have resulted in permanent changes in countries' bond positions because of the incompleteness of asset markets in my model. Following Schmitt-Grohe and Uribe (2003), Bergin (2006), and others, I extend the condition of uncovered interest rate parity implied by my model by a (linearized) risk premium that is proportional to holdings in bonds,  $\Psi \hat{D}_t$ , where I set  $\Psi = 0.004$ , based on the empirical estimates reported by Bergin (2006).

## 4.2 Simulation Results

I present my simulations results in three steps. In a first step, I compare the labor market statistics implied by my model with key labor market statistics of the United States. In a second step, I present impulse response functions

to graphically illustrate the mechanics of my model. In a third step, I report results of stochastic simulations that show how key labor market statistics change in the wake of financial market integration.

### 4.2.1 A Comparison of the Model with the Data

Table 4.2 summarizes key labor market statistics. I focus on the standard deviation of employment relative to that of output, the standard deviation of the real wage relative to that of output, and the contemporaneous correlation of employment and output, the real wage and output, and the real wage and employment.

In addition to the statistics for a model featuring fair wages, I report labor market statistics implied by a model that features a Walrasian labor market. In order to simulate the model with a Walrasian labor market, I replaced Equation (4.13) with the standard first-order condition  $N_t = w_t \lambda_t P_t$ . Finally, I report labor market statistics implied by a model featuring fair wages and, in addition, complete international asset markets. Complete international asset markets imply optimal international risk sharing. Optimal international risk sharing, in turn, implies that, in every state of nature, the ratio of the levels of domestic and foreign consumption is proportional to the real exchange rate,  $(\lambda_t P_t)/(\lambda_t^* P_t^*) = \varphi(S_t P_t^*/P_t)$ , where  $\varphi$  is a constant that reflects initial conditions. The labor market statistics implied by the three models are based on 1,000 simulations of every one of the three models, where every simulation has a length of 25 years of quarterly data (i.e., 100 periods).

The simulation results show that the labor market statistics implied by the model featuring fair wages closely resemble key labor market statistics of the United States. The model performs well in the volatilities of employment and the real wage relative to output, their correlation, and their comovement with output. The model does a better job in explaining the empirical labor market statistics than a model that features a Walrasian labor market.

It is also evident from the simulation results that the model featuring integrated international bond markets yields simulation results close to the simulation results implied by a model featuring complete international asset markets. This is what one would have expected, given my assumption that productivity shocks and monetary shocks are temporary. Baxter and Crucini (1995) have reported that the differences between a model featuring integrated international bond markets and complete international asset markets are small if shocks are temporary.

**Table 4.2:** *Labor Market Statistics*

Statistic	US Data	Model with Fair Wages	Model without Fair Wages	Model with Fair Wages and Complete Asset Markets
$\sigma_{N_t}/\sigma_{Y_t}$	0.81	0.80	0.29	0.80
$\sigma_{w_t}/\sigma_{Y_t}$	0.69	0.49	0.94	0.49
$\rho_{N_t, Y_t}$	0.82	0.86	0.46	0.87
$\rho_{w_t, Y_t}$	0.57	0.59	0.95	0.58
$\rho_{w_t, N_t}$	0.27	0.18	0.56	0.18

*Note:* The statistic  $\sigma_{N_t}/\sigma_{Y_t}$  denotes the standard deviation of employment relative to the standard deviation of output. The statistic  $\sigma_{w_t}/\sigma_{Y_t}$  denotes the standard deviation of the real wage relative to the standard deviation of output. The statistic  $\rho_{N_t, Y_t}$  denotes the coefficient of correlation between employment and output. The statistic  $\rho_{w_t, Y_t}$  denotes the coefficient of correlation between the real wage and output. The statistic  $\rho_{w_t, N_t}$  denotes the coefficient of correlation between the real wage and employment. Statistics for U.S. data were taken from Krause and Lubik (2006).

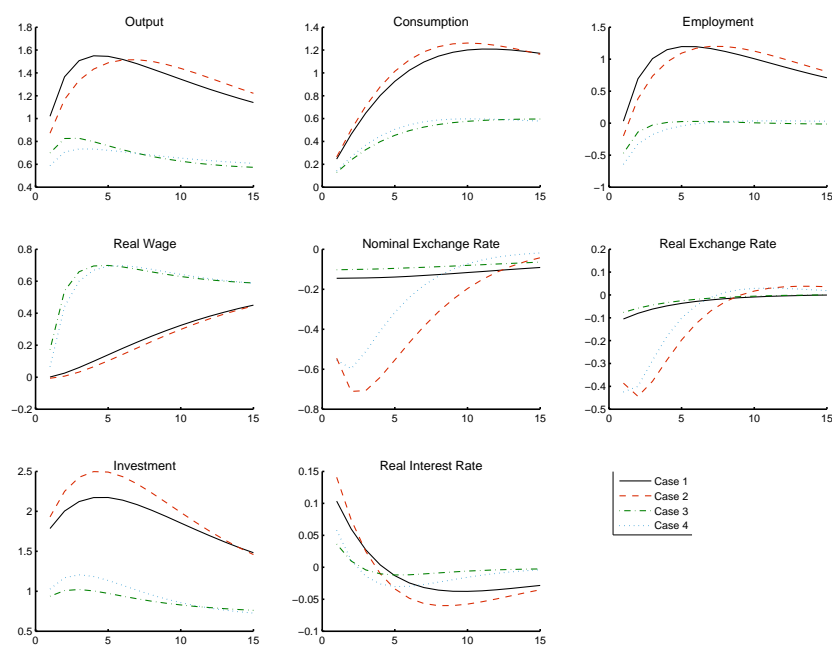
### 4.2.2 Impulse Response Functions

In order to illustrate how fair wages affect the propagation of productivity shocks and monetary shocks, I computed impulse response functions. The impulse response functions I shall report describe the dynamics of key macroeconomic variables in the aftermath of a shock in terms of percentage deviations from the steady state. I computed impulse response functions for four cases. Case 1 represents the case of fair wages and capital mobility. Case 2 represents the case of fair wages and financial autarchy. Case 3 represents the case of a Walrasian labor market and capital mobility. Finally, Case 4 represents the case of a Walrasian labor market and financial autarchy.

Figure 4.1 presents impulse response functions for a domestic productivity shock. A productivity shock increases the marginal product of capital and labor. Accordingly, firms' demand for capital and labor increases, and they are willing to pay a higher real wage. Firms' investment and the real interest rate increase. The effect of a productivity shock on the real wage is much smaller in a model featuring fair wages than in a model featuring a Walrasian labor market. Given households' effort function, the real wage adjusts only sluggishly.

As compared to the effect of a productivity shock on real wages, the effect on employment is large. Thus, the assumption of fair wages implies, in line with the stylized facts characterizing business cycles in many industrialized countries, that the volatility of the real wage is smaller than the volatility

Figure 4.1: Productivity Shock, Fair Wages, and Financial Market Integration



Note: The figure plots the responses of domestic variables to a unit standard-deviation positive domestic productivity shock. The horizontal axis measures quarters. The vertical axis measures logarithmic/percentage deviations from the steady state.



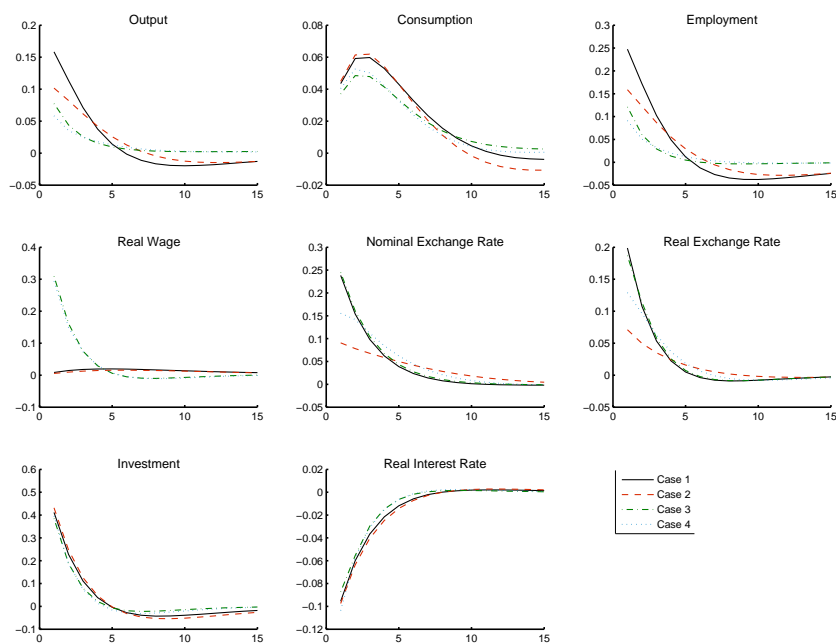
of employment. Moreover, the contemporaneous correlation of the real wage with employment is relatively low. In addition, a comparison of the response of the real wage to a productivity shock with that of output shows that the real wage is moderately procyclical. Moreover, the sluggish procyclical adjustment of the real wage increases the scope for output and employment to expand, and for the prices of differentiated products to contract (not shown). As a result, the ensuing expansion of output is larger in a model featuring fair wages than in a model featuring a Walrasian labor market.

Consumption increases gradually because of the "catching-up with the Joneses" effect in households' preferences. A direct consequence of the increase in consumption is that the demand for domestic currency increases, giving rise to an appreciation of the nominal exchange rate. Because the increase in consumption is stronger if the model features a non-Walrasian labor market, the appreciation of the nominal exchange rate is stronger than in a model featuring a Walrasian labor market. Because a non-negligible proportion of firms follows a PTM price-setting strategy, the condition of purchasing power parity does not hold. As a result, the appreciation of the nominal exchange rate goes hand in hand with an appreciation of the real exchange rate.

In Figure 4.1, capital mobility dampens the effect of a productivity shock on consumption. It also increases the short-run effects of a productivity shock on output, the nominal and real exchange rates, and employment. At the same time, capital mobility dampens the medium-run effects of such a shock on output and employment. Thus, in order to trace out the overall effects of changes in the degree of capital mobility on macroeconomic volatility, one should use stochastic simulations of the model. I shall present the results of stochastic simulations in Subsection 4.2.3.

Figure 4.2 presents impulse response functions for a monetary shock. The liquidity effect of a monetary shock results in a decrease in the real interest rate and an increase in investment. Consumption also increases, but only gradually because the "catching-up with the Joneses" effect in households' preferences requires a gradual adjustment of consumption. The increase in the demand for goods implies that a monetary policy shock results in an increase in output and employment. Firms are willing to pay higher wages, but the assumption of fair wages implies that a monetary policy shock exerts only a small effect on real wages. As in the case of a productivity shock, the assumption of fair wages implies that the volatility of the real wage is smaller than the volatility of employment, and that the real wage is weakly procyclical.

Figure 4.2: Monetary Shock, Fair Wages, and Financial Market Integration



Note: The figure plots the responses of domestic variables to a unit standard-deviation positive shock to domestic money growth rate. The horizontal axis measures quarters. The vertical axis measures logarithmic/percentage deviations from the steady state.

With regard to international capital mobility, the impulse response functions shown in Figure 4.2 confirm the insights I derived from the impulse response functions for a productivity shock. The effects of a monetary shock on output and employment increase in the short run, but the effects are dampened in the medium run. As in the case of a productivity shock, calculation of the overall effects of changes in the degree of capital mobility on macroeconomic volatility requires running stochastic simulations of the model.

### 4.2.3 The Effect of Capital Mobility on Labor Market Volatility

I use stochastic simulation to quantitatively analyze the effects of capital mobility on the following labor market statistics: the volatility of employment and the real wage, their correlation, and their comovement with output. To this end, I compute the relative difference (in percentage terms) between these labor market statistics under capital mobility and under financial autarchy. The model is simulated 1,000 times, where each simulation had a length of 25 years. As a robustness check, the model is simulated also for various alternative calibrations of the model. Specifically, I vary the parameters of the effort function,  $\eta_1$  and  $\eta_2$ , the proportion of firms following a PTM price-setting strategy,  $\xi$ , the country size,  $n$ , the probability of not adjusting goods prices,  $\gamma$ , and the degree of "catching up with the Joneses" effect in households' preferences,  $h$ . As yet another robustness check, I set  $\psi$ , implying that the ratio of the volatility of investment to the volatility of output assumes a value approximately equal to the value equal to the ratio implied by U.S. data. In order to analyze the sensitivity of my simulation results to the specification of the processes for productivity, I set the off-diagonal elements of the bivariate autoregressive model that describes the dynamics of domestic and productivity equal to zero. As a final robustness check, I compare the simulation results for a model featuring complete international asset markets with the simulations results for a model featuring financial autarchy.

Table 4.3 summarizes the simulation results. The relative differences between the labor market statistics under capital mobility and under financial autarchy are fairly small. In fact, in the majority of cases, the relative differences are smaller than one percent. Only the contemporaneous correlation of the real wage with employment increases, in the case where the average frequency of price changes is one quarter, about twelve percent. More than

Table 4.3: Capital Mobility and Labor Market Statistics

Statistic	$\tilde{\sigma}_{N_t, Y_t}$	$\tilde{\sigma}_{w_t, Y_t}$	$\tilde{\rho}_{N_t, Y_t}$	$\tilde{\rho}_{w_t, Y_t}$	$\tilde{\rho}_{w_t, N_t}$
Benchmark	0.39	-0.66	1.66	-2.43	-5.76
$\eta_1 = 0$	0.01	0.53	0.37	-1.15	-5.36
$\eta_1 = 0.1$	5.11	-2.57	6.19	-0.87	-0.87
$\eta_2 = 0.85$	-0.03	-0.53	0.74	-0.14	-0.48
$\eta_2 = 0.95$	0.66	-1.53	1.72	0.03	0.30
$\xi = 0$	2.66	-5.30	3.90	-3.60	-2.74
$n = 0.25$	3.39	-2.91	2.83	-0.03	8.04
$\gamma = 0.25$	-0.14	-0.57	0.79	2.29	12.02
$h = 0.4$	1.02	-0.73	2.07	-3.46	-7.31
$\psi = 0.75$	-0.10	0.13	0.14	0.65	4.27
No spillover	4.53	-5.72	3.35	10.15	5.86
Complete	2.65	-2.70	2.33	-2.51	-10.43

Note: The statistic  $\tilde{\sigma}_{N_t, Y_t}$  denotes the relative difference between the standard deviation of employment relative to the standard deviation of output under capital mobility and financial autarchy. The statistic  $\tilde{\sigma}_{w_t, Y_t}$  denotes the relative difference between the standard deviation of the real wage relative to the standard deviation of output under capital mobility and financial autarchy. The statistic  $\tilde{\rho}_{N_t, Y_t}$  denotes the relative difference between the coefficient of correlation between employment and output under capital mobility and financial autarchy. The statistic  $\tilde{\rho}_{w_t, Y_t}$  denotes the relative difference between the coefficient of correlation between the real wage and output under capital mobility and financial autarchy. The statistic  $\tilde{\rho}_{w_t, N_t}$  denotes the relative difference between the coefficient of correlation between the real wage and employment under capital mobility and financial autarchy. The row entitled No spillover gives the respective statistics for a comparison of a model featuring no spillover effects of technology shocks. The row entitled Complete gives the respective statistics for a comparison of a model featuring complete international asset markets with a model featuring financial autarchy.

half of the relative differences have a negative sign. Moreover, the simulation results do not change much when I assume complete international asset markets rather than trade in integrated financial markets for riskless one-period nominal bond. Taken together, my simulation results indicate that my model implies that capital mobility affects the propagation of shocks, but capital mobility per se is unlikely to be a major source of labor market volatility.

### 4.3 Conclusions

I have extended a two-country dynamic general equilibrium model to incorporate fair wages. I have used my model to analyze the implications of capital mobility for labor market volatility. My results suggest that capital mobility, in the form of international trade in financial assets, is unlikely to give rise to a significant increase in labor market volatility.

In future research, my analysis could be extended to explore the implications of other efficiency-wage theories (Danthine and Donaldson 1990) or other labor market frictions like, for example, labor market search (Hairault 2002) for the link between capital mobility and labor market performance in open-economy dynamic general equilibrium models. In addition, it would be interesting to analyze the implications for the link between capital mobility and labor market volatility of other structures of international financial market than the ones I have considered in this chapter. For example, Kehoe and Perri (2002) have developed a model with endogenous incomplete international financial markets. In their model, international loans are imperfectly enforceable because countries can renege on their debt and suffer the consequences for future borrowing.

Finally, it is important to note that I have not considered in my analysis that capital mobility may affect unskilled workers in a different way than skilled workers. Mukoyama and Sahin (2006) have argued that, under incomplete markets, the costs of business cycles may be higher for unskilled workers than for skilled workers. In a similar vein, Krusell and Smith (1999) have pointed out that the cost of business cycles may be high for unemployed agents with no wealth and no opportunity to insure against unemployment risk. A reasonable hypothesis for future research, therefore, is that differences in wealth across skilled and unskilled workers give rise to differences with regard to their access to international financial markets and, in consequence, their ability to benefit from international risk sharing.

I hope that the results I have reported in this chapter will set the stage for further fruitful analysis of the interaction between frictions in international financial markets and labor market frictions.

## Chapter 5

# Fair Wages, Financial Market Integration, & the Fiscal Multiplier

An important research question in international macroeconomics is how and to which extent the recent increase in financial market integration affects the propagation of macroeconomic policies in an open economy.<sup>1</sup> With regard to fiscal policy, conventional wisdom based on the basic textbook version of the by-now classic models of Fleming (1962) and Mundell (1963) suggests that the fiscal multiplier should become substantially smaller as financial markets become more integrated. The fiscal multiplier measures the accumulated effect of fiscal policy on output. The textbook version of the Mundell-Fleming model implies that an expansionary fiscal policy triggers capital inflows which, in turn, give rise to an exchange-rate induced crowding-out effect. Financial market integration reinforces the crowding-out effect and, as a result, the fiscal multiplier should become smaller.

The Mundell-Fleming model was, for a long time, the standard model for analyzing the implications of macroeconomic policies in an open economy. In recent years, however, it has been largely replaced by the type of “new-open-economy macroeconomic” (NOEM) models developed by Obstfeld and Rogoff (1995). NOEM models are macroeconomic dynamic general equilibrium models with a solid microeconomic foundation. Their microeconomic foundation renders it possible to take into account the intertemporal budget constraint and the dynamic optimization of the private sector when analyzing the propagation of fiscal policy in an open economy. Recently, Sutherland (1996) and Senay (1998) have used variants of the prototype NOEM model

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<sup>1</sup>Part of the material presented here is published in Çenesiz and Pierdzioch (2008).

developed by Obstfeld and Rogoff (1995) to argue that financial market integration should diminish the output effect of fiscal policy.

In contrast to the textbook Mundell-Fleming model, most of the NOEM models that have been analyzed in the recent literature are built on the assumption that the labor market can be described in Walrasian terms. In a Walrasian labor market, wages adjust rapidly, households are always on their labor supply schedule, and structural unemployment is absent. As a consequence, these models have problems to account for the stylized facts of real-world labor markets. For example, they cannot account for the fact that in many economies, and at almost any time, many households are unemployed. Moreover, these models cannot explain the empirically observed low correlation between real wages and employment, the high variability of employment relative to that of real wages, and the low procyclicality of real wages.

I extend the NOEM model developed by Obstfeld and Rogoff (1995) to incorporate a non-Walrasian labor market. To this end, I follow Collard and de la Croix (2000) and Danthine and Kurmann (2004) in resorting to the fair wage theory tracing back to the research of Akerlof (1982). According to the “gift exchange” theory of wages, workers dislike effort. They are, however, willing to provide effort beyond some reference level of effort (the gift of workers) if they feel that their firm treats them well. In order to motivate workers to provide a higher level of effort, firms respond to the behavior of workers by offering a wage above the Walrasian market-clearing wage (the gift of the firm). Thus, the assumption that wages are set according to fair-wage considerations implies that the optimizing behavior of workers and firms results in structural unemployment.

My results implies that that adding the assumption of fair wages to an otherwise standard NOEM model has substantial implications for the effect of financial market integration on the fiscal multiplier in an open economy. In line with the results of recent research by Dellas et al. (2005), my fair-wage model implies that financial market integration should increase the fiscal multiplier. This implication of my model is in contrast to the implications of the NOEM models used by Sutherland (1996) and Senay (1998). It is also in contrast to the conventional wisdom derived from the basic textbook version of the Mundell-Fleming model. The implication of my model, however, is in line with extensions of the Mundell-Fleming model that feature real-wage rigidities (Sachs 1980). In order to derive the implications of my fair-wage model, I lay out in Section 5.1 the structure of my NOEM model. I report in Section 5.2 the results of numerical simulations of my model. I report



the results of some robustness checks in Section 5.3. I offer some concluding remarks in Section 5.4.

## 5.1 The Model

The world consists of two countries of equal size. Each country is populated by a continuum of infinitely lived utility-maximizing households. Households form rational expectations. Firms produce differentiated traded goods that are sold in a monopolistically competitive goods market. The only production factor is labor. There are no transaction costs for transporting goods across countries. With households' preferences being the same across countries, these assumptions imply that both the law of one price and purchasing power parity hold.

### 5.1.1 Households

Households are large in the sense that they consist of a large number of household members of total measure unity. Because of fair wages, some members of households are unemployed, while the others are employed. This implies that households' members are identical *ex ante*, but not *ex post*. As in Alexopoulos (2004) and Danthine and Kurmann (2004), however, households are identical both *ex ante* and *ex post* because employment is randomly allocated across workers, and the proportion of unemployed household members is the same across households. Households make all intertemporal decisions, and redistribute consumption equally among their members.

Households have preferences over consumption, real balances, and effort. In my fair-wage model, households do not have preferences over leisure, implying that each household would like to spend all its time for working. Thus, each household inelastically supplies one unit of time for work. The representative household maximizes the following intertemporal utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{(C_t^j)^{1-\sigma^{-1}} - 1}{1 - \sigma^{-1}} + \frac{\chi}{1 - \sigma_m} \left( \frac{M_t^j}{P_t} \right)^{1-\sigma_m} - N_t^j \mathcal{G}(e_t^j) \right], \quad (5.1)$$

with  $j$  being the household index and  $0 < \beta < 1$ ,  $\sigma > 0$ ,  $\chi > 0$ , and  $\sigma_m > 0$ .  $E_t$  denotes the conditional expectations operator,  $N_t$  denotes the proportion of household members working,  $\mathcal{G}(e_t)$  denotes the disutility of effort,  $M_t/P_t$  denotes real money holdings, and  $C_t$  denotes a real consumption index. The real consumption index,  $C_t$ , is defined as the usual constant-elasticity-of-substitution index of domestic-produced and foreign-produced differentiated

goods  $c_t(z)$ ,  $z \in [0, 1]$ , where the elasticity of substitution is given by  $\theta$ . The consumer price index,  $P_t$ , is defined as the minimum expenditure required to buy one unit of  $C_t$ . The optimal consumption allocation is given by  $c_t(z) = [p_t(z)/P_t]^{-\theta} C_t$ , where  $p_t(z)$  denotes the home-currency price of good  $z$ . The law of one price implies  $p_t(z) = p_t^*(z)S_t$ , where  $S_t$  denotes the nominal exchange rate and an asterisk denotes a foreign variable. Purchasing power parity implies  $P_t = P_t^* S_t$ .

The disutility households derive from effort is determined by an effort function. In order to specify the effort function, I follow Danthine and Kurmann (2004). The effort function is given by

$$\mathcal{G}(e_t^j) = [e_t^j - (\phi_0 + \phi_1 \log w_t^j + \phi_2 \log N_t + \phi_3 \log w_t + \phi_4 \log w_{t-1}^j)]^2, \quad (5.2)$$

where  $\phi_1 > 1$ ,  $\phi_2 < 0$ ,  $\phi_3 < 0$ , and  $\phi_4 < 0$ . According to equation 5.2, households determine the level of effort they would like to provide by resorting to some reference level of effort. The reference level of effort is an increasing function of the individual households' current real wage,  $w_t^j$ . Thus, if a firm pays a higher real wage, it can motivate households to work harder. The reference level of effort is a decreasing function of the aggregate level of employment,  $N_t$ . When the aggregate level of employment is high, individual households realize that, if they lose their job because they provide a low level of effort, the probability of finding a new job is relatively high. The reference level of effort is a decreasing function of the aggregate real wage,  $w_t$ . If, for a given real wage received by a household, the aggregate real wage increases, individual households' relative compensation decreases. As a consequence, households perceive this to be unfair, and decrease the level of effort they provide. Finally, as in Collard and de la Croix (2000), and in line with Akerlof (1982), the reference level of effort is a decreasing function of an individual households' past wage,  $w_{t-1}^j$ . This is in line with the results of empirical research that pay-cuts hurt morale, and that changes in real wages from one period to the next are an important determinant of effort (Bewley 1998).

### 5.1.2 Financial Markets

The total income received by households consists of the yield on their holdings of bonds, the profit income yielded by their ownership of domestic firms (i.e., dividend income), and their labor income. Given their total income, households determine their optimal consumption and decide on their preferred holdings in bonds. The individual households' budget constraint is

given by

$$D_t^j = R_{t-1}D_{t-1}^j + M_{t-1}^j - M_t^j + w_t^j N_t^j P_t - C_t^j P_t + \Phi_t^j P_t + T_t P_t, \quad (5.3)$$

where  $D_t$  denotes the quantity of domestic nominal riskless one-period bonds,  $R_t$  denotes the gross nominal interest rate,  $T_t$  denotes real lump-sum transfers received from the government, and  $\Phi_t^j$  denotes the profit income the household receives from domestic firms.

Given the budget constraint, households maximize their intertemporal utility function with respect to consumption, money demand, holdings in bonds, and effort. The first-order conditions that describe the solution to an individual households' utility-maximization problem are given by

$$(C_t^j)^{-1/\sigma} = \lambda_t P_t, \quad (5.4)$$

$$\chi \left( \frac{M_t^j}{P_t} \right)^{-\sigma_m} = \lambda_t P_t - \beta P_t E_t \lambda_{t+1}, \quad (5.5)$$

$$\lambda_t = \beta R_t E_t \lambda_{t+1}, \quad (5.6)$$

$$e_t^j = \phi_0 + \phi_1 \log w_t^j + \phi_2 \log N_t + \phi_3 \log w_t + \phi_4 \log w_{t-1}^j, \quad (5.7)$$

where  $\lambda_t$  denotes the Lagrange multiplier on the households' budget constraint.

In order to study the implications of financial market integration for macroeconomic dynamics, consider two cases: the case of a world economy in which agents can trade in integrated financial markets for riskless one-period nominal bonds, and the case of a world economy in which markets for trade in international assets do not exist. The latter case of a world economy consisting of financially autarchic countries has been studied by Cole and Obstfeld (1991) and Heathcote and Perri (2002). In the case of financial autarchy, households can only trade the bonds of the country in which they reside. In the case of integrated financial markets, the condition of uncovered interest rate parity holds and the market-clearing condition for the integrated international bond market is given by

$$\int_j D_t^j dj + \int_j D_t^{j*} dj = 0. \quad (5.8)$$

The market-clearing conditions in the case of financial autarchy are given by

$$\int_j D_t^j dj = 0 \quad (5.9)$$

and

$$\int_j F_t^{j*} dj = 0 \quad (5.10)$$

where  $F_t^{j*}$  denotes the foreign-currency denominated bond.

### 5.1.3 Firms

The production function of firms is given by  $y(z) = A_t e_t(z) N_t(z)$ , where  $y_t(z)$  denotes the output of firm  $z$ , and  $A_t$  denotes an aggregate productivity shock. Given the level of effort provided by households, firms set the real wage and choose the level of employment in order to minimize total production costs. Firms minimize  $w_t(z) N_t(z)$  subject to the production function and households' effort function. Following Danthine and Kurmann (2004), I assume that firms replace the individual households past wage,  $w_{t-1}^j$ , with the aggregate past wage  $w_{t-1}$  in the effort function when minimizing total production costs. Because firms treat  $w_t$  as exogenous when minimizing total production costs, this assumption implies that they do not account for the consequences of offering a higher wage today for the future effort of households. The technical reason for invoking this assumption is that otherwise firms would have to solve a dynamic wage-setting problem. To this end, they would have to store information on the distribution of past wages of their employees. An economic reason to justify this assumption is that, in a symmetric equilibrium, all firms will pay identical wages. Moreover, Collard and de la Croix (2000) have found that a model in which the effort function features  $w_{t-1}$  empirically performs better than a model in which the effort function features  $w_{t-1}^j$  as an argument. Using  $w_{t-1}$  in the effort function, the first-order conditions for a firms' cost-minimization problem are given by

$$w_t(z) = mc_t(z) \frac{y_t(z)}{N_t(z)}, \quad (5.11)$$

$$N_t(z) = mc_t(z) \frac{y_t(z)}{e_t(z)} \frac{\phi_1}{w_t(z)}. \quad (5.12)$$

where  $mc_t$  denotes the real marginal cost of production. The first-order conditions imply  $e_t(z) = \phi_1$ , a condition known as the Solow (1979) condition.

Because of monopolistic competition in the goods market, firms can set the price of the good they produce. When setting the price, they must take into account the demand curve  $y_t(z) = (p_t(z)/P_t)^{-\theta} Q_t$ , where  $Q_t$  denotes

the total world demand. Denoting government spending by  $G_t$ , the total world demand can be expressed by  $Q_t = 1/2(C_t + C_t^* + G_t + G_t^*)$ . As in Calvo (1983), firms can change in every period the price with probability  $0 < 1 - \gamma < 1$ . Therefore, firms set the price so as to maximize the expected present discounted value of real profits. Letting  $R_{t,s}$  denote the relevant discount factor, profit maximization implies

$$p_t(z) = \frac{\theta}{\theta - 1} \frac{E_t \sum_{s=t}^{\infty} \gamma^{s-t} R_{t,s} (Q_s / P_s^{-\theta}) m c_s(z)}{E_t \sum_{s=t}^{\infty} \gamma^{s-t} R_{t,s} (Q_s / P_s^{1-\theta})}. \quad (5.13)$$

### 5.1.4 The Government Sector

The government sector consists of a single central bank and a fiscal authority. The budget constraint of the fiscal authority is given by

$$P_t G_t = M_t - M_{t-1} - P_t T_t. \quad (5.14)$$

### 5.1.5 Solution and Calibration of the Model

I log-linearized my model around a symmetric flexible-price steady state in which bond holdings and government spending in the domestic and foreign country are zero. I then simulated the calibrated model using the algorithm developed by Klein (2000) and McCallum (1998, 2001). The calibrated parameter values are summarized in Table 5.1. I calibrate the model to match quarterly data.

**Table 5.1:** *Calibrated Parameters*

Discount factor:	$\beta = 0.99$
Intertemporal elasticity Substitution:	$\sigma = 0.75$
Semi elasticity of money demand:	$\sigma_m = 9$
Elasticity of real wage w.r.t.	
a)employment:	$\eta_1 \equiv -\phi_2 / (\phi_1 + \phi_3) = 0.05$
b)past real wage:	$\eta_2 \equiv -\phi_4 / (\phi_1 + \phi_3) = 0.85$
Demand elasticity:	$\theta = 6$
Reset probability:	$1 - \gamma = 0.5$

My calibration of the model is rather standard. I assume  $\beta = 0.99$ , implying an annual real interest rate of approximately 4.1 percent. I also assume

$\theta = 6$ , which implies a steady-state markup of prices over marginal costs of 20 percent. I calibrate the Calvo-pricing parameter such that the average delay between price adjustments is two periods ( $\gamma = 0.5$ ). Furthermore, I assume  $\sigma = 0.75$  and  $\sigma_m = 9$ . My calibration of these parameters follows the calibration used by other authors who have analyzed variants of the model developed by Obstfeld and Rogoff (1995) to study the link between financial market integration and macroeconomic dynamics (Sutherland 1996, Senay 1998).

In order to calibrate the parameters of the effort function, I first derived the fair-wage function. The fair-wage function obtains when the Solow condition is used in the effort function. Apart from a constant, the fair-wage function, in a symmetric equilibrium, is given by

$$\log w_t = \eta_1 \log N_t + \eta_2 \log w_{t-1}, \quad (5.15)$$

where  $\eta_1 = -\phi_2/(\phi_1 + \phi_3)$  and  $\eta_2 = -\phi_4/(\phi_1 + \phi_3)$ . Using the two-stage least squares estimation technique described in detail in Danthine and Kurmann (2004), I estimated the parameters,  $\eta_1$  and  $\eta_2$ , of the fair-wage function in order to get an impression of their magnitude, and to inspect how these parameters differ across countries. To this end, I collected quarterly data from the International Financial Statistics CD-Rom published by the IMF on employment, wages, and the GDP deflator for Germany, Japan, and the United States. I used data for the sample period 1991:1 to 2004:4. In the case of Germany, I estimated  $\eta_1 = 0.05$  and  $\eta_2 = 0.75$ , in the case of Japan I estimated  $\eta_1 = 0.02$  and  $\eta_2 = 0.90$ , and in the case of the United States I estimated  $\eta_1 = 0.06$  and  $\eta_2 = 0.90$ .

Of course, my estimation results are only indicative. Using data for a longer sample period, and implementing a more sophisticated estimation technique would certainly yield more precise estimates of the parameters of the fair-wage function. Yet, my estimates provide a rough idea of the likely magnitude of the parameters of the fair-wage function. Given my estimation results, I assume  $\eta_1 = 0.05$  and  $\eta_2 = 0.85$  for the numerical simulation of my model. However, in order to assess the robustness of my results, I shall present in Section 5.3 simulation results that I obtain when I use alternative numerical values for the parameters of the fair-wage function to calibrate my model.

## 5.2 Simulation Results

In order to analyze how fair wages and financial market integration affect the propagation of fiscal policy and the fiscal multiplier, I computed impulse response functions. The impulse response functions I shall report describe the dynamics of key macroeconomic variables in the aftermath of a permanent unit shock to government spending. Thus, as in the classic Mundell-Fleming model, I measure fiscal policy in terms of changes in government spending. With respect to the cross-country correlation of shocks, following Sutherland (1996), Senay (1998), and Pierdzioch (2004), I assume a perfect negative correlation of shocks across countries, i.e., I assume that the domestic (foreign) country is hit by a positive (negative) unit shock. Assuming a perfect negative correlation of shocks across countries has the advantage that the impulse response functions in the foreign country are a mirror image of the impulse response functions in the domestic country. The impulse response functions for the domestic country, therefore, fully describe the macroeconomic dynamics in my two-country model.

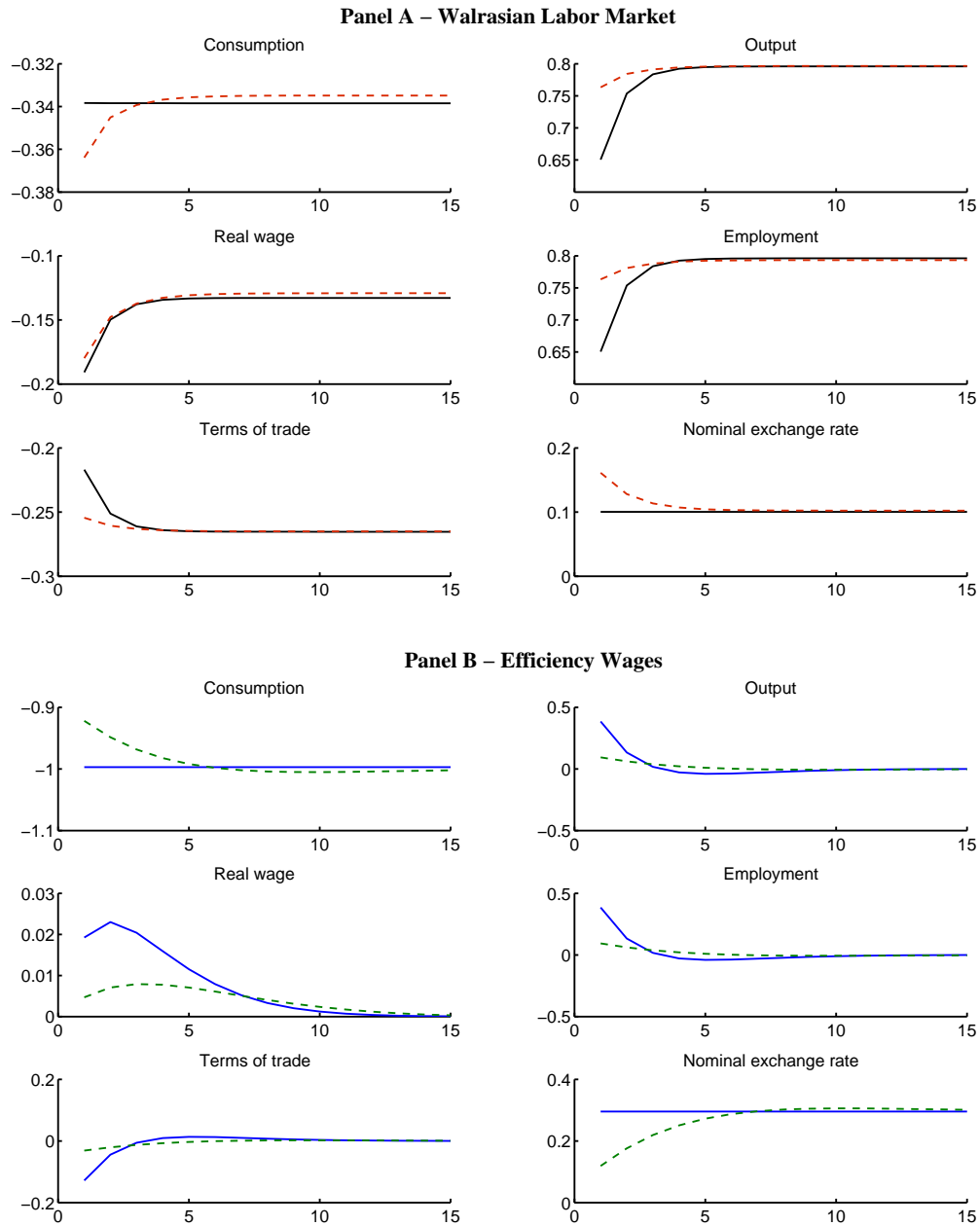
I computed impulse response functions for (1) the case of a Walrasian labor market and financial market integration, (2) the case of fair wages and financial market integration, (3) the case of a Walrasian labor market and financial autarchy, and, (4) the case of fair wages and financial autarchy. In order to compute the impulse response functions for the model featuring a Walrasian labor market, I assume that households' intertemporal utility function is given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{(C_t^j)^{1-\sigma^{-1}} - 1}{1 - \sigma^{-1}} + \frac{\chi}{1 - \sigma_m} \left( \frac{M_t^j}{P_t} \right)^{1-\sigma_m} - \frac{(N_t^j)^{1+\phi}}{1 + \phi} \right]. \quad (5.16)$$

Equation (5.16) implies that households' effort function given in equation (5.7) must be replaced in the case of a Walrasian labor market by the first-order condition  $(N_t^j)^\phi = w_t^j \lambda_t P_t$ . Utility functions similar to the one given in equation (5.16) are standard in the literature building on the seminal work of Obstfeld and Rogoff (1995). Following Sutherland (1996) and Senay (1998), I set  $\phi = 0.4$ .

The impulse response functions shown in Figure 5.1 summarize the simulation results. Panel A shows the impulse response functions for the model featuring a Walrasian labor market. Panel B shows the impulse response functions for the model featuring fair wages. The solid (dashed) impulse response functions represent the case of financial market integration (financial autarchy). Before focusing on the details of Figure 5.1, a short note on

Figure 5.1: Fiscal Policy, Fair Wages, and Financial Market Integration



Note: The figure plots the responses of domestic variables to a unit asymmetric permanent shock to government spending. The horizontal axis measures quarters. The vertical axis measures logarithmic/percentage deviations from the steady state. The solid responses represent the case of financial market integration. The dashed responses represent the case of financial autarchy.



my analysis of the effects of financial market integration on fiscal multiplier will be convenient because it is an analysis of the change (from autarchy to integration) in the change (stems from fiscal shock) in a variable, and, thus, can be seemingly cumbersome. Note that the steady-state effects of fiscal policy implied by the model featuring a Walrasian labor market differ from the steady state effects implied by the model featuring fair wages. For this reason, I do not directly compare the fiscal multipliers across the models with different labor market structures. What I directly compare is the fiscal multipliers across the models with different financial market structures in which the steady state effects of fiscal policy are the same. Then, under the implicit assumption that the structure of labor market does not change with the change in the structure of financial markets, I compare the change (from autarchy to integration) in the fiscal multipliers across the models with different labor market structures.

In the model featuring a Walrasian labor market (Panel A), the assumed asymmetric nature of fiscal policy implies that an increase in government spending does not change the level of aggregate demand. However, an increase in government spending implies that the domestic fiscal authority must cut transfers in order to keep the government budget balanced. For households, the lower transfers are equivalent to a higher tax bill. Because households seek to smooth consumption over time, they try to dampen the effect of the higher tax bill on their budget by reducing their holdings in bonds. For the bond market equilibrium to hold under financial autarchy, the real interest rate must increase, implying that the short-run fall in consumption exceeds the long-run fall in consumption. The fall in consumption results in a lower demand for domestic currency, giving rise to a nominal depreciation of the exchange rate. The exchange rate is given by  $\hat{S}_t = \hat{M}_t - \hat{M}_t^* - (\hat{C}_t - \hat{C}_t^*)/(\sigma\sigma_m) + \beta(\hat{R}_t - \hat{R}_t^*)/\sigma_m$ , where a hat over a variable denotes percentage deviations from the steady state. Because the prices of differentiated goods adjust sluggishly, the depreciation of the nominal exchange rate improves the terms of trade. The terms of trade are defined as  $\hat{x}_t = \hat{q}_t - \hat{q}_t^* - \hat{S}_t$ , where  $\hat{q}_t$  and  $\hat{q}_t^*$  are indexes of the prices of domestic-produced and foreign-produced differentiated goods. For the domestic economy, I define  $\hat{q}_t = (1 - \gamma) \sum_{s=0}^{\infty} \gamma^s \hat{p}_{t-s}(j)$ . The movement in the terms of trade results in an expenditure switching effect. As a result, the demand-determined output increases. The increase in output is accompanied by an increase in employment, requiring a drop in the real wage.

Under financial market integration, fiscal policy does not change the real interest rate, implying that consumption instantaneously falls to its new

long-run steady-state level. The fall in consumption under financial market integration is smaller in the short run than the fall in consumption under financial autarchy. In consequence, households enjoy a smoother intertemporal consumption path under financial market integration than under financial autarchy. Because financial market integration dampens the effect of fiscal policy on consumption, the depreciation of the nominal exchange rate under financial market integration is smaller than the depreciation under financial autarchy. As a result, financial market integration cushions the effect of fiscal policy on the terms of trade and on output. For example, the fiscal multiplier for output over 15 quarters, i.e. the area under the output response, decreases by 16% when one moves from financial autarchy to integrated financial markets. In other words, as in the basic textbook version of the Mundell-Fleming model and in the models developed by Sutherland (1996) and Senay (1998), the fiscal multiplier under financial market integration is smaller than the fiscal multiplier under financial autarchy in the model featuring a Walrasian labor market.

Panel B of Figure 5.1 shows the impulse response functions for the model featuring fair wages. As in the model featuring a Walrasian labor market, fiscal policy brings about a depreciation of the nominal exchange rate, an improvement in the terms of trade, and an increase in output and employment. In contrast to the model featuring a Walrasian labor market, however, the increase in employment, in line with the fair-wage function, precipitates an increase in the real wage. According to the Solow condition, the real wage must increase to keep the level of effort provided by workers constant. Because the lagged real wage enters into the fair-wage function, the real wage increases gradually. In line with the results of empirical research, the impulse response functions show that my model implies that the correlation between the real wage and employment is low. Similarly, the variability of employment relative to that of the real wage is large.

Although the real wage adjusts sluggishly, the fact that fiscal policy results in an increase in the real wage implies that marginal costs and, therefore, goods prices increase sharper than in the model featuring a Walrasian labor market. As a result, the real interest rate temporarily decreases under financial autarchy in the model featuring fair wages. The decrease in the real interest rate implies that the fall in consumption triggered by fiscal policy is smaller in the short run than in the long run. For bond market equilibrium to hold under financial autarchy, the magnitude of the fall in consumption must be larger in the model featuring fair wages than in the model featuring a Walrasian labor market.

As in the model featuring a Walrasian labor market, financial market integration implies that (asymmetric) fiscal policy leaves the real interest rate unaffected. In contrast to the model featuring a Walrasian labor market, however, the short-run fall in consumption under financial market integration exceeds the short-run fall in consumption under financial autarchy. The result is a sharp depreciation of the nominal exchange rate and a corresponding large movement in the terms of trade, employment, and output. Because the fair-wage function implies a sluggish adjustment of the real wage, the increase in employment is accompanied by a moderate increase in the real wage. The increase in the real wage under financial market integration exceeds the increase in the real wage under financial autarchy. The movement in the terms of trade, however, shows that the inflationary effect of the increase in the real wage on marginal costs is not large enough to compensate the expenditure switching effect brought about by the improvement in the terms of trade. Thus, the assumption of fair wages gives rise to a reversal in the effects of financial market integration on the fiscal multiplier. For example, the fiscal multiplier for output over 15 quarters increases by 15% (cf. 16% decrease in the model featuring a Walrasian labor market) when one moves from financial autarchy to integrated financial markets. In other words, financial market integration results in an increase in the fiscal multiplier in the model featuring fair wages.

### 5.3 Robustness Checks

In order to check the robustness of my results, I computed, for various calibrations and specifications of my model, the absolute value of the accumulated responses of key macroeconomic variables to a fiscal policy shock. I did this for the version of my model that operates under financial market integration and the version that operates under financial autarchy. Finally, I computed the relative fiscal multiplier,  $RFM$ , defined as

$$RFM(\hat{x}_t, i) = \frac{|\sum_{t=0}^i \hat{x}_{t, integration}|}{|\sum_{t=0}^i \hat{x}_{t, autarchy}|}, \quad (5.17)$$

where  $\hat{x}$  denotes the macroeconomic variable being analyzed and  $i$  denotes the horizon at which the relative fiscal multiplier is analyzed. I consider horizons of one quarter, one year, and two years. Thus, I set  $i \in \{1, 4, 8\}$ . If  $RFM > 1$ , then the fiscal multiplier is larger under financial market integration than under financial autarchy, et vice versa.

Table 5.2 summarizes the results. As a first robustness check, I compare the results for the benchmark calibration given in Table 5.1 with the results for a model featuring a Walrasian labor market. In order to simulate the model featuring a Walrasian labor market, I assume that households' intertemporal utility function is given by equation (5.16). In the benchmark model, the relative fiscal multiplier is larger than one, implying that financial market integration results in an increase rather than a decrease in the fiscal multiplier. The relative fiscal multipliers with regard to consumption, employment, and the nominal exchange rate are also larger than one. In contrast, in the model featuring a Walrasian labor market, the relative fiscal multipliers with regard to output, consumption, employment, and the nominal exchange rate are smaller than one. This result illustrates the conventional wisdom that the fiscal multiplier is smaller under financial market integration than under financial autarchy.

Because the case of  $\phi = 0.4$  may be too restrictive, I also computed the relative fiscal multiplier for a model featuring a Walrasian labor market in which this parameter assumes the value  $\phi = 1$ . This value has been used by, for example, Gali and Monacelli (2005) and Bergin (2006). The results show that the relative fiscal multipliers with regard to output, consumption, employment, and the nominal exchange rate are smaller than one. The results also illustrate that in the model featuring a Walrasian labor market the relative fiscal multipliers are increasing in the parameter  $\phi$ . When this parameter becomes large, the relative fiscal multipliers obtain values close to unity.

As a second robustness check, I report the results I obtain when I change the parameters of the fair-wage function to  $\eta_1 = 0.1$  and  $\eta_2 = 0.99$ . In order to analyze the implications of changes in the degree to which goods prices are sticky, I also report results for  $\gamma = 0.75$  and  $\gamma = 0.25$ . As in the case of the benchmark calibration, the relative fiscal multipliers are larger than one.

As a third robustness check, I assume that households have a home-product bias in preferences (Warnock 2003). This assumption formalizes the idea that households prefer to consume home-produced goods over foreign-produced goods for a given vector of relative prices. A home-product bias in preferences implies that fiscal policy can trigger changes in the real exchange rate and, thus, deviations from purchasing power parity. I build a home-product bias into households' preferences by assuming that the home consumption index,  $C_t$ , is defined over consumption goods produced in the

Table 5.2: Results of Robustness Checks

	Consumption	Output	Employment	Exchange Rate
Benchmark calibration				
1 quarter	1.0815	4.1089	4.1089	2.4839
1 year	1.0437	2.3652	2.3654	1.5450
2 years	1.0203	1.7239	1.7240	1.2287
Model featuring a Walrasian labor market ( $\phi = 0.4$ )				
1 quarter	0.9297	0.8521	0.8523	0.6219
1 year	0.9773	0.9511	0.9544	0.7873
2 years	0.9932	0.9754	0.9792	0.8704
Model featuring a Walrasian labor market ( $\phi = 1$ )				
1 quarter	0.9886	0.9705	0.9705	0.9146
1 year	0.9956	0.9923	0.9923	0.9645
2 years	0.9979	0.9963	0.9963	0.9817
Benchmark model with $\eta_1 = 0.1$				
1 quarter	1.0755	4.0185	4.0198	2.3282
1 year	1.0358	2.0210	2.0246	1.4309
2 years	1.0141	1.4952	1.5026	1.1596
Benchmark model with $\eta_2 = 0.99$				
1 quarter	1.0787	4.3246	4.3247	2.5207
1 year	1.0399	2.3736	2.3743	1.5373
2 years	1.0150	1.2945	1.2958	1.1996
Benchmark model with $\gamma = 0.75$				
1 quarter	1.1093	4.7093	4.7092	3.3370
1 year	1.0830	3.3566	3.3896	2.1787
2 years	1.0556	2.3283	2.3657	1.6238
Benchmark model with $\gamma = 0.25$				
1 quarter	1.0553	2.8580	2.8570	1.7763
1 year	1.0196	1.5689	1.5605	1.2096
2 years	1.0068	1.5390	1.5144	1.0759
Benchmark model with home-product bias, $\alpha = 1.8$				
1 quarter	1.0426	2.5497	2.5498	3.5282
1 year	1.0361	1.7895	1.7948	1.8361
2 years	1.0208	1.3059	1.3149	1.3161
Benchmark model with habit formation $h = 0.6$				
1 quarter	1.0044	1.0948	1.0948	1.0781
1 year	0.9990	1.1253	1.1261	1.0371
2 years	0.9930	0.9997	1.0018	0.9744
Benchmark model with $\mu_1 = 0, \mu_2 = -0.5, \mu_3 = -1.0$				
1 quarter	1.0734	3.7083	3.7080	2.3647
1 year	1.0415	2.5282	2.5242	1.6069
2 years	1.0194	1.7304	1.7244	1.2505
Benchmark model with $\mu_1 = 0, \mu_2 = -1.0, \mu_3 = -1.0$				
1 quarter	1.0727	3.5276	3.5263	2.3286
1 year	1.0418	2.7020	2.6990	1.6632
2 years	1.0193	1.7464	1.7417	1.2642
Benchmark model with $\mu_1 = 0, \mu_2 = 0, \mu_3 = -0.5$				
1 quarter	1.0741	3.8500	3.8709	2.3925
1 year	1.0411	2.3331	2.3566	1.5577
2 years	1.0196	1.6237	1.6552	1.2391
Blanchard-Gali real-wage rigidity ( $\rho_w = 0.9$ )				
1 quarter	0.7585	0.4822	0.4822	0.3221
1 year	0.7719	0.6486	0.6472	0.3247
2 years	0.8368	0.789	0.7872	0.4098
Blanchard-Gali real-wage rigidity ( $\rho_w = 0.999$ )				
1 quarter	0.7763	1.7450	1.7451	1.2117
1 year	0.7464	1.1522	1.1523	0.7982
2 years	0.7297	0.9023	0.9024	0.6417

Note: In order to produce the results summarized in this table, I computed the relative fiscal multiplier as defined in equation (5.17).

home country,  $c_t(z)$ , and in the foreign country,  $c_t^*(z)$ , as follows:

$$C_t = \left[ \int_0^1 \alpha^{1/\theta} c_t(z)^{(\theta-1)/\theta} dz + \int_0^1 (2-\alpha)^{1/\theta} (c_t^*(z))^{(\theta-1)/\theta} dz \right]^{\frac{\theta}{\theta-1}}, \quad (5.18)$$

where  $\alpha \in (0, 2)$ . If  $\alpha \in (1, 2)$ , then households have a bias for domestically produced goods. If  $\alpha = 1$ , then households' preferences do not feature a home-product bias. If  $\alpha \in (0, 1)$ , then households prefer to consume goods produced abroad over goods produced at home for a given vector of relative prices. Equation (5.18) implies that the price index and the demand curve are given by

$$P_t = \left[ \int_0^{1/2} \alpha p_t(z)^{1-\theta} dz + \int_{1/2}^1 (2-\alpha) (p_t^*(z))^{1-\theta} dz \right]^{\frac{1}{1-\theta}}, \quad (5.19)$$

$$y_t(z) = \alpha \left( \frac{p_t(z)}{P_t} \right)^{-\theta} \left( \frac{C_t + G_t}{2} \right) + (2-\alpha) \left( \frac{p_t(z)}{S_t P_t^*} \right)^{-\theta} \left( \frac{C_t^* + G_t^*}{2} \right). \quad (5.20)$$

I report in Table 5.2 the results for the case  $\alpha = 1.8$ . As in the benchmark model, the relative fiscal multipliers for output, consumption, employment, and the nominal exchange rate are larger than one.

As a forth robustness check, I extend my model to incorporate (internal) habit formation in consumption. Habit formation in consumption implies a smoother adjustment of consumption to a shock because households' utility depends on both the level of consumption and the rate of change of consumption. With habit formation in consumption, the consumption part of a households' intertemporal utility function is given by  $(1-\sigma^{-1})^{-1} (C_t^j)^{1-\sigma^{-1}} (C_{t-1}^j)^{-h(1-\sigma^{-1})}$ , where  $h$  is the so-called habit-formation parameter. Under habit formation, equation 5.4 is replaced by (dropping the household index)

$$(C_t^j)^{-\sigma^{-1}} (C_{t-1}^j)^{-h(1-\sigma^{-1})} - \beta h (C_t^j)^{-h(1-\sigma^{-1})-1} E_t (C_{t+1}^j)^{1-\sigma^{-1}} = \lambda_t P_t. \quad (5.21)$$

Drawing on the estimates of Smets and Wouters (2003) and Christiano et al. (2005), I assume  $h = 0.6$  when simulating a model featuring habit formation in consumption. Habit formation in consumption reduces the relative fiscal multipliers, implying that the fiscal multipliers for output, consumption, employment, and the nominal exchange rate under financial market integration are closer to those obtained under financial autarchy. I do not report but mention that when the habit formation parameter becomes very large, I obtain the standard Mundell-Fleming result that the fiscal multiplier with

regard to output is smaller under financial market integration than under financial autarchy. Thus, assuming habit formation in combination with fair wages can have important implications with regard to the implications of financial market integration for the propagation of fiscal policy in an open economy.

As a fifth robustness check, I extend my model to incorporate a monetary policy rule. I assume that the monetary policy conducted by the domestic central bank can be described in terms of the following monetary policy rule:

$$\hat{M}_t = \mu_1 \hat{M}_{t-1} + \mu_2 \Delta \hat{y}_t + \mu_3 \Delta \hat{P}_t \quad (5.22)$$

where  $\Delta$  denotes the first-difference operator. A similar monetary policy rule applies in the case of the foreign central bank. As compared to the Taylor-style interest-rate targeting rules often discussed in the literature (Taylor 1993), the monetary policy rule given in equation (5.22) has the advantage that it nests the monetary policy rules used by Sutherland (1996) and Senay (1998) to study the implications of financial market integration for macroeconomic dynamics. Their monetary policy rule obtains when I assume  $\mu_1 \in [0, 1]$  and  $\mu_2 = \mu_3 = 0$ . Moreover, Pierdzioch (2004) has used a similar monetary policy rule to analyze how interactions between monetary and fiscal policy change the implications of financial market integration for the fiscal multiplier in an open economy. Thus, it is straightforward to compare my results with the results reported in the recent literature.

I report results for three monetary policy rules. With regard to the first monetary policy rule, I assume  $\mu_1 = 0$ ,  $\mu_2 = -0.5$ , and  $\mu_3 = -1$ . Thus, in this first case, the central bank reacts to both a rise in inflation and a rise in the rate of output growth. Because the central bank responds to variations in changes in output rather than to variations in the level of output, the central bank conducts what Walsh (2003) has called a 'speed limit' policy. With regard to the second monetary policy rule, I assume  $\mu_1 = 0$  and  $\mu_2 = \mu_3 = -0.5$ . In this second case, the central bank targets nominal income (McCallum and Nelson 1999). With regard to the third monetary policy rule, I assume  $\mu_1 = \mu_2 = 0$  and  $\mu_3 = -1$ . In this third case, the central bank adopts a strategy of a strict inflation response. In all three cases, the relative fiscal multiplier is larger than one. When I use other values for the parameters of my monetary policy rule, I obtain results similar to those reported in Table 5.2.

As a sixth and final robustness check, I replace my fair-wage function given in equation (5.15) with the wage-setting model that has recently been

proposed by Blanchard and Gali (2007). Their wage-setting model is a partial adjustment model that explains the dynamics of the real wage in terms of an arithmetic average of the lagged real wage and the Walrasian real wage. The wage-setting model is given by  $\log w_t = \rho_w \log w_{t-1} + (1 - \rho_w) \log mrs_t$ , where  $mrs_t$  denotes the marginal rate of substitution between labor and consumption. Equation 5.16 implies  $mrs_t = N_t^\phi C_t^{1/\sigma}$ . The real wage, thus, depends on the lagged real wage and employment and, in addition, on consumption. The fair-wage function given in equation (5.15), in contrast, implies that the real wage depends on the lagged real wage and employment.

The results suggest that the weighting parameter,  $\rho_w$ , plays an important role for the relative fiscal multiplier. If the weighting parameter assumes the value  $\rho_w = 0.9$ , the relative fiscal multiplier is smaller than one, as in the model featuring a Walrasian labor market. If, in contrast, the weighting parameter assumes the value  $\rho_w = 0.999$ , the relative fiscal multiplier exceeds one, as in the benchmark fair-wage model. The economic intuition for this result is that, as witnessed by the impulse response functions shown in Figure 5.1, fiscal policy triggers a large response of consumption. The large response of consumption, in turn, results in a rapid adjustment of the real wage. Because the adjustment of the real wage is not sluggish enough in the model proposed by Blanchard and Gali (2007), the implications of their model with regard to the relative fiscal multiplier resemble the implications of a model featuring a Walrasian labor market.

## 5.4 Conclusions

Before general policy-relevant conclusions and empirically testable hypotheses can be derived from the type of analysis I have undertaken in this chapter, much more research on the link between the structure of labor markets, financial market integration, and the fiscal multiplier needs to be done. For example, I have reported results for the relatively simple two-country Obstfeld-Rogoff model. Their model has been extended in a number of dimensions to account for the stylized facts of international business cycles. Betts and Devereux (2000) have extended the model to incorporate pricing-to-market of firms, and Ganelli (2003) has extended the model to incorporate useful government spending. It would be interesting to analyze in future research how these extensions of the Obstfeld-Rogoff model interact with fair wages in shaping the changes in the fiscal multiplier that occur in the wake of financial market integration.



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It is also important to note that I have focused in my analysis on one specific labor-market rigidity: the fair-wage theory. Other efficiency-wage theories have been analyzed in the literature (Danthine and Donaldson 1990). Exploring in future research the implications of other efficiency-wage theories for the link between financial market integration and the fiscal multiplier is likely to yield significant insights. Finally, other forms of labor-market frictions than efficiency wages may have interesting implications for the way financial market integration affects the fiscal multiplier in NOEM models. For example, in the recent literature, theories of labor-market search have received considerable attention. Hairault (2002) and Walsh (2005) have analyzed the business-cycle implications of such theories in dynamic general equilibrium models. The analysis of the potentially complex links between search frictions in the labor market, financial market integration, and the fiscal multiplier is a challenging task that awaits future research.

# Chapter 6

## Fair Wages & Fair Prices in an Open Economy

In this chapter, I develop a two country dynamic stochastic general equilibrium model to study the implications of fair wages and fair prices, the properties of which have been detailed in the previous chapters. Particularly, I embed the closed economy model of Chapter 3 to a two country framework. This allows me to answer the question whether and, if so, to which extent the results reported in Chapter 3 hold if international goods and capital transactions are taken into account. It also allows me to analyze the implications of fair wages and fair prices for the international transmission of shocks and for international asset prices (the real exchange rate).

The open economy structure of my model is akin to those recently developed by Chari et al. (2002) and Steinsson (2008). Specifically, open economy components of my model that are absent in the standard new open economy macroeconomic model of Obstfeld and Rogoff (1995) are as follows. The model features a home-product bias in preferences (Warnock 2003). This assumption formalizes the puzzling feature of data that households prefer to consume home-produced goods over foreign-produced goods (Obstfeld and Rogoff 2000a). The model further features pricing-to-market (Krugman 1987). Under pricing-to-market, firms can tailor the prices to specific local demand conditions, i.e., firms can engage in third degree price discrimination. Finally the model features local-currency pricing (Devereux 1997). Under local-currency pricing, exporters' prices are denominated in the local currency of buyers.<sup>1</sup> These assumptions allow for deviations from the purchasing power parity condition and, thus, for fluctuations of the real ex-

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<sup>1</sup>See Obstfeld and Rogoff (2000b) for a review of pricing-to-market and local-currency pricing approaches.

change rate.

I find that the propagation of monetary and technology shocks in my open economy model is quite similar to that in the closed economy model of Chapter 3. My results also show that the model is capable of generating a response of the real exchange rate to a technology shock that exhibits a hump shaped pattern. This result confirms the findings of Steinsson (2008). I also find that consumption and the real exchange rate dynamics significantly change by restricting the households' access to international asset markets. This results contradicts the findings of previous research (Baxter and Crucini 1995, Kollmann 1996, and Schmitt-Grohè and Uribe 2003).

I organize the remainder of this chapter as follows. I set up my model in Section 6.1. The setup is rather minimalistic because it combines the main features of the closed economy model of Chapter 3 with above described features (home-bias, pricing-to-market, local-currency pricing). In Section 6.2, I report the results of numerical simulations of my model. In Section 6.3, I offer some concluding remarks.

## 6.1 The Model

The world consists of two countries of equal size. Each country is populated by a continuum of infinitely lived utility-maximizing households. Households are internationally immobile. Households form rational expectations, and they consume, trade in complete international financial markets, hold money, own firms, and supply labor. Households' preferences are biased in favor of home goods. Firms sell their differentiated consumption goods in a monopolistically competitive goods market. Firms set the prices of their goods in the currency of their customers, i.e. firms practice local-currency-pricing. Moreover, firms has the exclusive right to sell their goods in the two countries. Consequently, international differences in goods prices are not possible to arbitrage away even though there are no transaction costs for transporting goods across countries. Thus, firms can price-discriminate across the countries, i.e., firms can price-to-market.

### 6.1.1 Households

Households are large in the sense that they consist of a large number of workers of total measure unity. As a consequence of efficiency wage, some members of households are unemployed. But because each household pools

consumption, and distributes employment randomly across its members, and because the fraction of employed household members is the same across households, I can abstract from distributional issues. Thus, I can analyze the model by studying the decisions taken by a representative household. The representative household maximizes the following utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ \log(C_t^j - hC_{t-1}^j) + \frac{\chi}{1 - \sigma_m} \left( \frac{M_t^j}{P_t} \right)^{1 - \sigma_m} - N_t^j \mathcal{G}(e_t^j) \right], \quad (6.1)$$

with  $j$  being the domestic-household index,  $j \in [0, 1]$ , and  $0 < \beta < 1$ ,  $\chi > 0$ , and  $\sigma_m > 0$ .  $E_t$  denotes the conditional expectations operator,  $N_t$  denotes the proportion of household members working,  $\mathcal{G}(e_t)$  denotes the disutility of effort,  $M_t/P_t$  denotes real money holdings, and  $C_t$  denotes a real consumption index. The disutility households derive from effort is determined by an effort function:

$$\mathcal{G}(e_t^j) = [e_t^j - (\phi_0 + \phi_1 \log w_t^j + \phi_2 \log N_t + \phi_3 \log w_t + \phi_4 \log w_{t-1}^j)]^2, \quad (6.2)$$

where  $w_t$  denotes the real wage rate and  $\phi_1 > 1$ ,  $\phi_2 < 0$ ,  $\phi_3 < 0$ , and  $\phi_4 < 0$ .

The period-by-period budget constraint is given by

$$\frac{E_t \Lambda_{t,t+1} B_{t+1}^j + M_t^j}{P_t} + C_t^j = \frac{B_t^j + M_{t-1}^j + T_t^j}{P_t} + w_t^j N_t^j + \Phi_t^j, \quad (6.3)$$

where  $B_t^j$  denotes the state contingent payoff on household  $j$ 's financial portfolio, and  $\Lambda_{t,t+1}$  denotes a stochastic discount factor that prices  $B_{t+1}^j$ ,  $P_t$  denotes the consumer price index,  $T_t^j$  is the lump-sum transfers from the monetary authority, and  $\Phi_t^j$  is the sum of the household's real profit income. To rule out Ponzi schemes, I assume that there exists a borrowing limit for households.

The first-order conditions associated with domestic households' utility-maximization problem are given by

$$(C_t^j - hC_{t-1}^j)^{-1} - h\beta (E_t C_{t+1}^j - hC_t^j)^{-1} = \lambda_t, \quad (6.4)$$

$$\chi \left( \frac{M_t^j}{P_t} \right)^{-\sigma_m} = \lambda_t - \beta E_t \left[ \frac{\lambda_{t+1}}{\pi_{t+1}} \right], \quad (6.5)$$

$$e_t^j = \phi_0 + \phi_1 \log w_t^j + \phi_2 \log N_t + \phi_3 \log w_t + \phi_4 \log w_{t-1}^j, \quad (6.6)$$

$$\Lambda_{t,t+i} = \beta^i \left[ \frac{\lambda_{t+i} P_t}{\lambda_t P_{t+i}} \right], \quad (6.7)$$

where  $\pi_t = P_t/P_{t-1}$ . A standard transversality condition holds as well.

Using a no-arbitrage argument, the (gross) nominal interests rate can be expressed by

$$R_t = \frac{1}{E_t \Lambda_{t,t+1}}. \quad (6.8)$$

To derive an equation that describes the real exchange rate, it will be convenient addressing the foreign households' problem partially. The period-by-period budget constraint that a foreign household faces is given by

$$\frac{E_t \Lambda_{t,t+1} B_{t+1}^{j*}}{S_t P_t^*} + \frac{M_t^{j*}}{P_t^*} + C_t^{j*} = \frac{B_t^{j*}}{S_t P_t^*} + \frac{M_{t-1}^{j*} + T_t^{j*}}{P_t^*} + w_t^{j*} N_t^{j*} + \Phi_t^{j*}, \quad (6.9)$$

with  $j^*$  being the foreign household index,  $j^* \in (1, 2]$ .<sup>2</sup>  $B_{t+1}^{j*}$  denotes the payoff on foreign household  $j^*$ 's financial portfolio consisting of domestic currency denominated state contingent assets, and  $S_t$  denotes the nominal exchange rate defined as the price of one unit of foreign currency in terms domestic currency. Maximizing the foreign counterpart of (6.1) with respect to  $B_{t+1}^{j*}$  gives then the first order condition:

$$\Lambda_{t,t+i} \frac{S_{t+i}}{S_t} = \beta^i \left[ \frac{\lambda_{t+i}^* P_t^*}{\lambda_t^* P_{t+i}^*} \right]. \quad (6.10)$$

Let  $r_t$  denote the real exchange rate defined as  $r_t = S_t P_t^*/P_t$ . Then, combining equations (6.7) and (6.10) accordingly and iterating the result backwards to  $t = 0$ , I obtain

$$r_t = r_0 \frac{\lambda_0 \lambda_t^*}{\lambda_0^* \lambda_t}. \quad (6.11)$$

Hence, complete financial markets assumption implies that the real exchange rate is given by the ratio of marginal utilities.

### 6.1.2 Indexes of Goods and Prices

A continuum of domestic firms indexed by  $z \in [0, 1]$  and a continuum of foreign firms indexed by  $v \in (1, 2]$  operate in the international goods market. Consumption preferences of domestic households are described by the

<sup>2</sup>For notational convenience, I use an asterisk to denote the foreign counterpart of a variable.

following composite consumption index of domestic and foreign bundles of goods:

$$C_t = \left[ \chi_H^{1/\eta} C_{H,t}^{\frac{\eta-1}{\eta}} + \chi_F^{1/\eta} C_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \quad (6.12)$$

where  $\eta > 0$  is the elasticity of substitution between home and foreign goods, and  $\chi_H > 0$  and  $\chi_F > 0$  are the preference parameters capturing the bias for home and foreign goods, with  $\chi_H + \chi_F = 1$ . Notice that  $\chi_H > \chi_F$  implies domestic households' preferences are biased towards home goods. Home and foreign goods indexes are defined as the standard constant-elasticity-of-substitution indexes:

$$C_{H,t} = \left[ \int_0^1 c_t(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}} \quad (6.13)$$

and

$$C_{F,t} = \left[ \int_1^2 c_t(v)^{\frac{\theta-1}{\theta}} dv \right]^{\frac{\theta}{\theta-1}}, \quad (6.14)$$

where  $\theta > 0$  denotes the elasticity of substitution among differentiated goods, and  $c_t(i)$  denotes the consumption goods produced by firm  $i$ . Expenditure minimization by domestic and foreign households implies that the domestic demand and the foreign demand for good  $z$  is given, respectively, by

$$c_t(z) = \left[ \frac{P_t(z)}{P_{H,t}} \right]^{-\theta} \left[ \frac{P_{H,t}}{P_t} \right]^{-\eta} \chi_H C_t, \quad (6.15)$$

and

$$c_t^*(z) = \left[ \frac{P_t^*(z)}{P_{H,t}^*} \right]^{-\theta} \left[ \frac{P_{H,t}^*}{P_t^*} \right]^{-\eta} \chi_H^* C_t^*, \quad (6.16)$$

where  $P_t(z)$  denotes the domestic price of good  $z$ , and  $P_t^*(z)$  denotes the foreign price of good  $z$ . The latter is denominated in foreign currency. Expenditure minimization by domestic and foreign households also implies that the consumer price indexes are given by

$$P_t = \left[ \chi_H P_{H,t}^{1-\eta} + \chi_F P_{F,t}^{1-\eta} \right]^{\frac{1}{1-\eta}}, \quad (6.17)$$

and

$$P_t^* = \left[ \chi_H^* P_{H,t}^{*1-\eta} + \chi_F^* P_{F,t}^{*1-\eta} \right]^{\frac{1}{1-\eta}}. \quad (6.18)$$

The subindexes  $P_{H,t}$ ,  $P_{H,t}^*$ ,  $P_{F,t}$ , and  $P_{F,t}^*$  are defined accordingly as:

$$P_{H,t} = \left[ \int_0^1 P_t(z)^{1-\theta} dz \right]^{\frac{1}{1-\theta}}, \quad P_{H,t}^* = \left[ \int_0^1 P_t^*(z)^{1-\theta} dz \right]^{\frac{1}{1-\theta}},$$

$$P_{F,t} = \left[ \int_1^2 P_t(v)^{1-\theta} dv \right]^{\frac{1}{1-\theta}}, \quad \text{and} \quad P_{F,t}^* = \left[ \int_1^2 P_t^*(v)^{1-\theta} dv \right]^{\frac{1}{1-\theta}}.$$

### 6.1.3 Firms

To simplify the profit maximization problem of firms suppose that each firm consists of a production unit and a pricing unit. The production technology of firm  $z$  is given by  $y_t(z) = A_t e_t(z) N_t(z)$ , where  $y_t(z)$  denotes the world demand for good  $z$ , and  $A_t$  denotes an aggregate technology shock to productivity. The production unit minimizes the cost of production,  $w_t(z) N_t(z)$ , subject to the constraints (i) that effort level of the workers should sustain the norm (equation 6.6), and (ii) that the production should keep up with the demand ( $y_t(z) \leq A_t e_t(z) N_t(z)$ ).<sup>3</sup> Optimal choices of the labor demand and the real wage rate by the production unit of firm  $z$  imply that Solow (1979) condition,  $e_t(z) = \phi_1$ , holds, and

$$w_t(z) = mc_t(z) \frac{y_t(z)}{N_t(z)}, \quad (6.19)$$

where  $mc_t(z)$  denotes the real marginal cost of production.

To maximize the profit of the firm, the pricing unit of firm  $z$  chooses the prices they charge in the domestic market,  $P_t(z)$ , and in the foreign market,  $P_t^*(z)$ . As in Rotemberg (2005), the pricing unit can change the domestic price in every period with probability  $0 < 1 - \gamma_{H,t} < 1$  and the foreign price in every period with  $0 < 1 - \gamma_{H,t}^* < 1$ . In denotation of these probabilities, I use country indexes because these probabilities depend on the states of the corresponding economies. As the price cannot be adjusted in each period, the maximization problem of the pricing unit is not a static but a dynamic one. Let  $rp_{H,t}$  denote the optimally chosen relative domestic price of good  $z$ ,  $rp_{H,t}^*$  denote the optimally chosen relative foreign price good  $z$ , and  $\Gamma_{H,t,t+i}$  be defined as  $\Gamma_{H,t,t+i} \equiv \prod_{l=1}^i \gamma_{H,t+l}$ , with  $\Gamma_{H,t,t} \equiv 1$ . Then, optimal choices of the domestic and foreign prices by the pricing unit of firm  $z$  imply the following first order conditions:<sup>4</sup>

$$rp_{H,t} = \frac{\theta}{\theta - 1} \frac{E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \Gamma_{H,t,t+i} (P_{t+i}/P_t)^{1+\eta} (P_{H,t+i}/P_t)^{\theta-\eta} C_{t+i} mc_{t+i}}{E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \Gamma_{H,t,t+i} (P_{t+i}/P_t)^{\eta} (P_{H,t+i}/P_t)^{\theta-\eta} C_{t+i}}, \quad (6.20)$$

$$rp_{H,t}^* = \frac{\theta}{\theta - 1} \frac{E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \Gamma_{H,t,t+i}^* (P_{t+i}^*/P_t^*)^{1+\eta} (P_{H,t+i}^*/P_t^*)^{\theta-\eta} C_{t+i}^* mc_{t+i}}{E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \Gamma_{H,t,t+i}^* (P_{t+i}^*/P_t^*)^{\eta} (P_{H,t+i}^*/P_t^*)^{\theta-\eta} C_{t+i}^* r_{t+i}}.$$

<sup>3</sup>In equation (6.6), following Danthine and Kurmann (2004), I replaced  $w_{t-1}(z)$  with  $w_{t-1}$ .

<sup>4</sup>By deriving the optimal price equations, I assume that each firm maximizes its value in the currency of the economy it belongs to.

$$(6.21)$$

Following Rotemberg (2005), the probabilities that a pricing unit of a domestic firm cannot change the prices are given by

$$\log \gamma_{H,t} = \omega_{rp} \log rp_{H,t} + \omega_{\pi} \log \pi_{t-1}, \quad (6.22)$$

and

$$\log \gamma_{H,t}^* = \omega_{rp} \log rp_{H,t}^* + \omega_{\pi} \log \pi_{t-1}^*, \quad (6.23)$$

with  $\omega_{rp} > 0$  and  $\omega_{\pi} < 0$ .

The law of motion of the technology shock is governed by

$$\log A_t = \rho_A \log A_{t-1} + \epsilon_t^A, \quad (6.24)$$

where  $\epsilon_t^A$  is a normally distributed mean zero shock. Notice that, in contrast to the technology shock process assumed in Chapter 4, equation (6.24) does not feature any spillover effects arising from an innovation in technology in the foreign country.

#### 6.1.4 The Monetary Authority

The monetary authority of each country finances lump-sum transfers by newly printed money. For the domestic country this relation is given by

$$\int_0^1 T_t^j dj = M_t - M_{t-1}, \quad (6.25)$$

where  $M_t$  is the money supply which grows at a gross rate of  $m_t$ , namely

$$M_t = m_t M_{t-1}. \quad (6.26)$$

The growth rate of money supply follows the following process:

$$\log m_t = \log \pi^{1-\rho_m} + \rho_m \log m_{t-1} + \epsilon_t^m, \quad (6.27)$$

where  $\epsilon_t^m$  is a normally distributed mean zero shock.



Table 6.1: *Calibrated Parameters*

Discount factor:	$\beta = 1.03^{-1/4}$
Semi elasticity of money demand:	$\sigma_m = 10.85$
Degree of habit formation;	$h = 0.62$
Elasticity of real wage w.r.t.	
a)employment:	$\eta_1 \equiv -\phi_2/(\phi_1 + \phi_3) = 0.03$
b)past real wage:	$\eta_2 \equiv -\phi_4/(\phi_1 + \phi_3) = 0.99$
Demand elasticity:	$\eta = \theta = 10$
Degree of home bias	$\chi_H = 0.94$
Steady-state value of reset probability:	$1 - \gamma = 0.25$
Steady-state value of gross inflation:	$\pi = 1.04^{1/4}$
Elasticity of $\gamma_t$ w.r.t.	
a)optimal relative price:	$\omega_{rp} = 1.5$
b)past inflation:	$\omega_\pi = -15$
Serial correlation of the money growth rate:	$\rho_m = 0.60$
Serial correlation of the technology process:	$\rho_A = 0.96$

### 6.1.5 Solution Method and the Calibration of the Model

As a result of assumed trend inflation in both countries, all nominal variables other than domestic and foreign nominal interest rates are nonstationary. Accordingly, they are normalized prior to solving the model. I solve the model by log-linearizing it around a steady state with trend inflation. I then use the numerical algorithm developed by Klein (2000) and McCallum (2001) to compute the equilibrium dynamics of the calibrated model. Calibration of the model is mainly the same as in Chapter 3. Parameters absent in Chapter 3 are  $\chi_H$  and  $\eta$ .<sup>5</sup> These two parameters are calibrated as in Steinsson (2008). I set  $\chi_H = 0.94$ , a value used also by Chari et al. (2002). I set  $\eta = \theta = 10$  implying a markup rate of 11%. The benchmark calibration of the model is summarized in Table 6.1.

## 6.2 Simulation Results

I present impulse response functions in order to analyze the dynamic properties of my model. I do not present business cycle statistics, i.e., second moments, mainly because the baseline model above is based on a small-scale macroeconomic model extended to feature two unorthodox specifications. It

<sup>5</sup>As  $\chi_H + \chi_F = 1$ , the value of  $\chi_F$  is implied by the value of  $\chi_H$ . Balanced trade requires  $\chi_H = \chi_F^*$ .

abstracts from many specifications that are important to account for business cycles dynamics of real economies, such as investment, variable capacity utilization, costly investment/capital adjustment, time-to-build technology, home production, different real shocks, just to name a few. Including such specifications, however, makes the model unnecessarily complicated to disentangle the specific roles played by fair price and wage setting mechanisms, and, thus, to evaluate their importance.<sup>6</sup> Moreover, economic intuition one gains from impulse response functions is to a great extent superior as they present the direct response to each type of shock (Gali 1999).

I report impulse response functions for the baseline model and for some of its variants. I opt for two groups of variants of the baseline model. The first group of variants is chosen in order to highlight and disentangle the joint implications of the wage and price setting mechanisms used in the baseline model. To this end, I consider a price setting mechanism formulated by Calvo (1983), and a Walrasian labor market. The second group of variants is chosen to examine the robustness of the implications of the baseline model across its three features: (i) Financial markets completeness, (ii) Description of monetary policy, and (iii) Real wage rigidity. To this end, I consider a model featuring incomplete financial markets, a model featuring a Taylor (1993) type interest rate rule, and a model featuring Blanchard and Gali (2007) type wage rigidity.

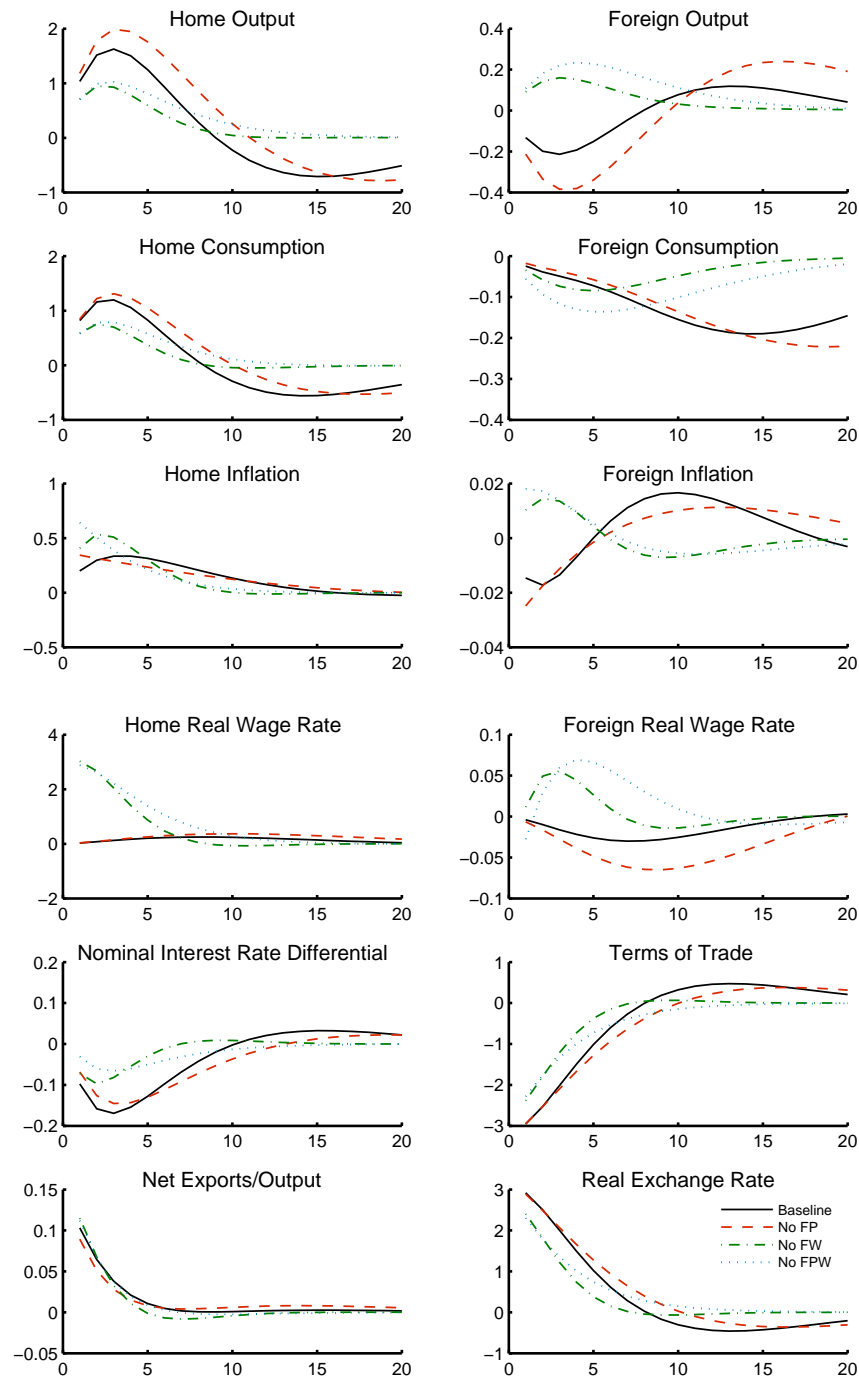
### 6.2.1 Interaction of Fair Prices and Fair Wages

#### Implications for a Nominal Shock

Figure 6.1 presents impulse response functions of the baseline model and its three variants for a domestic monetary shock. The first variant features Calvo-type price setting, and is obtained by setting  $\gamma_{I,t} = \gamma_{I,t}^* = \gamma$  for  $I = H, F$  and all  $t$ . The second variant features a Walrasian labor market, and is obtained by replacing equation (6.6) of the baseline model with  $N_t^j = w_t^j \lambda_t$ . The third variant features Calvo-type price setting and a Walrasian labor market. Because I shall refer to these variants repeatedly, I suggest using the following shorthand: No-fair-prices (No-FP; dashed line) for the first variant, no-fair-wages (No-FW; dot-dashed line) for the second variant and no-fair-prices/wages (No-FPW; dotted line) for the third variant.

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<sup>6</sup>In a separate work, I have extended the baseline model of this chapter to feature investment and investment related specifications. Main results reported in this section holds there as well.

Figure 6.1: *Impulse Response Functions for a Monetary Shock*

Note: The figure plots the responses of key macroeconomic aggregates to a unit standard deviation shock to the domestic money growth rate. The horizontal axis measures quarters. The vertical axis measures logarithmic/percentage deviations from the steady state.

The impulse response functions illustrate that qualitative effects of a monetary policy shock on domestic aggregates are the same under baseline model and its variants. A domestic monetary policy shock gives rise to depreciation of the real exchange rate, which, in turn, makes the current home consumption cheaper relative to future home consumption. Therefore, home consumption increases, and, analogously, foreign consumption decreases (See also the international nominal interest rate differential). But, because consumers have strong preferences for home goods, and because, as a result of pricing-to-market cum local-currency-pricing strategy of firms, immediate exchange-rate-pass-through is zero, the responses of foreign aggregates are quantitatively much smaller than that of domestic aggregates. As a result, given that prices are sticky, an expansion of domestic money supply triggers an expansion of aggregate world demand.

Comparing the impulse response functions for the models with different labor market structures (baseline model versus No-FW model and No-FP model versus No-FPW) reveals that fair wages amplifies the responses of domestic country aggregates, and causes reversals in the responses of foreign output, foreign inflation, and the foreign real wage rate. The reason for the amplification is that in the models featuring fair wages, the real wage rate hardly responds to a monetary expansion, while in the models with a Walrasian labor market, the biggest impact effect of monetary policy is on the domestic real wage rate. This implies that the scope of firms for expanding their production to meeting the increase in demand is much larger in the models featuring fair wage than in the models featuring a Walrasian labor market. This last point also explains the reversals in the responses of some foreign variables. In the models featuring a Walrasian labor market, the substantial initial increase of the domestic real wage rate brings about the increase in foreign output. Consistently, the foreign real wage rate and, thus, foreign inflation rise. In the models featuring fair wages, domestic firms expand their production to fully meet the increase in domestic demand, and foreign output decreases as foreign demand decreases. The decrease in foreign output drives down the foreign real wage rate and, thus, foreign inflation.

In contrast to fair wages, fair price has a dampening effect on the responses, and does not have a reversal effect. The main reason for this dampening effect is that the inflationary effect of the monetary shock on domestic country brings about an increase in the frequency of price adjustment because the customer resistance to price adjustments decreases in past inflation. With more frequently adjusted prices, we have a higher inflation response. As a result, the response of output is dampened. Fair prices affect also the

shape of the inflation response: Only in the models with fair prices, inflation responds with a delay to a monetary shock, and the delay exceeds by one quarter the delay in the output response.

The responses of the terms of trade and net exports are consistent to the response of the real exchange rate. The terms of trade,  $tot_t$ , are defined as the relative price of domestic imports in terms of domestic exports, namely:

$$P_{F,t}(S_t P_{H,t}^*)^{-1}$$

Net exports,  $nx_t$ , are defined as the ratio of nominal net exports to nominal output, namely:

$$\left( S_t \int_0^1 c_t^*(z) P_t^*(z) dz - \int_1^2 c_t(v) P_t(v) dv \right) \left( P_t \int_0^1 y_t(z) dz \right)^{-1}$$

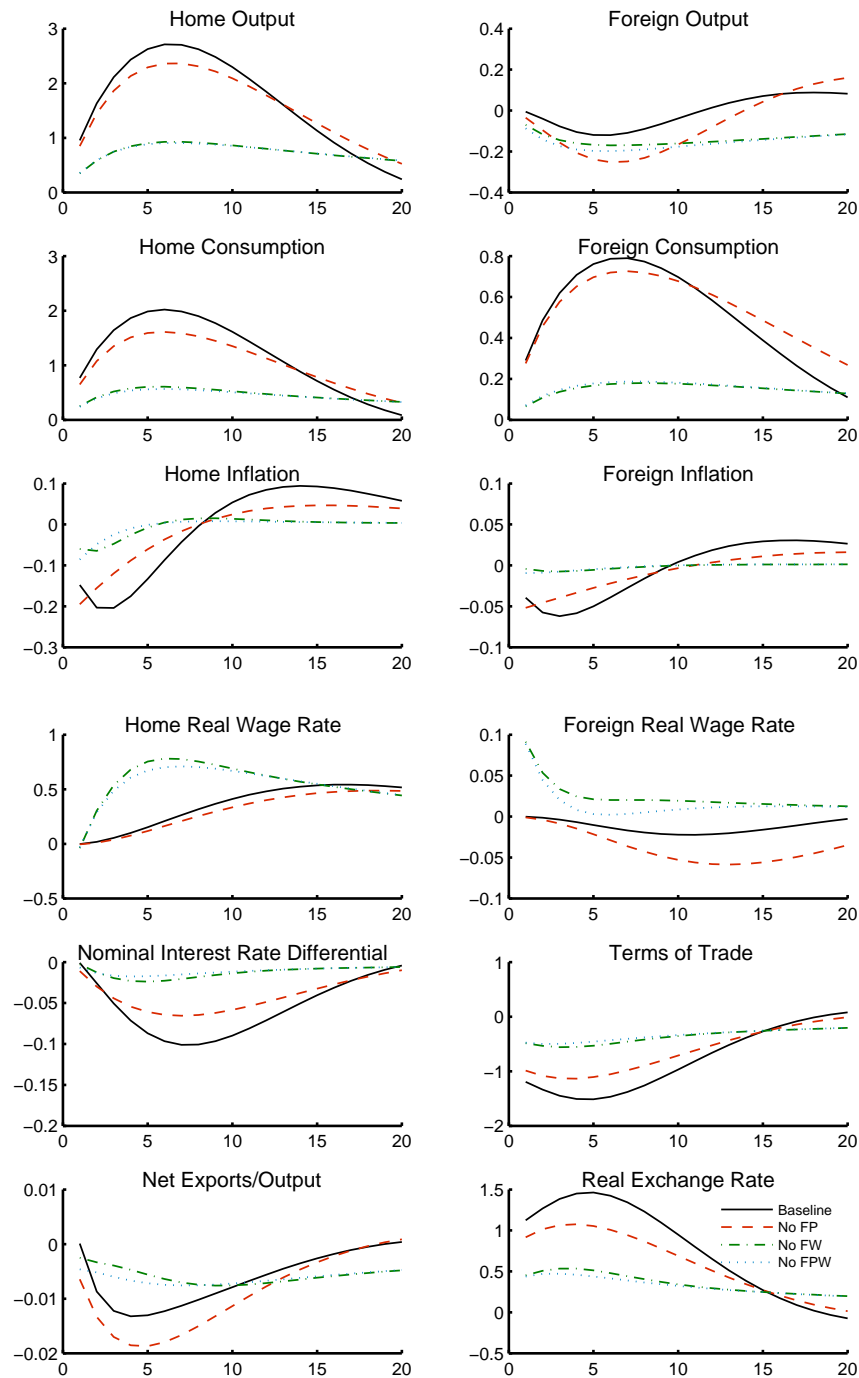
The real exchange rate is the main driving force behind the dynamics of these above defined two variables. The depreciation of the real exchange rate triggered by a monetary shock improves the terms of trade, to which net exports positively responds. The response of the real exchange to a monetary shock does not exhibit a hump shaped pattern, and neither do the responses of net exports and the terms of trade.

### Implications for a Real Shock

Figure 6.2 presents impulse response functions of the baseline model and its above mentioned three variants for a domestic technology shock. The impulse response functions illustrate that except for the inflation responses in the models featuring Calvo type price setting, the responses of all variables display hump shaped patterns. Especially regarding the real exchange rate dynamics, this is an attractive feature of the baseline model and its variants given the celebrated Dornbusch (1976) paper and since then growing literature on the delayed overshooting puzzle.

Specifically, three issues regarding the dynamics of the real exchange rate is empirically appealing in the baseline model: The persistence of the real exchange response, the volatility of the real exchange rate, and the delay in the peak of the real exchange rate response. In the baseline model, all these measures are higher than the other three variants. This result distinguishes the combination of the fair-price and fair-wage settings. The intuition behind this results is as in the case of a monetary shock, and what follows briefly explains this intuition.

Figure 6.2: Impulse Response Functions for a Technology Shock



Note: The figure plots the responses of key macroeconomic aggregates to a unit standard deviation shock to domestic technology. The horizontal axis measures quarters. The vertical axis measures logarithmic/percentage deviations from the steady state.

The fair-wage setting has a magnifying effect on the responses of all variables except the responses of the real wage rates. Note that in the models featuring the fair-wage setting, the domestic real wage rate reaches its peak after around three years, and during this three years, many variables revert to their mean. This implies that the extent to which a technology shock affect quantities and ratios other than the real wage rate is much higher in the models featuring the fair-wage setting than in the models with a Walrasian labor market because in the former models the real wage rate adjusts sluggishly. Furthermore, for the same reason, the fair-wage setting has also a delay-increasing-effect on the dynamics of macroeconomic aggregates.

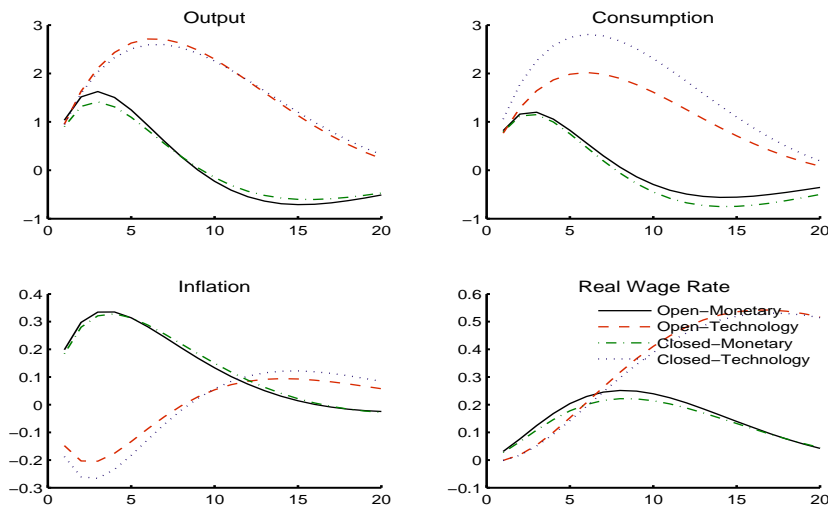
For a technology shock, fair prices amplifies the most of the responses of the aggregates. This is in stark contrast to the case of a monetary shock, but the factor behind this result is the same as for the dampening effect of fair prices in the case of a monetary shock: A domestic technology shock has disinflationary effects because with the increase in productivity the supply curve shifts rightwards, and for a given demand and for a given trend in prices, the rate of change of prices decreases. This disinflationary effect decreases the frequency of price adjustments, which, in turn, leads to a further decrease in inflation. For this reason, the extent to which firms can expand their production in response to a technology shock is larger in the models featuring fair prices than in the models featuring Calvo-type price setting.

### Closed versus Open

A striking aspect of what the impulse response functions for the home country variables (output, consumption, inflation, the real wage rate) illustrate is that they are qualitatively the same as those calculated in the closed economy model of Chapter 3. Furthermore, for these macroeconomic aggregates, quantitative differences between the impulse response functions calculated in Chapter 3 and those calculated in the present chapter are not significant. To visualize this point, Figure 6.3 presents the impulse response functions of both models sharing the same calibration. Only noticeable difference is that the consumption response for the open economy model to a technology shock is smoother than that for the closed economy model. But this results is not surprising as in the open economy model consumers have access to international asset markets. Thus, the implications of fair prices and fair wages for the propagation of monetary policy and technology shocks and the corresponding results that I reported in Chapter 3 do not change under

the assumptions of the present model that are related to the open economy setting.

**Figure 6.3:** *Closed Economy versus Open Economy*



*Note:* Solid (dot-dashed) lines represent the responses to a monetary shock in the open (closed) economy setup. Dashed (dotted) lines represent the responses to a technology shock in the open (closed) economy setup.

### 6.2.2 Financial Markets Completeness, Monetary Policy Instrument, and Real Wage Rigidity

I now turn to the second group of variants of the baseline model which I chose to study the robustness of the implications of the baseline model across its three features: (i) Financial markets completeness, (ii) Monetary policy instrument, and (iii) Real wage rigidity. Figure 6.4 compares the baseline model to these variants for a monetary shock (Panel A) and for a technology shock (Panel B).

#### Incomplete Financial Markets

Because the complete financial markets structure of the baseline model can be a too restrictive assumption, I replace it with an incomplete financial markets one. In this case, the budget constraints of the domestic and foreign households and the market-clearing condition for the international financial



market are given by

$$\frac{D_t^j}{P_t} + \frac{M_t^j}{P_t} + C_t^j = \frac{R_{t-1}D_{t-1}^j}{P_t} + \frac{M_{t-1}^j + T_t^j}{P_t} + w_t^j N_t^j + \Phi_t^j, \quad (6.28)$$

$$\frac{D_t^{j*}}{S_t P_t^*} + \frac{F_t^{j*}}{P_t^*} + \frac{M_t^{j*}}{P_t^*} + C_t^{j*} = \frac{R_{t-1}D_{t-1}^{j*}}{S_t P_t^*} + \frac{R_{t-1}^* F_{t-1}^{j*}}{P_t^*} + \frac{M_{t-1}^{j*} + T_t^{j*}}{P_t^*} + w_t^{j*} N_t^{j*} + \Phi_t^{j*}. \quad (6.29)$$

and

$$\int_j D_t^j dj + \int_j D_t^{j*} dj = 0, \quad (6.30)$$

where  $D_t$  ( $D_t^*$ ) denotes the domestic (foreign) households' holdings of bonds denominated in domestic currency, and  $F_t^*$  denotes the foreign households' holdings of bonds denominated in foreign currency. These equations imply that an international market for foreign currency denominated bonds does not exist.<sup>7</sup> First order conditions with respect to  $D_t$ ,  $D_t^*$ , and  $F_t^*$  imply, as a first order approximation, the standard uncovered interest rate parity (UIP) condition:  $\tilde{R}_t = \tilde{R}_t^* + E_t \tilde{S}_{t+1} - \tilde{S}_t$ , where a tilde over variable denotes its log-deviation from steady state. This standard form of UIP condition, however, cannot be used as an equilibrium condition since it results in instationarity. For this reason, following Schmitt-Grohé and Uribe (2003), I add a debt elastic risk premium to the UIP condition. To obtain the model with incomplete financial markets, I replace the log-linear version of equation (6.11) of the baseline model with

$$\tilde{R}_t = \tilde{R}_t^* + E_t \tilde{S}_{t+1} - \tilde{S}_t - \Psi \tilde{D}_t. \quad (6.31)$$

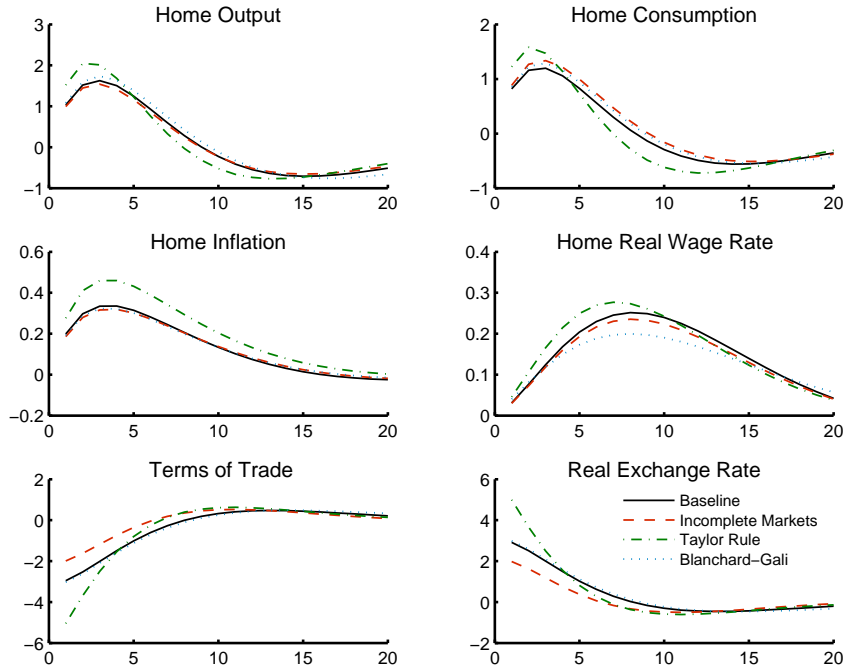
The motivating argument for adding the risk premium to the UIP condition is that to compensate for default risk of a large debt, households require a higher interest rate. For example, a negative  $\tilde{D}_t$  imply that the domestic economy has a net debtor position, and therefore the domestic households should pay higher interest rate on their debts. In contrast, a positive  $\tilde{D}_t$  imply that the domestic economy is in a net lender position, and therefore foreign households should pay higher interest rate on their debts. I set  $\Psi = 0.004$ , based on the empirical estimates reported by Bergin (2006).

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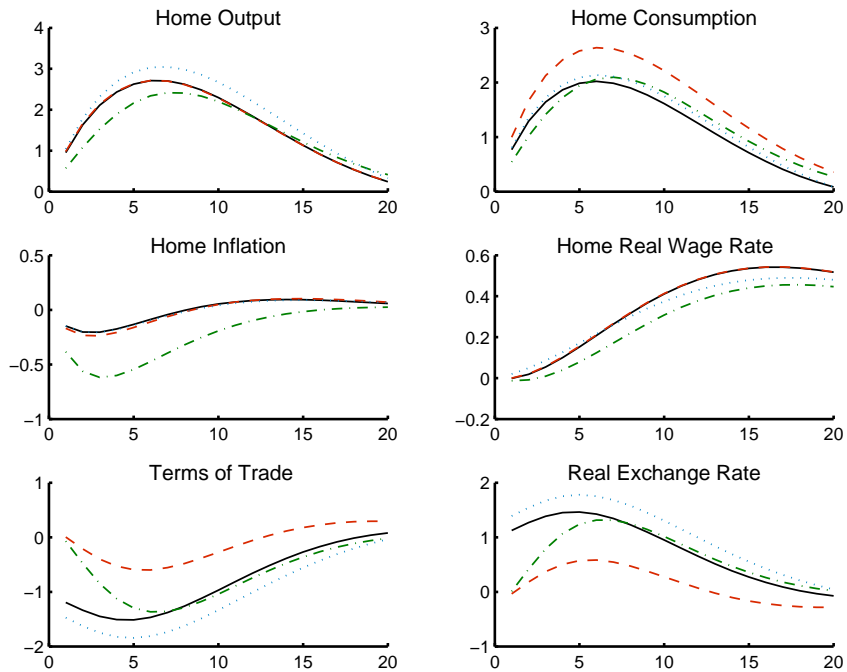
<sup>7</sup>An international market for foreign currency denominated bonds can easily be introduced to the model. I refrained from doing so because such a market would be redundant for equilibrium dynamics of the model.

Figure 6.4: Impulse Response Functions

Panel A - for a Monetary Shock



Panel B - for a Technology Shock



Panel A of Figure 6.4 illustrates that changing the structure of financial markets as above hardly affects the dynamics of the macroeconomic aggregates in the aftermath of a monetary shock. Incomplete financial markets specification (dashed line) slightly increases the response of consumption, and dampens the depreciation of the real exchange rate and the improvement of the terms of trade. The reason for this result is that a restriction on the trade of international financial assets lessens households' ability to smooth consumption by trading in international financial assets. As a result of the lessened ability to smooth consumption, a monetary shock has larger effect on consumption and smaller effect on prices of international financial assets (the real exchange rate). Same arguments hold also for the effects of a technology shock (responses are shown in Panel B), though the change in the responses of consumption, the real exchange rate and the terms trade with respect to the change in the structure of international financial market is of much larger magnitude for a technology shocks than for the a monetary shock. The magnitude of change in the response of consumption and the real exchange rate becomes smaller if one considers Calvo or Walrasian labor market variants of my model (both not shown).

### Taylor Rule

Because Taylor (1993) type interest rate rules can provide a more accurate description of monetary policy than the one I propose in Subsection 6.1.4, it will be convenient to contrast the implications of them. To this end, I assume that the monetary authority conducts its policy according to an interest rate rule given by

$$\log R_t = \rho_R \log R_{t-1} + (1 - \rho_R) (a \log \pi_t + b \log y_t) + \varepsilon_t^R, \quad (6.32)$$

where  $\varepsilon_t^R$  is a normally distributed mean zero shock. Based on the estimation results of Clarida et al. (2000), I set  $\rho = 0.9$ ,  $a = 2.15$ , and  $b = 0.15$ .

Panel A of Figure 6.4 illustrates that changing the description of monetary policy has in general small effects on the dynamics of macroeconomic aggregates in the aftermath of a monetary shock. With an interest rate rule (dot-dashed line) the inflation response becomes more persistent, and the impact effect of a monetary policy shock is larger on the all variables. The reason for the latter is that in the model featuring an interest rate rule, in the first quarter, international nominal interest rate differential (not shown in the figure) is 230 basis points while the same statistic is 10 basis points in the baseline model. Consequently, all other variables' responses are larger on impact. A larger impact effect on inflation increases the frequency of

price adjustment, and in turn, inflation increases further. Once again, same arguments hold also for the effects of a technology shock, but this time the international nominal interest rate differential is around 366 basis points in the model featuring an interest rate rule while it is zero in the baseline model. For this reason, we observe larger impact effects on the macroeconomic aggregates, which translates itself to a amplified response of inflation.<sup>8</sup> For a technology shock, an interesting implication of an interest rate rule is that the delay in the overshooting of the real exchange rate response is more pronounced.

### An Alternative Real Wage Rigidity

In a recent paper Blanchard and Gali (2007) propose a new wage setting model to account for the real wage rigidity. Their wage-setting model is a partial adjustment model that explains the dynamics of the real wage in terms of an arithmetic average of the lagged real wage and the Walrasian real wage. Specifically, their wage-setting model is given by

$$\log w_t = \rho_w \log w_{t-1} + (1 - \rho_w) \log mrs_t, \quad (6.33)$$

where  $mrs_t$  denotes the marginal rate of substitution between labor and consumption and given by  $mrs_t = N_t/\lambda_t$ . The real wage, thus, depends on the lagged real wage and employment and, in addition, on consumption (cf. equation 6.4). In the baseline model, in contrast, the real wage depends on the lagged real wage and employment. Recall that in a model featuring a Walrasian labor market real wage rate depends on employment and consumption. Thus, the model of Blanchard and Gali provides a combination of the fair-wage setting and Walrasian wage setting. To analyze the implications of this model, I replaced equation 6.6 of the baseline model with equation 6.33. Following the calibration of Blanchard and Gali, I set  $\rho_w = 0.9$ .

Panel A of Figure 6.4 illustrates that the model featuring the real wage rigidity of Blanchard and Gali (dotted line) generates virtually the same responses to a monetary shock as the baseline model (solid line). Only exception is the response of the real wage rate which is slightly muted in the former model. It appears from Panel B of Figure 6.4 that the effect of Blanchard and Gali consideration is mainly pronounced for the dynamics of exchange rate and the terms of trade as the responses of the variables are amplified. The responses of other variables are not affected significantly.

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<sup>8</sup>See Subsection 6.2.1 for a detailed explanation of the propagation of a technology shock in the baseline model.

## 6.3 Conclusions

From the analysis above, it appears that the results I report for the closed economy model of Chapter 3 do not change under the assumptions that are related to the open economy setting. Furthermore, even though my model is relatively small, the responses of macroeconomic aggregates to monetary and technology shocks match those implied by large scale open economy macroeconomic models (Erceg, Guerrieri, and Gust 2006). Another important finding of my analysis is that assuming complete or incomplete asset markets matters for consumption and the real exchange rate dynamics in the aftermath of a technology shock. This result contradicts the findings of previous research, (e.g., Baxter and Crucini 1995, Kollmann 1996, and Schmitt-Grohè and Uribe 2003), and does not hold if I remove fair price and/or fair wage specifications from my model.

This brief summary of my results presents a clear evidence that fair prices and fair wages have important implications also for open economy macroeconomics. Future research can employ other shocks (such as shocks to government spending, preferences, uncovered interest rate parity condition, oil price) to analyze the implications of fair prices and fair wages. Another possible extension is that incorporating fair prices and/or fair wages with endogenously incomplete asset markets to study their joint implications for international asset prices.

# Chapter 7

## Outlook on Future Research

What must be the general conclusion from the analyses I have undertaken in this dissertation? My results suggest that fair wages and fair prices may have profound and far-reaching implications. In Chapter 2, I have extended the model of Rotemberg (2005) such that the extended model implies a positive relationship between the nominal interest rate and the frequency of price adjustment, and this implication stems from the supply side effects of monetary policy. The extended model can account both for the persistence of the output response and for the muted and delayed inflation response to monetary policy shocks. In Chapter 3, I have shown that incorporating fair prices and fair wages can explain the dynamic relationship between output and inflation we observe in data. Further, in the aftermath of monetary policy shock, In Chapters 4 and 5, I have added fair wages to an otherwise standard two-country (New Keynesian) model to account for the stylized facts of real-world labor markets. My analysis induces that international trade in financial assets is unlikely to give rise to a significant increase in labor market volatility. Further, my results suggest that financial market integration should increase the output effect of fiscal policy. This last point contradicts the result derived from the textbook version of the Mundell (1963)-Fleming (1962) model. In Chapter 6, I have shown that extending the closed economy model of Chapter 3 to allow for open economy related dynamics does not bring about a significant difference in the dynamics of the key aggregates. I have shown that the model is capable of generating delayed exchange rate overshooting in the aftermath of a technology shock. I have also found that consumption and the real exchange rate dynamics significantly change by restricting the households' access to international asset markets. This results contradicts the findings of previous research (Baxter and Crucini 1995, Kollmann 1996, and Schmitt-Grohè and Uribe 2003).

Each of these results is self evidently important. But much more research should be conducted before a conclusive policy advice can be drawn. The reason for this is that as Carlstrom and Fuerst (2001, p.295) remark:

... Hippocrates advised the doctor to do no harm. This minimal advice is equally important to the central banker. In particular, a necessary condition for good monetary policy is that it does not introduce sunspot fluctuations into the real economy. ... Hence, a central conclusion ... is that we need to think much more carefully about basic modeling assumptions when writing down monetary models. A lot depends on apparently trivial assumptions.

Besides we do not have fully-fledged microeconomic foundations of fairness concerns as we do not have fully-fledged microeconomic foundations of nominal-price and labor-market rigidities. Therefore, a potentially promising path for future research appears to be microeconomics of fairness concerns. Rabin (1993), Rotemberg (2004), and Yengin (2007) are important advances in this direction.

In future research, my analysis could be extended to explore the implications of other forms of market imperfectness and incompleteness. For example, incorporating fairness concerns with search models of labor market (Mortensen and Pissarides 1994) and models with endogenously incomplete international financial markets (Kehoe and Perri 2002) can have important implications for the dynamics of the macroeconomic aggregates.

I have used a two-country framework to analyze issues specific to international economics. For small industrial economies a more relevant framework may be a small open economy model such as the one developed by Galí and Monacelli (2005). It would be interesting to analyze how fair prices and fair wages interact with features that are specific to small open economies. Another interesting subject for future research is the welfare evaluation of alternative policy regimes under households' and workers' fairness concerns.

We have started the dissertation with a quotation. We can finish with another one that may shed light on our discussion of fluctuations.

... *As long as the roots are not severed, all is well and all will be well in the garden.*

... *In a garden, growth has its season. There is spring and summer, but there is also fall and winter. And then spring and summer again.*

... *There will be growth in the spring.*

*Chance the Gardener*<sup>1</sup>

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<sup>1</sup>Peter Sellers character from the movie *Being There*.

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10/1998 – 08/2000      *University of Warwick:* M.Sc. in Economics  
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### RELEVANT POSITIONS HELD:

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04/2005 – 11/2008      *Research and Teaching Assistant, Chair of Macroeconomics and International Economics, Saarland University, Germany*  
08/2004 – 03/2005      *Student Assistant, Kiel Institute for World Economics, Germany*  
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### TEACHING EXPERIENCE:

At *Saarland University*:      Tutorials for graduate students on *Monetary Economics, Dynamic Macroeconomic Analysis, International Trade: Theory and Policy, International Financial Markets, Exchange Rates and Open Economy Macroeconomics*.  
   Tutorials for undergraduate students on *Introduction to Macroeconomics*.  
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## **COMPLETED WORK:**

“Efficiency Wages, Financial Market Integration, and the Fiscal Multiplier” (forthcoming, *Journal of International Money and Finance*) (with C. Pierdzioch)

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“A New Cost Channel of Monetary Policy”

“International Financial Integration, Labor Adjustment Costs, and Macroeconomic Volatility” (*International Review of Economics and Finance*, 2008, 17: 467-76) (with C. Pierdzioch)

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25<sup>th</sup> GDRE Symposium on Money, Banking and Finance, 2008, Luxembourg

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Several Departmental Seminars at the University of Kiel, Saarland University, and the University of Porto



**Eidesstattliche Erklärung:**

Ich erkläre hiermit an Eides Statt, dass ich meine Doktorarbeit „*Fair Prices and Fair Wages: Implications for Macroeconomic Dynamics in Closed and Open Economies*“ selbständig und ohne fremde Hilfe angefertigt habe und dass ich alle von anderen Autoren wörtlich übernommenen Stellen, wie auch die sich an die Gedanken anderer Autoren eng anlehnenden Ausführungen meiner Arbeit, besonders gekennzeichnet und die Quellen nach den mir angegebenen Richtlinien zitiert habe.

Datum

Unterschrift





