# Market Deregulation and Optimal Monetary Policy in a Monetary Union*

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**Abstract**

The global crisis that began in 2008 reheated the debate on market deregulation as a tool to spur economic performance. This paper addresses the consequences of increased flexibility in goods and labor markets for the conduct of monetary policy in a monetary union. We model a two-country monetary union with endogenous product creation, labor market frictions, and price and wage rigidities. We allow regulation in goods and labor markets to differ across countries. We first characterize optimal monetary policy when regulation is high and show that the Ramsey allocation requires significant departures from price stability both in the long run and over the business cycle. Welfare gains from the Ramsey-optimal policy are sizable. Second, we show that the adjustment to market reform requires expansionary policy to reduce transition costs. Third, deregulation reduces static and dynamic inefficiencies, making price stability more desirable. International coordination of reforms is beneficial as it eliminates policy tradeoffs generated by asymmetric deregulation.

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## 1 Introduction

The global crisis that began in 2008 reheated the debate on market deregulation as a tool to spur economic performance. Calls for removal, or at least reduction, of regulation in goods and labor markets have been part of the policy discussions on both sides of the Atlantic.[1] The argument is that more flexible markets would foster a more rapid recovery from the recession generated by the crisis and, in general, would result in better economic performance. Deregulation of product markets would accomplish this by facilitating producer entry, boosting business creation, and enhancing competition; deregulation of labor markets would do it by facilitating reallocation of resources and speeding up the adjustment to shocks. Results in the academic literature support these arguments[2], but they do not address the consequences of market deregulation for the conduct of macroeconomic policy. Important questions remain open: What is the optimal policy response to the dynamics triggered by goods and labor market reform? How does deregulation affect the central bank's long-run inflation target? And how does optimal policy change as reforms affect the characteristics of the business cycle?

This paper addresses these questions from the perspective of monetary policy in a monetary union. We study how deregulation that increases flexibility in product and/or labor markets affects the long-run inflation target of the welfare-maximizing central bank of a monetary union; how the central bank responds to the transition dynamics generated by the deregulation; and how deregulation affects the conduct of optimal monetary policy over the business cycle. We do this in a two-country, dynamic, stochastic, general equilibrium (DSGE) model of a monetary union with endogenous product creation subject to sunk costs as in Bilbiie, Ghironi, and Melitz (2007)—BGM below—and search-and-matching frictions in labor markets as in Diamond (1982a,b) and Mortensen and Pissarides (1994)—DMP below. We introduce nominal rigidities in the form of sticky prices and wages.[3] Sunk entry costs in product markets reflect both a technological constraint and barriers

[1] The title on the front page of the February 18, 2012 issue of *The Economist* ("Over-regulated America") and the discussion of increasing regulation of U.S. product markets are indicative of the attention to the issue in the United States. There has also been resistance to the introduction of regulation in U.S. financial markets, where earlier deregulation and the resulting financial innovations are viewed by many as responsible for the crisis. In August of 2011, in the midst of Europe's sovereign debt crisis, then European Central Bank President Jean-Claude Trichet and President-to-be Mario Draghi took the unprecedented step of addressing a letter to the Italian government making market deregulation a condition for the central bank's intervention in support of Italian government bonds.

[2] In the recent literature, see, for instance, Blanchard and Giavazzi (2003), Cacciatore and Fiori (2011), Ebell and Haefke (2009), Felbermayr and Prat (2011), Fiori, Nicoletti, Scarpetta, and Schiantarelli (2011), Griffith, Harrison, and Macartney (2007), and Messina and Vallanti (2004).

[3] Wage rigidity takes the form of costly Nash bargaining over nominal wages as in Arseneau and Chugh (2008), Gertler, Trigari, and Sala (2008), and Thomas (2008), while price rigidity is introduced by assuming costly price adjustment as in Rotemberg (1982) and many other studies.

to entry induced by regulation. Deregulation of product markets reduces the size of sunk entry costs. In labor markets, deregulation is captured by a reduction of unemployment benefits and workers' bargaining power. We study how deregulation affects the optimal monetary policy chosen by a Ramsey central bank in a variety of scenarios for the monetary union, including the possibility of existing market asymmetries across countries.

We show that our model successfully reproduces several features of the business cycle in Europe's Economic and Monetary Union (EMU) when the union's central bank follows an interest rate rule that reproduces the historical behavior of the European Central Bank (ECB). We find that regulation in goods and labor markets has a significant effect on optimal monetary policy. First, in the current highly regulated regime, the Ramsey-optimal policy prescribes a positive long-run inflation target of 1.2 percent and significant departures from the historical Taylor rule (which, in turn, approximates a policy of price stability). Total welfare gains from optimal policy are not negligible: Implementing the optimal policy increases welfare by approximately 0.5 percent of annual steady-state consumption under the historical rule.[4] Second, the optimal response to product and/or labor market deregulation is more expansionary than historical behavior, with a beneficial effect on welfare during the transition.[5] When the effects of deregulation are fully materialized, the welfare gap between historical and Ramsey policy is narrower, and price stability is more desirable both in the long run and over the business cycle for countries that undertake reforms. The welfare gap, however, remains large in countries that do not deregulate their markets. Third, there are gains from international coordination of market reforms: The welfare increase from deregulation under the Ramsey-optimal policy is larger if market reforms are synchronized across countries.

The intuition for our results is straightforward. We show that high regulation in goods and labor markets implies that steady-state markups are too high and job creation too low. Inefficiency wedges with respect to the first-best allocation are sizable. Regulation makes cyclical unemployment fluctuations too volatile, which amplifies their welfare cost. The Ramsey policymaker uses positive long-run inflation to mitigate long-run inefficiencies, and (s)he uses departures from price stability over the cycle to reduce the procyclicality of job creation (at the cost of more volatile product creation).

[4] Assuming euro area per capita GDP at $27,000$ euros and the share of consumption in GDP at a 60 percent historical mean, this yields 80 euros.

[5] The welfare effect over a five-year horizon is approximately 1.4 percent of annual pre-deregulation steady-state consumption for the economy that deregulates both product and labor markets, and 1.9 percent for the other.

Deregulation (even asymmetric across countries) reduces real distortions in goods and labor markets. Since the benefits take time to materialize, the Ramsey central bank expands monetary policy more aggressively than the historical ECB to generate lower markups and boost job creation along the transition. Once the beneficial effects of reforms are fully materialized, there is less need of positive long-run inflation to close inefficiency gaps, and price stability over the cycle is less costly for economies that deregulated their markets. International spillovers from asymmetric deregulations across countries are positive but small. As a result, the costs of the historical policy of near-price stability continue to be relatively high in rigid countries, at approximately 0.5 percent of annual steady-state consumption. The welfare benefits of optimal policy depend on the union-wide pattern of deregulation. Asymmetric deregulation alters the policy tradeoffs facing the Ramsey central bank, because optimal policy must strike a balance between countries that differ in the desirability of price stability both in the long run and over the cycle. Internationally synchronized reforms remove this tradeoff, resulting in larger welfare gains from optimal policy: Market reforms are beneficial for welfare under both historical and Ramsey-optimal policy, but they are more beneficial if monetary policy is chosen optimally, and the benefit increases if reforms are synchronized. From the perspective of deregulating countries, the welfare benefit of optimal policy relative to the historical Taylor rule is larger if optimal policy is implemented in a symmetrically deregulated monetary union.

Our paper contributes to the recent literature that studies how endogenous entry and product variety affect business cycles and optimal policy in closed and open economies.[6] In this literature, our work is most closely related to Cacciatore and Fiori (2011), who study the consequences of product and labor market deregulation in a flexible-price BGM-DMP model.[7] We extend Cacciatore and Fiori's model to a two-country, monetary-union framework with sticky prices and wages to

[6] On entry and product variety over the cycle in closed-economy models, and related evidence, see BGM and references therein. Cacciatore and Fiori (2011) and Shao and Silos (2008) extend the BGM model to incorporate DMP search-and-matching frictions. Colciago and Rossi (2011) augment the BGM-DMP framework to consider the consequences of Bertrand or Cournot competition between large firms. Entry over the business cycle in open economies is a key mechanism in Cacciatore (2010), Contessi (2010), Ghironi and Melitz (2005), Rodríguez-López (2011), and Zlate (2010), among others. On optimal policy with endogenous producer entry, see Bergin and Corsetti (2008), Bilbiie, Fujiwara, and Ghironi (2011), Cacciatore and Ghironi (2012), Chugh and Ghironi (2011), Faia (2010), and Lewis (2010), among others. Auray and Eyquem (2011) and Cavallari (2011) study the role of monetary policy for shock transmission in two-country versions of the BGM model, but they do not analyze optimal monetary policy. Auray and Eyquem find that policies of price stability in each country imply welfare costs relative to interest rate rules with moderate responses to output.

[7] Cacciatore and Fiori extend the analysis of Blanchard and Giavazzi (2003) to a DSGE framework. This allows Cacciatore and Fiori to study the transition dynamics following deregulation, as well as its effects on the business cycle. A result of their exercise is that goods and labor market deregulation reduces the persistence and overall volatility of fluctuations, but amplifies the impact effect of shocks.

study the interaction of deregulation and monetary policy. Our results on optimal monetary policy extend those in Bilbiie, Fujiwara, and Ghironi (2011): As in that paper, an inefficiency wedge in product creation is among the reasons for the Ramsey central bank of our monetary union to use positive long-run inflation, but our model features a wider menu of sources of inefficiency, with the labor margin affected by a larger number of distortions. Differently from Bilbiie, Fuijwara, and Ghironi, we find that the interaction of distortions in our model results in sizable departures from price stability over the business cycle.

The paper is also related to the vast literature on monetary transmission and optimal monetary policy in New Keynesian macroeconomic models.[8] In particular, we contribute to the strand of this literature that incorporates labor market frictions.[9] Arseneau and Chugh (2008) study optimal monetary (and fiscal) policy in a DMP model with sticky nominal wages; Faia (2009) focuses on the case of sticky prices, while Thomas (2008) considers both wage and price rigidity. Different from us, Faia and Thomas find that zero long-run inflation is optimal (because the steady state is not distorted in Thomas' exercise, while DMP distortions and the effect of monopoly power on equilibrium labor are not sufficient to motivate positive long-run inflation in Faia's sticky-price setup). Optimal long-run inflation can be positive in Arseneau and Chugh, depending on the scenario they consider. All three papers, like us, find that it is optimal to deviate from price stability over the business cycle, but deviations are small in Faia and Thomas.[10] By allowing for asymmetries between countries in our monetary union, we contribute to the study of optimal monetary policy in economies with potentially heterogeneous regions or sectors.[11] While we cast our model and discussion in terms of a two-country monetary union and we choose EMU for our calibration, it is straightforward to re-cast the model (and re-calibrate it) to apply its lessons to the United States (itself a monetary union of states with potentially asymmetric state-level regulations).

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 describes monetary policy: We consider a historical rule for the ECB's interest rate setting and the Ramsey-optimal policy. To build intuition for the tradeoffs facing the Ramsey authority, Section 4 derives the social planner equilibrium and discusses the inefficiency wedges and sources of distortions that

[8] See Galí (2008), Walsh (2010), Woodford (2003), and references therein.

[9] See Galí (2011), Galí, Smets, and Wouters (2011), and Zanetti (2007) for an alternative to DMP search-and-matching frictions in New Keynesian models emphasizing indivisible labor and workers' monopoly power.

[10] Larger volatility of inflation arises in Arseneau and Chugh's sticky-wage DMP model with exogenous government spending and Ramsey-optimal monetary and tax policy. Government spending alone has been shown to imply deviations from price stability in a variety of environments. See Adão, Correia, and Teles (2003), Khan, King, and Wolman (2003), and Woodford (2003, Ch. 6.5).

[11] Aoki (2001) and Benigno (2004) are early analyses of the consequences of heterogeneity in nominal rigidity.

characterize the market economy. Section 5 presents the calibration and discusses the performance of the model in relation to the data. Section 6 studies optimal monetary under the current regulatory environment and the consequences of deregulation for monetary policy. Section 7 discusses the benefits from international synchronization of reforms. Section 8 concludes.

## 2 The Model

We model a monetary union that consists of two countries, Home and Foreign. Foreign variables are denoted with a superscript star. We focus on the Home economy in presenting our model, with the understanding that analogous equations hold for Foreign. We abstract from monetary frictions that would motivate a demand for cash currency in each country, and we model our monetary union as a cashless economy following Woodford (2003).

Each economy in the union is populated by a unit mass of atomistic households, where each household is thought of as an extended family with a continuum of members along the unit interval. In equilibrium, some family members are unemployed, while some others are employed. As common in the literature, we assume that family members perfectly insure each other against variation in labor income due to changes in employment status, so that there is no *ex post* heterogeneity across individuals in the household (see Andolfatto, 1996, and Merz, 1995).

### Household Preferences

The representative household in the Home economy maximizes the expected intertemporal utility function $E_0 \sum_{t=0}^{\infty} \beta^t [u(C_t) - l_t v(h_t)]$, where $\beta \in (0,1)$ is the discount factor, $C_t$ is a consumption basket that aggregates domestic and imported goods as described below, $l_t$ is the number of employed workers, and $h_t$ denotes hours worked by each employed worker. Period utility from consumption, $u(\cdot)$, and disutility of effort, $v(\cdot)$, satisfy the standard assumptions.

The consumption basket $C_t$ aggregates bundles $C_{d,t}$ and $C^*_{x,t}$ of Home and Foreign consumption varieties in Armington form with elasticity of substitution $\phi > 0$:

$$C_t = \left[ (1-\alpha)^{\frac{1}{\phi}} C_{d,t}^{\frac{\phi-1}{\phi}} + \alpha^{\frac{1}{\phi}} C_{x,t}^{*\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}}, \quad 0 < \alpha < 1.$$

A similar basket describes consumption in the Foreign country. In each country's consumption basket, $1-\alpha$ is the weight attached to the country's own output bundle and captures the degree

of home bias in preferences.[12] The corresponding consumption-based price index is given by:

$$P_t = \left[(1-\alpha)P_{d,t}^{1-\phi} + \alpha P_{x,t}^{*1-\phi}\right]^{\frac{1}{\phi-1}}.$$

Following BGM, the number of consumption goods available in each country is endogenously determined. Denote with $\Omega_d$ and $\Omega_x^*$ the overall numbers of Home and Foreign goods over which the preference aggregators $C_{d,t}$ and $C_{x,t}^*$ are defined. At any given $t$, only subsets of goods $\Omega_{d,t} \subset \Omega_d$ and $\Omega_{x,t}^* \subset \Omega_x^*$ are actually available for consumption at Home.

We assume that the aggregators $C_{d,t}$ and $C_{x,t}^*$ take a translog form following Feenstra (2003a,b). As a result, the elasticity of substitution across varieties within each sub-basket $C_{d,t}$ and $C_{x,t}^*$ (and $C_{d,t}^*$ and $C_{x,t}$ in the Foreign consumption basket) is an increasing function of the number of goods available. The translog assumption allows us to capture the pro-competitive effect of goods market deregulation on (flexible-price) markups. As shown in BGM and Cacciatore and Fiori (2011), lower entry barriers in production of goods result in increased entry, a larger number of available goods, and—by inducing higher substitutability—lower markups.[13]

Translog preferences are characterized by defining the unit expenditure function (i.e., the price index) associated with the preference aggregator. Let $p_{d,t}(\omega)$ be the price of a variety $\omega$ produced and sold at Home, and $p_{x,t}^*(\omega^*)$ the price of a variety $\omega^*$ produced in the Foreign country and exported to Home. The unit expenditure function on the basket of domestic goods $C_{d,t}$ is given by:

$$\begin{aligned}\ln P_{d,t} &= \frac{1}{2\sigma}\left(\frac{1}{N_t} - \frac{1}{\tilde{N}}\right) + \frac{1}{N_t}\int_{\omega\in\Omega_{d,t}} \ln p_{d,t}(\omega)d\omega \\ &\quad + \frac{\sigma}{2N_t}\int_{\omega\in\Omega_{d,t}}\int_{\omega'\in\Omega_{d,t}} \ln p_{d,t}(\omega)(\ln p_{d,t}(\omega) - \ln p_{d,t}(\omega'))d\omega d\omega',\end{aligned}$$

where $\sigma > 0$, $N_t$ is the total number of Home products available at time $t$, and $\tilde{N}$ is the mass of

[12] Consumption preferences are identical across countries only in the knife-edge case $\alpha = 1/2$. Preferences are biased in favor of domestic goods whenever $\alpha < 1/2$. Departures of $\alpha$ from $1/2$ induce deviations from purchasing power parity in our model.

[13] The assumption of translog preferences has been found to have appealing empirical properties in a variety of contexts. For a review of its applications in the trade literature, see Feenstra (2003b). BGM find that translog preferences and endogenous producer entry result in markup dynamics that are remarkably close to U.S. data. Bergin and Feenstra (2000, 2001) show that a translog expenditure function makes it possible to generate empirically plausible endogenous persistence in macro and international macro models by virtue of the implied demand-side pricing complementarities. (Feenstra, 2003a, shows that the properties of the translog function used by Bergin and Feenstra hold also when the number of goods varies.) Rodríguez-López (2011) extends Ghironi and Melitz's (2005) model to include translog preferences and nominal rigidity. He obtains plausible properties for exchange rate pass-through, markup dynamics, and cyclical responses of firm-level and aggregate variables to shocks.

$\Omega_d$. The unit expenditure function on the basket of imported goods $C^*_{x,t}$ is instead given by:

$$\begin{aligned}\ln P^*_{x,t} &= \frac{1}{2\sigma}\left(\frac{1}{N^*_t}-\frac{1}{\tilde{N}^*}\right)+\frac{1}{N^*_t}\int\limits_{\omega^*\in\Omega^*_{x,t}}\ln p^*_{x,t}(\omega^*)d\omega^* \\ &+\frac{\sigma}{2N^*_t}\int\limits_{\omega^*\in\Omega^*_{x,t}}\int\limits_{\omega^{*\prime}\in\Omega^*_{x,t}}\ln p^*_{x,t}(\omega^*)(\ln p^*_{x,t}(\omega^*)-\ln p^*_{x,t}(\omega^{*\prime}))d\omega^* d\omega^{*\prime},\end{aligned}$$

where $N^*_t$ is the total number of Foreign products available at time $t$, and $\tilde{N}^*$ is the mass of $\Omega^*_x$.[14]

**Production**

In each country, there are two vertically integrated production sectors. In the upstream sector, perfectly competitive firms use labor to produce a non-tradable intermediate input. In the downstream sector, monopolistically competitive firms purchase intermediate inputs and produce the differentiated varieties that are sold to consumers in both countries. This production structure greatly simplifies the introduction of labor market frictions in the model.

*Intermediate Goods Production*

There is a unit mass of intermediate producers. Each of them employs a continuum of workers. Labor markets are characterized by search and matching frictions as in the DMP framework. To hire new workers, firms need to post vacancies, incurring a cost of $\kappa$ units of consumption per vacancy posted.[15] The probability of finding a worker depends on a constant-return-to-scale matching technology, which converts aggregate unemployed workers, $U_t$, and aggregate vacancies, $V_t$, into aggregate matches, $M_t = \chi U_t^{1-\varepsilon} V_t^{\varepsilon}$, where $\chi > 0$ and $0 < \varepsilon < 1$. Each firm meets unemployed workers at a rate $q_t \equiv M_t/V_t$. As in Krause and Lubik (2007) and other studies, we assume that newly created matches become productive only in the next period. For an individual firm, the inflow of new hires in $t+1$ is therefore $q_t \upsilon_t$, where $\upsilon_t$ is the number of vacancies posted by the firm in period $t$.[16]

[14] Since we will abstract from producer heterogeneity and endogenous determination of the range of traded consumption variety, the total number of Home (Foreign) varieties available to Home (Foreign) consumers will also be the number of varieties imported by Foreign (Home). This will imply $mass(\Omega_d) = mass(\Omega_x)$, $mass(\Omega_{d,t}) = mass(\Omega_{x,t})$, $mass(\Omega^*_d) = mass(\Omega^*_x)$, and $mass(\Omega^*_{d,t}) = mass(\Omega^*_{x,t})$. Ghironi and Melitz (2005) introduce heterogeneity and endogenous determination of the traded set in an international macroeconomic model with C.E.S. Dixit-Stiglitz preferences.

[15] Results are not affected significantly if we assume quadratic costs of vacancy posting.

[16] In equilibrium, $\upsilon_t = V_t$.

Firms and workers can separate exogenously with probability $\lambda \in (0,1)$. As a result the law of motion of employment, $l_t$ (those who are working at time $t$), in a given firm is given by:

$$l_t = (1-\lambda) l_{t-1} + q_{t-1} \upsilon_{t-1}. \tag{1}$$

As in Arsenau and Chugh (2008), firms faces a quadratic cost of adjusting the hourly nominal wage rate, $w_t$. For each worker, the real cost of changing the nominal wage between period $t$ and $t+1$ is $\vartheta \pi_{w,t}^2/2$, where $\vartheta \geq 0$ is in units of consumption, and $\pi_{w,t} \equiv (w_t/w_{t-1}) - 1$ is the net wage inflation rate. If $\vartheta = 0$, there is no cost of wage adjustment.

The representative intermediate firm produces output $y_t^I = Z_t l_t h_t$, where $Z_t$ is exogenous aggregate productivity.[17] We assume the following bivariate process for Home and Foreign productivity:

$$\begin{bmatrix} \log Z_t \\ \log Z_t^* \end{bmatrix} = \begin{bmatrix} \phi_{11} & \phi_{12} \\ \phi_{21} & \phi_{22} \end{bmatrix} \begin{bmatrix} \log Z_{t-1} \\ \log Z_{t-1}^* \end{bmatrix} + \begin{bmatrix} \epsilon_t \\ \epsilon_t^* \end{bmatrix},$$

where $\phi_{11}$ and $\phi_{22}$ are strictly between 0 and 1, and $\epsilon_t$ and $\epsilon_t^*$ are normally distributed innovations with variance-covariance matrix $\Sigma_{\epsilon,\epsilon^*}$.

Intermediate goods producers sell their output to final producers at a real price $\varphi_t$ in units of consumption. Intermediate producers choose the number of vacancies, $\upsilon_t$, and employment, $l_t$, to maximize the expected present discounted value of their profit stream:

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{u_{C,t}}{u_{C,0}} \left( \varphi_t Z_t l_t h_t - \frac{w_t}{P_t} l_t h_t - \kappa \upsilon_t - \frac{\vartheta}{2} \pi_{w,t}^2 l_t \right),$$

where $u_{C,t}$ denotes the marginal utility of consumption in period $t$, subject to equation (1). Future profits are discounted with the stochastic discount factor of domestic households, who are assumed to own Home firms.

Combining the first-order conditions for vacancies and employment yields the following job creation equation:

$$\frac{\kappa}{q_t} = E_t \left\{ \beta_{t,t+1} \left[ (1-\lambda) \frac{\kappa}{q_{t+1}} + \varphi_{t+1} Z_{t+1} h_{t+1} - \frac{w_{t+1}}{P_{t+1}} h_{t+1} - \frac{\vartheta}{2} \pi_{w,t+1}^2 \right] \right\}, \tag{2}$$

where $\beta_{t,t+1} \equiv \beta u_{C,t+1}/u_{C,t}$ is the one-period-ahead stochastic discount factor. The job creation

[17] Note that the assumption of a unit mass of intermediate producers ensures that $y_t^I$ is also the total output of the intermediate sector.

condition states that, at the optimum, the vacancy creation cost incurred by the firm per current match is equal to the expected discounted value of the vacancy creation cost per future match, further discounted by the probability of current match survival $1-\lambda$, plus the profits from the time-$t$ match. Profits from the match take into account the future marginal revenue product from the match and its wage cost, including future nominal wage adjustment costs. Forward iteration of equation (2) implies that, at the optimum, the vacancy creation cost per match, $\kappa/q_t$, is equal to the expected present discounted value of the stream of profits generated by the match over its expected lifetime:

$$\frac{\kappa}{q_t} = E_t \sum_{s=t+1}^{\infty} \left[\beta(1-\lambda)\right]^{s-t} \frac{u_{C,s}}{u_{C,t}} \left( \varphi_s Z_s h_s - \frac{w_s}{P_s} h_s - \frac{\vartheta}{2} \pi_{w,s}^2 \right).$$

**Wage Determination** The nominal wage is the solution of an individual Nash bargaining process, and the wage payment divides the match surplus between workers and firms. Due to the presence of nominal rigidities, we depart from the standard Nash bargaining convention by assuming that bargaining occurs over the nominal wage payment rather than the real wage payment.[18] With zero costs of nominal wage adjustment ($\vartheta = 0$), the real wage that emerges would be identical to the one obtained from bargaining directly over the real wage. This is no longer the case in the presence of adjustment costs.

Let $J_t$,be the real value of an existing, productive match for a producer, determined by:

$$J_t = \varphi_t Z_t h_t - \frac{w_t}{P_t} h_t - \frac{\vartheta}{2} \pi_{w,t}^2 + E_t \beta_{t,t+1} (1-\lambda) J_{t+1}. \tag{3}$$

Intuitively, $J_t$ is the per period marginal value product of the match, $\varphi_t Z_t h_t$, net of the wage bill and costs incurred to adjust wages, plus the expected discounted continuation value of the match in the future.[19]

Next, denote with $W_t$ the worker's asset value of being matched, and with $U_{u,t}$ the value of being unemployed. The value of being employed at time $t$ is given by the real wage bill the worker receives plus the expected future value of being matched to the firm. With probability $1-\lambda$ the match will survive, while with probability $\lambda$ the worker will be unemployed. As a result:

[18] The same assumption is made by Arseneau and Chugh (2008), Gertler, Trigari, and Sala (2008), and Thomas (2008).

[19] Note that equations (2) and (3) together imply that there is a difference between the value of an existing match to the producer and the vacancy creation cost per match today (which becomes productive tomorrow), reflecting the expected discounted change in the per-period profitability of the match between today and tomorrow. If matches were productive immediately, it would be $J_t = \kappa/q_t$.

$$W_t = \frac{w_t}{P_t} h_t + E_t \left\{ \beta_{t,t+1} \left[ (1-\lambda) W_{t+1} + \lambda U_{u,t+1} \right] \right\}. \tag{4}$$

The value of unemployment is given by:

$$U_{u,t} = \frac{v(h_t)}{u_{C,t}} + b + E_t \left\{ \beta_{t,t+1} [(\iota_t W_{t+1} + (1-\iota_t) U_{u,t+1}] \right\}. \tag{5}$$

In this expression, $v(h_t)/u_{C,t}$ is the utility gain from leisure in terms of consumption, $b$ is an unemployment benefit from the government (financed with lump sum taxes), and $\iota_t$ is the probability of becoming employed at time $t$, equal to the ratio between the total number of matches and the total number of workers searching for jobs at time $t$: $\iota_t \equiv M_t/U_t$.

Equations (4) and (5) imply that the worker's surplus $H_t \equiv W_t - U_{u,t}$ is determined by:

$$H_t = \frac{w_t}{P_t} h_t - \left( \frac{v(h_t)}{u_{C,t}} + b \right) + (1-\lambda-\iota_t) E_t \left( \beta_{t,t+1} H_{t+1} \right). \tag{6}$$

Nash bargaining maximizes the joint surplus $J_t^{\eta} H_t^{1-\eta}$ with respect to $w_t$, where $\eta \in (0,1)$ is the firm's bargaining power. The first-order condition implies:

$$\eta H_t \frac{\partial J_t}{\partial w_t} + (1-\eta) J_t \frac{\partial H_t}{\partial w_t} = 0, \tag{7}$$

where:

$$\frac{\partial J_t}{\partial w_t} = -\frac{h_t}{P_t} - \vartheta \frac{\pi_{w,t}}{w_{t-1}} + (1-\lambda)\vartheta E_t \left[ \beta_{t,t+1} (1+\pi_{w,t+1}) \frac{\pi_{w,t+1}}{w_t} \right], \tag{8}$$

and:

$$\frac{\partial H_t}{\partial w_t} = \frac{h_t}{P_t}. \tag{9}$$

The sharing rule can then be rewritten as:

$$\eta_t H_t + (1-\eta_t) J_t = 0, \tag{10}$$

where:

$$\eta_t = \frac{\eta}{\eta - (1-\eta) \left( \frac{\partial H_t}{\partial w_t} / \frac{\partial J_t}{\partial w_t} \right)}. \tag{11}$$

Equation (10) shows that, as in Gertler and Trigari (2009), bargaining shares are time-varying due to the presence of wage adjustment costs. Absent wage adjustment costs, we would have

$\partial J_t/\partial w_t = -\partial H_t/\partial w_t$ and a time-invariant bargaining share $\eta_t = \eta$.

The bargained wage satisfies:

$$\begin{aligned}\frac{w_t}{P_t}h_t &= \eta_t\left(\frac{v(h_t)}{u_{C,t}}+b\right)+(1-\eta_t)\left(\varphi_t Z_t h_t-\frac{\vartheta}{2}\pi_{w,t}^2\right)\\ &\quad +E_t\left\{\beta_{t,t+1}J_{t+1}\left[(1-\lambda)(1-\eta_t)-(1-\lambda-\iota_t)(1-\eta_{t+1})\frac{\eta_t}{\eta_{t+1}}\right]\right\}. \qquad (12)\end{aligned}$$

With flexible wages, $\eta_t = \eta$, and the third term in the right-hand side of this equation reduces to $(1-\eta)\,\iota_t E_t\left(\beta_{t,t+1}J_{t+1}\right)$, or, in equilibrium, $\kappa\,(1-\eta)\,\iota_t/q_t$. In this case, the real wage bill per worker is a linear combination—determined by the constant bargaining parameter $\eta$—of worker's outside option and the marginal revenue product generated by the worker (net of wage adjustment costs) plus the expected discounted continuation value of the match to the firm (adjusted for the probability of worker's employment). The stronger the bargaining power of firms (the higher $\eta$), the smaller the portion of the net marginal revenue product and continuation value to the firm appropriated by workers as wage payments, while the outside option becomes more relevant. When wages are sticky, bargaining shares are endogenous, and so is the distribution of surplus between workers and firms. Moreover, the current wage bill reflects also expected changes in bargaining shares.

Equation (12) implies that the value of a match to a producer can be rewritten as:

$$J_t = \eta_t\left[\varphi_t Z_t h_t-\frac{\vartheta}{2}\pi_{w,t}^2-\left(\frac{v(h_t)}{u_{C,t}}+b\right)\right]+E_t\left\{\beta_{t,t+1}J_{t+1}\left[(1-\lambda)\eta_t+(1-\lambda-\iota_t)(1-\eta_{t+1})\frac{\eta_t}{\eta_{t+1}}\right]\right\}. \qquad (13)$$

The second term in the right-hand side of this equation reduces to $[1-\lambda-(1-\eta)\,\iota_t]\,E_t\left(\beta_{t,t+1}J_{t+1}\right)$ when wages are flexible. The firm's equilibrium surplus is the share $\eta$ of the marginal revenue product generated by the worker, net of wage adjustment costs and the worker's outside option, plus the expected discounted future surplus, adjusted for the probability of continuation, $1-\lambda$, and the portion appropriated by the worker, $(1-\eta)\,\iota_t$. Sticky wages again introduce an effect of expected changes in the endogenous bargaining shares.

As common practice in the literature we assume that hours per worker are determined by firms and workers in a privately efficient way, i.e., so as to maximize the joint surplus of their employment relation.[20] The joint surplus is the sum of the firm's surplus and the worker's surplus, i.e., $J_t + H_t$. Maximization yields a standard intratemporal optimality condition for hours worked that equates

[20] See, among others, Thomas (2008) and Trigari (2009).

the marginal revenue product of hours per worker to the marginal rate of substitution between consumption and leisure: $v_{h,t}/u_{C,t} = \varphi_t Z_t$, where $v_{h,t}$ is the marginal disutility of effort. Notice that hours are independent of the wage, precisely because they are chosen to maximize the joint surplus.

*Final Goods Production*

In each country, there is a continuum of monopolistically competitive final-sector firms, each of them producing a different variety.[21] Final goods are produced using domestic intermediate inputs, and they are sold domestically and abroad.[22]

The producer of final good $\omega$ at Home faces the following domestic and Foreign demands for its output:

$$y_{d,t}(\omega) = (1-\alpha)\sigma \ln\left(\frac{\bar{p}_{d,t}}{p_{d,t}(\omega)}\right)\frac{P_{d,t}}{p_{d,t}(\omega)}\left(\frac{P_{d,t}}{P_t}\right)^{-\phi} Y_t^C, \tag{14}$$

$$y_{x,t}(\omega) = \alpha\sigma \ln\left(\frac{\bar{p}_{x,t}}{p_{x,t}(\omega)}\right)\frac{P_{x,t}}{p_{x,t}(\omega)}\left(\frac{P_{x,t}}{P_t^*}\right)^{-\phi} Y_t^{C*}, \tag{15}$$

where

$$\ln \bar{p}_{d,t} = \frac{1}{\sigma N_t} + \frac{1}{N_t}\int\limits_{\omega\in\Omega_{d,t}} \ln p_{d,t}(\omega)d\omega \quad \text{and} \quad \ln \bar{p}_{x,t} = \frac{1}{\sigma N_t} + \frac{1}{N_t}\int\limits_{\omega\in\Omega_{x,t}} \ln p_{x,t}(\omega)d\omega$$

are the maximum prices that a domestic producer can charge in the Home and Foreign markets while still having a positive market share. In the demand expressions (14) and (15), $Y_t^C$ and $Y_t^{C*}$ denote aggregate demand of the final consumption basket at Home and abroad, recognizing that aggregate demand of the final basket in each country includes sources other than household consumption. Aggregate demand in each country takes the same Armington form as the country's consumption basket, with the same elasticity of substitution $\phi > 0$ between demand sub-bundles of Home and Foreign products ($Y_{d,t}$ and $Y_{x,t}^*$ at Home, and $Y_{d,t}^*$ and $Y_{x,t}$ in Foreign), which take the same translog form as the sub-bundles in consumption. This ensures that the consumption price index and the price sub-indexes for the translog consumption aggregators in each country are also

[21] Following the convention in BGM and Ghironi and Melitz (2005), we refer to an individual final-good producer as a firm. However, as discussed in BGM and Ghironi and Melitz (2005), final-sector productive units in the model are best interpreted as product lines at multi-product firms whose boundaries we are leaving unspecified by exploiting continuity.

[22] We do not assume separate productivity shocks in the final production sector, which implies that marginal production cost in this sector is simply $\varphi_t$. However, if we re-cast intermediate-sector firms as the "labor-intensive" departments of (integrated) final-sector firms, $Z_t$ measures the effectiveness of labor in final goods production.

the price index and sub-indexes for aggregate demand of the final basket and sub-bundles.

Absent trade costs, and since all goods are traded in the model, the law of one price holds, implying that: $p_{x,t}(\omega) = p_{d,t}(\omega)$ and $\bar{p}_{x,t} = \bar{p}_{d,t}$. Differently from Bergin and Feenstra (2001), translog preferences do not imply pricing-to-market in our model. This happens because producers face the same elasticity of substitutions across domestic and export markets when all goods are traded.[23] The only difference implied by translog preferences relative to the C.E.S. case is that the symmetric elasticity of substitution is not constant, but it varies in response to changes in the number of competitors.

Total demand for final Home producer $\omega$ can then be written as:

$$y_{d,t}(\omega) + y_{x,t}(\omega) = \sigma \frac{\ln\left(\frac{\bar{p}_{d,t}}{p_{d,t}(\omega)}\right)}{p_{d,t}(\omega)} \left(\frac{P_{d,t}^{1-\phi}}{P_t^{\phi}}\right) \left[(1-\alpha)Y_t^C + \alpha Y_t^{C*}\right].$$

We introduce price stickiness by following Rotemberg (1982) and assuming that final producers must pay a quadratic price adjustment cost $\Gamma_t(\omega) \equiv \nu \pi_{d,t}^2(\omega) p_{d,t}(\omega)(y_{d,t}(\omega) + y_{x,t}(\omega))/2$, where $\nu \geq 0$ determines the size of the adjustment cost (prices are flexible if $\nu = 0$) and $\pi_{d,t}(\omega) = (p_{d,t}(\omega)/p_{d,t-1}(\omega)) - 1$.[24] When a new final-good firm sets the price of its output for the first time, we appeal to symmetry across producers and interpret the $t-1$ price in the expression of the price adjustment cost as the notional price that the firm would have set at time $t-1$ if it had been producing in that period. An intuition for this simplifying assumption is that all producers (even those that are setting the price for the first time) must buy the bundle of goods $\Gamma_t(\omega)/P_t$ when implementing a price decision. As noted in Bilbiie, Fujiwara, and Ghironi (2011), however, this assumption is entirely consistent both with the original Rotemberg (1982) setup and with our timing assumption below. Specifically, new entrants behave as the (constant number of) price-setters do in Rotemberg's framework, where an initial condition for the individual price is dictated by nature. In our framework, new entrants at any time $t$ who start producing and setting prices at $t+1$ are subject to precisely the same assumption as price setters in Rotemberg's original setup. Moreover, the assumption that a new entrant, at the time of its first price setting decision, knows what will turn out to be the average Home product price last period is consistent with the timing assumption that an entrant starts producing only one period after entry, hence being able to "learn"

[23] See the Appendix for the proof.

[24] Notice that the total price adjustment cost is proportional to the firm's total revenue. The total real adjustment cost can be interpreted as the bundle of goods that the firm needs to purchase when implementing a price change. The size of this bundle is assumed to be larger when the size of the firm (measured by its revenue) increases.

the average product price during the entry period.[25]

Total real profits $d_t(\omega)$, returned to households as dividends, are given by:

$$d_t(\omega) = \left[\frac{p_{d,t}(\omega)}{P_t}\left(1 - \frac{\nu}{2}\pi_{d,t}^2(\omega)\right) - \varphi_t\right](y_{d,t}(\omega) + y_{x,t}(\omega)).$$

Firms maximize the expected present discounted value of the stream of current and future real profits: $E_t \sum_{s=t}^{\infty} [\beta(1-\delta)]^{s-t} (u_{C,s}/u_{C,t})\, d_s(\omega)$. Future profits are discounted with the Home household's stochastic discount factor, as Home households are assumed to own Home final goods firms. As discussed below, there is a probability $\delta \in (0,1)$ that each final good producer is hit by an exogenous, exit-inducing shock at the end of each period. Therefore, discounting is adjusted for the probability of firm survival.

The first-order condition with respect to $p_{d,t}(\omega)$ implies that the (real) output price $\rho_{d,t}(\omega) \equiv p_{d,t(\omega)}/P_t$ is equal to a markup $\mu_t(\omega)$ over marginal cost $\varphi_t$: $\rho_{d,t}(\omega) = \mu_t(\omega)\varphi_t$. The endogenous, time-varying markup $\mu_t(\omega)$ is given by:

$$\mu_t(\omega) \equiv \frac{\theta_t(\omega)}{(\theta_t(\omega) - 1)\,\Xi_t},$$

where $\theta_t(\omega) = -\partial \ln (y_{d,t}(\omega) + y_{x,t}(\omega)) / \partial \ln \rho_{d,t}(\omega)$ denotes the price elasticity of total demand for variety $\omega$, and:

$$\Xi_t \equiv 1 - \frac{\nu}{2}\pi_{d,t}^2(\omega) + \frac{\nu}{\theta_t(\omega) - 1}\left\{\begin{array}{c} (\pi_{d,t}(\omega) + 1)\,\pi_{d,t}(\omega) \\ -E_t\left[\beta_{t,t+1}(1-\delta)(\pi_{d,t+1}(\omega) + 1)\,\pi_{d,t+1}(\omega)\frac{\rho_{d,t+1}(\omega)}{\rho_{d,t}(\omega)}\left(\frac{y_{d,t+1}(\omega)+y_{x,t+1}(\omega)}{y_{d,t}(\omega)+y_{x,t}(\omega)}\right)\right] \end{array}\right\}.$$

There are two sources of endogenous markup variation in our model: First, translog preferences imply that substitutability across varieties increases with the number of available varieties. As a consequence, the price elasticity of total demand facing producer $\omega$ increases when the number of Home producers is larger. Second, price stickiness introduces an additional source of markup variation as the cost of adjusting prices gives firms an incentive to change their markups over time in order to smooth price changes across periods. When prices are flexible ($\nu = 0$), only the first

[25] Symmetry of the equilibrium will imply $p_{d,t-1}(\omega) = p_{d,t-1} \forall \omega$. Bilbiie, Ghironi, and Melitz (2008a) study the consequences of relaxing the assumption that new price setters are subject to the same rigidity as incumbents. They show that alternative assumptions generate quantitatively significant differences only if the average rate of product turnover in the economy is unrealistically high.

source of markup variation is present, and the markup reduces to $\theta_t(\omega)/(\theta_t(\omega)-1)$.

Given the law of one price, the real export price (relative to the Foreign price index $P_t^*$) is given by $\rho_{x,t}(\omega) \equiv p_{x,t}(\omega)/P_t^* = p_{d,t}(\omega)/P_t^* = \rho_{d,t}(\omega)/Q_t = \mu_t(\omega)\varphi_t/Q_t$, where $Q_t$ is the consumption-based real exchange rate: $Q_t \equiv P_t^*/P_t$.

**Producer Entry and Exit** Prior to entry, final sector firms face a sunk entry cost $f_{E,t}$ in units of intermediate input.[26] Sunk entry costs reflect both a technological constraint ($f_{T,t}$) and administrative costs related to regulation ($f_{R,t}$), i.e., $f_{E,t} \equiv f_{T,t} + f_{R,t}$. In every period $t$, there is an unbounded mass of prospective entrants in the final goods sector in each country. Prospective entrants are forward looking and form rational expectations of their future profits $d_s$ in any period $s > t$ subject to the exogenous probability $\delta$ of incurring an exit-inducing shock at the end of each period. Following BGM and Ghironi and Melitz (2005), we introduce a time-to-build lag in the model and assume that entrants at time $t$ will start producing only at $t+1$. Prospective entrants compute their expected post-entry value $e_t$, given by the expected present discounted value of the stream of per-period profits $d_s$: $e_t = E_t \sum_{s=t}^{\infty} [\beta(1-\delta)]^{s-t} (u_{C,s}/u_{C,t})\, d_s$. Entry occurs until firm value is equalized to the entry cost, leading to the free entry condition $e_t = \varphi_t f_{E,t}$.[27] Our assumptions on exit shocks and the timing of entry and production imply that the law of motion for the number of producing Home firms is given by $N_t = (1-\delta)(N_{t-1} + N_{E,t-1})$.

**Household Budget Constraint and Intertemporal Decisions**

The representative household can invest in two types of assets: shares in mutual funds of final-sector and intermediate-sector firms and a non-contingent, internationally traded bond denominated in units of the common currency.[28] Investment in the mutual fund of final-sector firms in the stock market is the mechanism through which household savings are made available to prospective entrants to cover their entry costs. Since there is no entry in the intermediate sector (and, therefore, no need to channel resources from households for the financing of such entry), we do not model trade in intermediate-sector equity explicitly, but simply assume that the profits of intermediate

[26] This assumption replicates the assumption in BGM and Ghironi and Melitz (2005) that the same input is used to produce existing varieties and create new ones.

[27] This condition holds as long as the mass of new entrants $N_{E,t}$ is positive. We verify that this condition is never violated in our exercises.

[28] For simplicity, we assume extreme home bias in equity holdings and rule out international trade in firm shares. See Hamano (2011) for a version of the Ghironi-Melitz (2005) model with international trade in equities.

sector firms are rebated to households in lump-sum fashion.[29]

Let $x_t$ be the share in the mutual fund of Home final-sector firms held by the representative household *entering* period $t$. The mutual fund pays a total profit in each period (in units of currency) that is equal to the total profit of all firms that produce in that period, $P_t N_t d_t$. During period $t$, the representative household buys $x_{t+1}$ shares in a mutual fund of $N_t + N_{E,t}$ firms (those already operating at time $t$ and the new entrants). Only a fraction $1-\delta$ of these firms will produce and pay dividends at time $t+1$. Since the household does not know which firms will be hit by the exogenous exit shock $\delta$ at the *end* of period $t$, it finances the continuing operation of all pre-existing firms and all new entrants during period $t$. The date $t$ price of a claim to the future profit stream of the mutual fund of $N_t + N_{E,t}$ firms is equal to the average nominal price of claims to future profits of Home firms, $P_t e_t$.

Let $A_{t+1}$ denote nominal bond holdings at Home entering period $t+1$. To induce steady-state determinacy and stationary responses to temporary shocks in the model, we follow Turnovsky (1985) and, more recently, Benigno (2009), and we assume a quadratic cost of adjusting bond holdings $\tau \left(A_{t+1}/P_t\right)^2/2$ (in units of Home consumption). This cost is paid to financial intermediaries whose only function is to collect these transaction fees and rebate the revenue to households in lump-sum fashion in equilibrium.

The Home household's period budget constraint is:

$$A_{t+1} + P_t \frac{\tau}{2}\left(\frac{A_{t+1}}{P_t}\right)^2 + P_t C_t + x_{t+1} N_{E,t} e_t = \left(1+i_t\right) A_t + x_t P_t N_t \left(d_t + e_t\right) + w_t l_t h_t + P_t b \left(1-l_t\right) + T_t^g + T_t^f + T_t^i,$$

where $i_t$ is the nominal interest rate on the internationally traded bond (the policy instrument of the monetary union's central bank), $T_t^g$ is a lump-sum transfer (or tax) from the government, $T_t^f$ is a lump-sum rebate of the cost of adjusting bond holdings from the intermediaries to which it is paid, and $T_t^i$ is a lump-sum rebate of profits from intermediate goods producers.[30] We use the timing convention in Obstfeld and Rogoff (1995) for the nominal interest rate: $i_{t+1}$ is the interest

[29] Even if intermediate producers are perfectly competitive, our assumptions on the labor market imply that their profits are not zero. To understand this, note that as long as the wage negotiated by workers and firms is inside the bargaining set (and, therefore, smaller than or equal to the firm's outside option), the surplus from a match that goes to the firm is positive. Since all workers are identical, the total surplus of the intermediate sector is positive, and so is the profit rebate to households.

[30] In equilibrium,

$$T_t^g = -P_t b\left(1-l_t\right), \quad T_t^f = P_t \frac{\tau}{2}\left(\frac{A_{t+1}}{P_t}\right)^2, \quad \text{and} \quad T_t^i = P_t\left(\varphi_t Z_t l_t h_t - \frac{w_t}{P_t} l_t h_t - \kappa V_t - \frac{\vartheta}{2}\pi_{w,t}^2 l_t\right).$$

rate between $t$ and $t+1$, and it is known with certainty in period $t$.

Let $a_{t+1} \equiv A_{t+1}/P_t$ denote Home real bond holdings. The Euler equation for bond holdings is:

$$1 + \tau a_{t+1} = \beta \left(1 + i_{t+1}\right) E_t \left[ \frac{u_{C,t+1}}{u_{C,t}} \frac{1}{(1 + \pi_{C,t+1})} \right],$$

where $\pi_{C,t+1} = (P_t/P_{t-1}) - 1$. The Euler equations for share holdings is:

$$e_t = \beta \left(1 - \delta\right) E_t \left[ \frac{u_{C,t+1}}{u_{C,t}} \left(d_{t+1} + e_{t+1}\right) \right].$$

As expected, forward iteration of this equation and absence of speculative bubbles yield the expression for firm value used in the free entry condition above.[31]

**Symmetric Equilibrium**

The aggregate stock of employed labor in the Home economy in period $t$ is determined by $l_t = (1-\lambda)l_{t-1} + q_{t-1}V_{t-1}$. Furthermore, symmetry across final producers implies that $\theta_t(\omega) = \theta_t = 1 + \sigma N_t$. Hence, $\rho_{d,t}(\omega) = \rho_{d,t}$ and $\rho_{x,t}(\omega) = \rho_{x,t}$.[32] Wage inflation and consumer price inflation are tied by $1 + \pi_{w,t} = \left(w_t^r / w_{t-1}^r\right)(1 + \pi_{C,t})$, where $w_t^r$ denotes the real wage, $w_t/P_t$, at time $t$. Producer price inflation and consumer price inflation are such that $1 + \pi_{d,t} = \left(\rho_{d,t}/\rho_{d,t-1}\right)(1 + \pi_{C,t})$. Home and Foreign consumer price inflation are such that $1 + \pi_{C,t} = (Q_{t-1}/Q_t)\left(1 + \pi_{C,t}^*\right)$.

The equilibrium price index satisfies:

$$1 = (1-\alpha)\left[\rho_{d,t} \exp\left(\frac{\tilde{N} - N_t}{2\sigma \tilde{N} N_t}\right)\right]^{1-\phi} + \alpha \left[\rho_{x,t}^* \exp\left(\frac{\tilde{N}^* - N_t^*}{2\sigma \tilde{N}^* N_t^*}\right)\right]^{1-\phi},$$

where $\exp(X)$ denotes the exponential of $X$. (We use this notation rather than $e^X$ to avoid confusion with the notation for firm value.)

Labor market clearing requires:

$$l_t = \frac{N_{E,t} f_{E,t}}{Z_t h_t} + \frac{N_t (y_{d,t} + y_{x,t})}{Z_t h_t}.$$

Aggregate demand of the consumption basket must be equal to the sum of consumption, the

[31] We omit the transversality conditions that must be satisfied to ensure optimality.

[32] The (flexible-price) price elasticity does not depend on $N_t^*$ because of the assumption of an Armington aggregator of Home and Foreign sub-bundles. This same assumption implies that the price elasticity facing a Foreign producer in both markets depends on $N_t^*$, but not $N_t$.

costs of posting vacancies, and the costs of adjusting wages and prices:

$$Y_t^C = C_t + \kappa V_t + \frac{\vartheta}{2}\pi_{w,t}^2 l_t + \frac{\nu}{2}\pi_{d,t}^2 \rho_{d,t}(y_{d,t} + y_{x,t})N_t.$$

We define GDP, denoted with $Y_t$, as total income: the sum of labor income, dividend income from final producers, and profit income from intermediate producers. Formally: $Y_t \equiv (w_t/P_t)\, l_t h_t + N_t d_t + T_t^i$.

Bonds are in zero net supply, which implies the equilibrium condition $a_{t+1} + Q_t a_{t+1}^* = 0$ in all periods. We show in the Appendix that Home net foreign assets are determined by:

$$a_{t+1} = \frac{1+i_t}{1+\pi_{C,t}} a_t + N_t \rho_{d,t} y_{x,t} - N_t^* Q_t \rho_{d,t}^* y_{x,t}^*. \tag{16}$$

Denoting the real interest rate with $r_t$, we have $1 + r_t = (1 + i_t) / (1 + \pi_{C,t})$, and the change in net foreign assets between $t$ and $t+1$ is determined by the current account:

$$a_{t+1} - a_t = CA_t \equiv r_t a_t + TB_t,$$

where $TB_t$ is the trade balance: $TB_t \equiv N_t \rho_{d,t} y_{x,t} - N_t^* Q_t \rho_{d,t}^* y_{x,t}^*$.

## 3 Monetary Policy

To close the model described in the previous section, we must specify the behavior of monetary policy. We compare the Ramsey-optimal conduct of monetary policy to a representation of historical behavior for the central bank, captured by a standard rule for interest rate setting in the spirit of Taylor (1993), Woodford (2003), and much other literature. Before describing this interest-rate setting rule, however, we must address an issue that concerns the data that are actually available to the central bank in its historical policymaking, and hence the empirically-relevant variables that should enter the theoretical representation of historical policy. We turn to this issue next.

### Data-Consistent Variables and Historical Monetary Policy

In the presence of endogenous producer entry and preferences that exhibit "love for variety," variables measured in units of consumption do not have a direct counterpart in the data, i.e., they are not data-consistent. This point is highlighted by Ghironi and Melitz (2005). As the economy experiences entry of Home and Foreign firms, the welfare-consistent aggregate price index $P_t$ can

fluctuate even if product prices remain constant. In the data, however, aggregate price indexes do not take these variety effects into account.[33] To resolve this issue, we follow Ghironi and Melitz (2005) and BGM, and we construct an average price index $\tilde{P}_t$ as:

$$\tilde{P}_t = \Omega_t^{\frac{1}{\phi-1}} P_t,$$

where $P_t$ is the welfare-based price index:

$$P_t = \left\{ (1-\alpha) \left[ p_{d,t} \exp\left( \frac{\tilde{N} - N_t}{2\sigma \tilde{N} N_t} \right) \right]^{1-\phi} + \alpha \left[ p^*_{x,t} \exp\left( \frac{\tilde{N}^* - N^*_t}{2\sigma \tilde{N}^* N^*_t} \right) \right]^{1-\phi} \right\}^{\frac{1}{1-\phi}},$$

and $\Omega_t$ is the variety effect, defined as

$$\Omega_t \equiv (1-\alpha) \exp\left( \frac{\tilde{N} - N_t}{2\sigma \tilde{N} N_t} \right) + \alpha \exp\left( \frac{\tilde{N}^* - N^*_t}{2\sigma \tilde{N}^* N^*_t} \right).$$

The average price index $\tilde{P}_t$ is closer to the actual CPI data constructed by statistical agencies than the welfare-based index $P_t$, and, therefore, it is the data-consistent CPI implied by the model. In turn, given any variable $X_t$ in units of consumption, its data-consistent counterpart is:

$$X_{R,t} \equiv \frac{X_t P_t}{\tilde{P}_t} = \frac{X_t}{\Omega_t^{\frac{1}{\phi-1}}}.$$

The European Central Bank has a mandate of price stability defined in terms of a (harmonized) index of consumer price inflation. Since we will calibrate the model to features of EMU, this motivates our specification of the historical rule for interest-rate setting as a rule in which policy responds to movements in a country-weighted average of data-consistent CPI inflation and data-consistent GDP gaps relative to the equilibrium with flexible wages and prices:

$$1 + i_{t+1} = (1 + i_t)^{\varrho_i} \left[ (1+i) \left( 1 + \tilde{\pi}^U_{C,t} \right)^{\varrho_\pi} \left( \tilde{Y}^U_{g,t} \right)^{\varrho_Y} \right]^{1-\varrho_i}, \tag{17}$$

where $\tilde{\pi}^U_{C,t} \equiv \tilde{\pi}^{\frac{1}{2}}_{C,t} \tilde{\pi}^{*\frac{1}{2}}_{C,t}$ is data-consistent, union-wide CPI inflation, and $\tilde{Y}^U_{g,t} \equiv \tilde{Y}^{\frac{1}{2}}_{g,t} \tilde{Y}^{*\frac{1}{2}}_{g,t}$ is the data-consistent, union-wide GDP gap.[34]

[33] There is much empirical evidence that gains from variety are mostly unmeasured in CPI data, as documented most recently by Broda and Weinstein (2010).

[34] All union-wide variables below are defined as $X^U_t \equiv X^{\frac{1}{2}}_t X^{*\frac{1}{2}}_t$.

Table 1 summarizes the key equilibrium conditions of the model, including the policy rule (17). We rearranged some equations appropriately for transparency of comparison to the planner's optimum obtained below, which we will use to build intuition for the tradeoffs facing the Ramsey policymaker. The table contains 21 equations that determine 21 endogenous variables of interest: $C_t, C_t^*, \rho_{d,t}, \rho_{d,t}^*, l_t, l_t^*, V_t, V_t^*, N_t, N_t^*, J_t, J_t^*, h_t, h_t^*, \pi_{w,t}, \pi_{w,t}^*, \pi_{C,t}, \pi_{C,t}^*, i_{t+1}, Q_t$,and $a_{t+1}$. (Other variables that appear in the table are determined as described above.)

**Ramsey-Optimal Monetary Policy**

The Ramsey authority maximizes aggregate welfare under the constraints of the competitive economy. Let $\{\Lambda_{1,t}, ..., \Lambda_{20,t}\}_{t=0}^{\infty}$ be the Lagrange multiplier associated to the equilibrium conditions in Table 1 (excluding the interest-rate setting rule).[35] The Ramsey problem consists in choosing

$$\{\pi_{C,t}, \pi_{C,t}^*, \pi_{w,t}, \pi_{w,t}^*, C_t, C_t^*, l_t, l_t^*, V_t, V_t^*, J_t, J_t^*, h_t, h_t^*, \rho_{d,t}, \rho_{d,t}^*, N_{t+1}, N_{t+1}^*, Q_t, i_{t+1}, a_{t+1}\}_{t=0}^{\infty},$$
$$\text{and } \{\Lambda_{1,t}, ..., \Lambda_{20,t}\}_{t=0}^{\infty}$$

to maximize:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{1}{2} \left( u\left(C_t\right) - l_t v\left(h_t\right) \right) + \frac{1}{2} \left( u\left(C_t^*\right) - l_t^* v\left(h_t^*\right) \right) \right] \tag{18}$$

subject to the constraints in Table 1 (excluding the interest rate rule).[36]

As common practice in the literature, we write the original non-stationary Ramsey problem in a recursive stationary form by enlarging the planner's state space with additional (pseudo) co-state variables. Such co-state variables track the value to the planner of committing to the pre-announced policy plan along the dynamics.

The Ramsey planner uses its policy instrument (the interest rate) to address the consequences of a set of distortions that exist in the market economy. To understand these distortions and the tradeoffs they create for optimal policy, it is instructive to compare the equilibrium conditions of the market economy summarized in Table 1 to those implied by the solution to a first-best, optimal planning problem. This allows us to define inefficiency wedges for the market economy (relative to the planner's optimum) and describe Ramsey policy in terms of its implications for these wedges.

[35] We assume that the other variables that appear in the table have been substituted out by using the appropriate equations and definitions above.

[36] In the primal approach to Ramsey policy problems described by Lucas and Stokey (1983), the competitive equilibrium is expressed in terms of a minimal set of relations involving only real allocations. In the presence of sticky prices and wages, it is impossible to reduce the Ramsey planner's problem to a maximization problem with a single implementability constraint.

## 4 Social Planner Allocation and Inefficiency Wedges

In this section, we derive the first-best allocation chosen by a benevolent social planner for the monetary union as a whole, and we define the inefficiency wedges that characterize the market economy.

The benevolent social planner chooses $\{C_t, C_t, l_t, l_t^*, V_t, V_t^*, h_t, h_t^*, Y_{d,t}, Y_{d,t}^*, Y_{x,t}, Y_{x,t}^*, N_{t+1}, N_{t+1}^*\}_{t=0}^{\infty}$ to maximize the welfare criterion (18) subject to six constraints (three for each economy). In the list of variables chosen by the planner, $Y_{d,t}, Y_{d,t}^*, Y_{x,t}$, and $Y_{x,t}^*$ denote the sub-bundles of country-specific final goods that enter the Armington aggregator for total absorption of consumption output ($Y_t^C$ and $Y_t^{C*}$) in each country. As usual, we present relevant equations for the Home economy, with the understanding that analogous equations hold in Foreign.

The first constraint is that intermediate inputs are used to produce final goods and create new product lines:

$$Z_t l_t h_t = \exp\left(\frac{\tilde{N} - N_t}{2\sigma \tilde{N} N_t}\right)(Y_{d,t} + Y_{x,t}) - \left(\frac{N_{t+1}}{1-\delta} - N_t\right) f_{T,t}, \tag{19}$$

where the exponential term converts units of consumption sub-bundles into units of intermediate inputs. Note that the only entry cost that is relevant to the social planner is the technological component of the overall entry cost $f_{E,t}$ facing firms in the decentralized economy. We denote the Lagrange multiplier associated to the constraint (19) with $\varpi_t$, which corresponds to the social marginal cost of producing an extra unit of intermediate output.

The second constraint is that total output can be used for consumption and vacancy creation:

$$C_t + \kappa V_t = \left[(1-\alpha)^{\frac{1}{\phi}} Y_{d,t}^{\frac{\phi-1}{\phi}} + \alpha^{\frac{1}{\phi}} Y_{x,t}^{*\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}}. \tag{20}$$

The Lagrange multiplier associated to this constraint, $\xi_t$, represents the social marginal utility of consumption resources. In the social planner's environment, $Y_t^C = C_t + \kappa V_t$. Note that, as for the technological cost of product creation $f_{T,t}$, we assume that the cost of vacancy posting $\kappa V_t$ is a feature of technology—the technology for job creation—that characterizes also the planner's environment. (This is a standard assumption in the literature on the DMP model.)

Finally, the third constraint is that the stock of labor in the current period is equal to the number of workers that were not exogenously separated plus previous period matches that become

productive in the current period:

$$l_t = (1-\lambda)l_{t-1} + \chi(1-l_{t-1})^{\varepsilon} V_{t-1}^{1-\varepsilon}. \tag{21}$$

The Lagrange multiplier associated to this constraint, $\zeta_t$, denotes the real marginal value of a match to society.

The first-order condition for consumption implies that $\xi_t = u_{C,t}$. The demand schedules for Home output are obtained by combining the first-order conditions with respect to $Y_{d,t}$, $Y_{x,t}$, $Y^*_{d,t}$ and $Y^*_{x,t}$:

$$Y_{d,t} = (1-\alpha)\left[\frac{\varpi_t}{\xi_t}\exp\left(\frac{\tilde{N}-N_t}{2\sigma\tilde{N}N_t}\right)\right]^{-\phi} Y_t^C, \qquad Y_{x,t} = \alpha\left[\frac{\varpi_t}{\xi_t^*}\exp\left(\frac{\tilde{N}-N_t}{2\sigma\tilde{N}N_t}\right)\right]^{-\phi} Y_t^{C*}. \tag{22}$$

Using the results in (22) and the analogs for Foreign output, it is possible to re-write equation (20) as:

$$1 = (1-\alpha)\left[\frac{\varpi_t}{\xi_t}\exp\left(\frac{\tilde{N}-N_t}{2\sigma\tilde{N}N_t}\right)\right]^{1-\phi} + \alpha\left[\frac{\varpi_t^*}{\xi_t}\exp\left(\frac{\tilde{N}^*-N_t^*}{2\sigma\tilde{N}^*N_t^*}\right)\right]^{1-\phi}$$

The optimality condition for $N_{t+1}$ equates the cost of creating a new product to its expected discounted benefit:

$$f_{T,t}\varpi_t = \beta(1-\delta)E_t\left\{\varpi_{t+1}\left[f_{T,t+1} + \exp\left(\frac{\tilde{N}-N_{t+1}}{2\sigma\tilde{N}N_{t+1}}\right)\frac{1}{2\sigma N_{t+1}}\left(\frac{Y_{d,t+1}+Y_{x,t+1}}{N_{t+1}}\right)\right]\right\}. \tag{23}$$

The first-order conditions for vacancies and employment yield:

$$\frac{\kappa}{q_t} = \beta E_t\left\{\frac{\xi_{t+1}}{\xi_t}\left[\varepsilon\left(\frac{\varpi_{t+1}}{\xi_{t+1}}Z_{t+1}h_t - \frac{v_{h,t}}{\xi_{t+1}}\right) + \left[1-\lambda-(1-\varepsilon)\,\iota_{t+1}\right]\frac{\kappa}{q_{t+1}}\right]\right\}, \tag{24}$$

where $q_t \equiv M_t/V_t = \chi\left[(1-l_t)/V_t\right]^{1-\varepsilon}$.is the probability of filling a vacancy implied by the matching function $M_t = \chi\,(1-l_t)^{1-\varepsilon}\,V_t^{\varepsilon}$, and $\iota_t \equiv M_t/\,(1-l_t) = \chi\left[V_t/(1-l_t)\right]^{\varepsilon}$ is the probability for a worker to find a job. Equation (24) shows that the expected cost of filling a vacancy $\kappa/q_t$ must be equal to its (social) expected benefit. The latter is given by the value of output produced by one worker net of the disutility of labor, augmented by the continuation value of the match.

Finally, the first-order condition for hours implies $v_{h,t} = \varpi_t Z_t$.

Table 2 summarizes the equilibrium conditions for the planned economy. To facilitate the

comparison between planned and market economy, we define the following relative prices for the planner's equilibrium: $\rho_{d,t} \equiv \varpi_t/\xi_t$, $\rho^*_{d,t} \equiv \varpi^*_t/\xi^*_t$, $\rho_{x,t} \equiv \varpi_t/\xi^*_t$, and $\rho^*_{x,t} \equiv \varpi^*_t/\xi_t$. Defining the social real exchange rate as $Q_t \equiv \xi^*_t/\xi_t$, the planner's outcome is characterized by optimal risk sharing: $Q_t = u^*_{C,t}/u_{C,t}$. Moreover, the law of one price holds also in the planned economy $\rho_{x,t} = \rho_{d,t}/Q_t$ and $\rho^*_{x,t} = Q_t\rho^*_{d,t}$. Finally, recall that $Y_{d,t}$ represents the aggregate demand for Home goods at Home. The amount of output produced by each Home firm for the Home market is given by $y_{d,t} = \exp\left(\frac{\tilde{N}-N_t}{2\sigma\tilde{N}N_t}\right) Y_{d,t}/N_t$. Analogously, the amount of output produced by each Home firm for the export market is $y_{x,t} = \exp\left(\frac{\tilde{N}-N_t}{2\sigma\tilde{N}N_t}\right) Y_{x,t}/N_t$.

We can now derive the inefficiency wedges induced by distortions in the model. We do so by comparing the equilibrium allocation in the decentralized economy (Table 1) to the one chosen by the social planner (Table 2). Table 3 summarizes the distortions that characterize the decentralized economy.

Comparing the socially efficient outcome to the market economy shows that our model features eleven sources of distortion that affect five margins of adjustment and the resource constraint for consumption output:

- **Product creation margin:** Translog preferences and sticky prices result in inefficient time-variation of markups: $\Upsilon_{\mu,t} \equiv \mu_{t-1}/\mu_t - 1$. Moreover, both price stickiness and translog preferences imply that the (time-varying) net markup is not aligned with the benefit of product variety to consumers: $\Upsilon_{N,t} \equiv \mu_{t-1}\left(1 - \nu\pi^2_{d,t}/2\right) - 1 - 1/(2\sigma N_t)$. These distortions are at work in Bilbiie, Fujiwara, and Ghironi (2011). The product creation margin in our model is distorted also by the existence of a non-technological component, $f_{R,t}$, of the overall entry cost, $f_{E,t}$, which results in the regulation distortion $\Upsilon_{R,t} \equiv f_{R,t}$.[37] As we show in the Appendix, these three distortions are combined in the product creation wedge $\Sigma_{PC,t}$ between the market economy and the planned outcome:

$$\Sigma_{PC,t} \equiv -\Upsilon_{R,t} + \beta(1-\delta)E_t\left\{\frac{\rho_{d,t+1}}{\rho_{d,t}}\left[\begin{array}{c}\Upsilon_{\mu,t+1}f_{T,t+1} + (1+\Upsilon_{\mu,t+1})\Upsilon_{R,t+1} \\ +\left(\Upsilon_{N,t+1} - \Upsilon_{\mu,t+1}\right)\left(y_{d,t+1} + y_{x,t+1}\right)\end{array}\right]\right\}.$$

  Absent the distortions ($\Upsilon_{\mu,t} = \Upsilon_{N,t} = \Upsilon_{R,t} = 0$), the product creation wedge is zero.

[37] Bilbiie, Ghironi, and Melitz (2008b) and Chugh and Ghironi (2011) consider the case $f_{R,t} = -\tau^E_t f_{T,t}$ and discuss the determination of optimal product creation subsidies $\tau^E_t$ in a first- or second-best environment, respectively. We focus on the consequences of an exogenous deregulation that reduces non-technological barriers to entry, abstracting from the issue of optimal entry subsidies (or taxes).

- **Job creation margin:** Monopoly power distorts the job creation decision by inducing a suboptimally low return from vacancy posting, captured by $\Upsilon_{\varphi,t} \equiv (1/\mu_t) - 1$. Failure of the Hosios condition (for which equality of the firm's bargaining share and the vacancy elasticity of the matching function is necessary for efficiency) is an additional distortion in this margin, measured by $\Upsilon_{\eta,t} \equiv \eta_t - \varepsilon$. This is affected both by the flexible-wage value of the bargaining share ($\eta$, which can be different from $\varepsilon$) and the presence of wage stickiness, which induces time variation of $\eta_t$. Sticky wages are sufficient to generate a wedge between private and social returns to vacancy posting. Moreover, they distort job creation also by affecting the outside option of firms through an additional term $\Upsilon_{\pi_w,t} \equiv \vartheta \pi_{w,t}^2/2$. Finally, unemployment benefits increase the workers' outside option above its efficient level: $\Upsilon_{b,t} \equiv b$. (As for regulation, we do not discuss the optimal determination of unemployment benefits, and we simply take $b$ as exogenous.) In the Appendix, we show that these four distortions combine in the job creation wedge $\Sigma_{JC,t}$:

$$\begin{aligned}\Sigma_{JC,t} &= \Upsilon_{\eta,t}\left(\Upsilon_{\varphi,t}\rho_{d,t}Z_t h_t - \frac{v_{h,t}}{u_{C,t}}\right) - \eta_t\left(\Upsilon_{\pi_w,t} + \Upsilon_{b,t}\right) \\ &\quad + E_t\left\{\beta_{t,t+1}\left[\left((1-\lambda)\eta_t + (1-\lambda-\iota_t)(1-\eta_{t+1})\frac{\eta_t}{\eta_{t+1}}\right) - \left(1-\lambda-(1-\varepsilon)\,\iota_t\right)\right]\Sigma_{JC,t+1}\right\},\end{aligned}$$

which is zero (by contraction mapping with discounting) when $\Upsilon_{\varphi,t} = \Upsilon_{\eta,t} = \Upsilon_{b,t} = \Upsilon_{\pi_w,t} = 0$.

- **Labor supply margin:** With endogenous labor supply, monopoly power in product markets, $\Upsilon_{\varphi,t} \equiv (1/\mu_t) - 1$, induces a misalignment of relative prices between consumption goods and leisure, as discussed in Bilbiie, Ghironi, and Melitz (2008b). This is the distortion that characterizes standard New Keynesian models without labor market frictions. The associated wedge $\Sigma_{h,t} \equiv \Upsilon_{\varphi,t}$, which is time-varying for the presence of translog preferences and sticky prices, is also at work in Bilbiie, Fujiwara, and Ghironi (2011).

- **Cross-country risk sharing margin:** Incomplete markets imply inefficient risk sharing between Home and Foreign households, resulting in the distortion $\Upsilon_{Q,t} \equiv \left(u_{C,t}^*/u_{C,t}\right) - Q_t$. The departure of relative consumption from the perfect risk sharing outcome is also affected by the costs of adjusting bond holdings (the distortion $\Upsilon_{a,t} \equiv \tau a_{t+1}$ and its Foreign mirror image in the Euler equations for Home and Foreign holdings of bonds). We summarize the combined effect of these distortions with the financial inefficiency wedge $\Sigma_{RS,t} \equiv \left(u_{C,t}^*/u_{C,t}\right) - Q_t = \Upsilon_{Q,t}$.

- **International relative price margin:** Adjustment of international relative prices in the model is summarized by the condition that ties real exchange rate dynamics to relative inflation in consumer price indexes: $Q_t/Q_{t-1} = \left(1+\pi^*_{C,t}\right)/\left(1+\pi_{C,t}\right)$. With sticky wages and prices, as long as the model does not satisfy the conditions such that a fixed exchange rate is optimal, monetary union distorts this margin of adjustment by removing adjustment through the nominal exchange rate.[38] Unfortunately, this distortion cannot be summarized by an analytically defined wedge relative to the planner's optimum, because the planned economy does not feature nominal rigidity. (A consequence of this is that there is no expression for this distortion in Table 3.)

- **Consumption resource constraint:** Sticky wages and prices imply diversion of resources from consumption and creation of new product lines and vacancies, with the distortions $\Upsilon_{\pi_w,t} \equiv \vartheta\pi^2_{w,t}/2$ and $\Upsilon_{\pi_d,t} = \nu\pi^2_{d,t}/2$. The associated wedge (defined by the sum of these distortions: $\Sigma_{Y^C,t} \equiv \Upsilon_{\pi_w,t} + \Upsilon_{\pi_d,t}$) is zero under flexible wages and prices.

The market allocation is efficient only if all the distortions and associated inefficiency wedges are zero at all points in time. Efficiency can be achieved only if the following two conditions are jointly satisfied: (i) Countries are fully symmetric at each point in time; and (ii) governments in each country have access to an appropriate set of distortionary and lump-sum fiscal instruments that are optimally chosen *together* with monetary policy. Full symmetry across countries is required to overcome the consequences of financial market incompleteness and the fixed nominal exchange rate. In the symmetric case, optimal monetary policy sets producer price inflation to zero (which also ensures zero wage inflation under full symmetry). Optimal fiscal policy realigns benefit from variety and markup, eliminates the effects of monopoly power, and sets unemployment benefits and product regulation to zero.[39] Since we abstract from optimal fiscal policy and focus on asymmetric shocks, it follows that we work in a second-best environment in which the efficient allocation cannot be achieved. In this second-best environment, the Ramsey central bank optimally uses its leverage on the economy via the sticky-price and sticky-wage distortions, trading off their costs (including the resource costs) against the possibility of addressing the distortions that characterize the market economy under flexible wages and prices.

[38] With flexible exchange rates, it would be $Q_t/Q_{t-1} = \left(1+\pi^*_{C,t}\right) S_t/\left[\left(1+\pi_{C,t}\right) S_{t-1}\right]$, where $S_t$ is the nominal exchange rate. Note that this distortion from the irrevocably fixed exchange rate is at work also when asset markets are complete.

[39] See Bilbiie, Ghironi, and Melitz (2008b) and Chugh and Ghironi (2011) for discussions of optimal fiscal policy in the BGM model.

## 5 Calibration and Model Properties

### Calibration

We interpret periods as quarters and calibrate the model to match Euro Area macroeconomic data from 1985:Q1 to 2007:Q4. Table 4 summarizes the calibration, which is assumed symmetric across countries. (Variables without time indexes denote steady-state levels.) We set the discount factor $\beta$ to 0.99, implying an annual real interest rate of 4 percent. The period utility function is given by $u_t = C_t^{1-\gamma_C}/(1-\gamma_C) - l_t h_t^{1+\gamma_h}/(1+\gamma_h)$. The risk aversion coefficient $\gamma_C$ is equal to 2, while the Frisch elasticity of labor supply $1/\gamma_h$ is set to 0.2, a value consistent with empirical micro estimates.[40] To calibrate the translog parameter, $\sigma$, we proceed as follows. In Ghironi and Melitz's (2005) model with Dixit-Stiglitz (1977) preferences, the elasticity of substitution across product varieties is set to 3.8 following Bernard, Eaton, Jensen, and Kortum (2003), who find that this value fits U.S. plant and macro trade data. We set $\sigma$ so that our model with translog preferences implies the same steady-state markup as Ghironi and Melitz's calibration.[41] As Ghironi and Melitz, we set substitutability between Home and Foreign goods in the consumption aggregator, $\phi$, to 3.8.[42] The degree of home bias $1-\alpha$ is set to 0.8, a conventional value in the literature. To ensure steady-state determinacy and stationarity of net foreign assets, we set the bond adjustment cost $\tau$ to 0.0025 as in Ghironi and Melitz (2005).

The scale parameter for the cost of adjusting prices, $\nu$, is equal to 80, as in Bilbiie, Ghironi, and Melitz (2008a). We choose $\vartheta$, the scale parameter of nominal wage adjustment costs, so that the model reproduces the volatility of unemployment relative to GDP observed in the data. This implies $\vartheta = 60$.

We keep technological entry costs not related to bureaucratic procedures constant: $f_{T,t} = f_T$ in all periods. Following Barseghyan and DiCecio (2011), we assume that $f_T$ is 18 percent of quarterly output. As a proxy for goods market regulation in the Euro Area, we consider a weighted average of regulation costs across member countries, with weights equal to the contributions of individual

[40] The value of this elasticity has been a source of controversy in the literature. Students of the business cycle tend to work with elasticities that are higher than microeconomic estimates, typically unity and above. Most microeconomic studies, however, estimate this elasticity to be much smaller, between 0.1 and 0.6. For a survey of the literature, see Card (1994). Our results are not affected significantly if we hold hours constant at the optimally determined steady-state level.

[41] This implies a 36 percent markup of price over marginal cost. It may be argued that this is too high. However, in our model, free entry ensures that firms earn zero profit net of entry cost. This means that firms price at average cost (inclusive of the entry cost). Thus, although our calibration implies a fairly high markup over marginal cost, it delivers plausible results with respect to pricing and average cost.

[42] The conventional choice of 1.5 for this Armington elasticity does not alter any of our main results significantly.

countries' GDPs to Euro Area total GDP. To calibrate the initial value of entry costs related to regulation, $f_R$, we use Pissarides's (2003) index of entry delay, which computes the number of business days that it takes (on average) to fulfill entry requirements. Following Ebell and Haefke (2009), we convert this index in months of lost output. The implied cost of regulation is 69 percent of quarterly steady-state output.

We set unemployment benefits, $b$, so that the model reproduces the average replacement rate, $b/(wh)$, for the Euro Area reported by OECD (2004). The elasticity of the matching function, $\varepsilon$, is equal to 0.5, within the range of estimates reported by Petrongolo and Pissarides (2006). The steady-state bargaining share of firms, $\eta$, is equal to $\varepsilon$, so that the Hosios condition holds in steady state. The exogenous separation rate between firms and workers, $\lambda$, is 6 percent, as reported in Campolmi and Faia (2011). To pin down exogenous producer exit, $\delta$, we target the portion of worker separation due to plant exit. This number ranges between 25 and 55 percent in EMU members (see Haltiwanger, Scarpetta, and Schweiger, 2008). We choose a midpoint of these estimates so that the exit of plants accounts for 40 percent of overall job destruction.[43]

Two labor market parameters are left for calibration: the scale parameter for the cost of vacancy posting, $\kappa$, and the matching efficiency parameter, $\varkappa$. As common practice in the literature, we calibrate these parameters to match the steady-state average unemployment rate across EMU countries and the probability of filling a vacancy. The former is 9.8 percent, while the latter is 70 percent, in line with estimates reported by ECB (2002) and Weber (2000).

For the bivariate productivity process, we set persistence and spillover parameters consistent with evidence in Baxter (1995) and Baxter and Farr (2005), implying zero spillovers across countries and persistence equal to 0.999. We refer to this as Baxter calibration below. We perform sensitivity analysis by considering also values in Backus, Kehoe, and Kydland (1992, 1994), with lower persistence at 0.906 and positive spillovers at 0.088 (BKK calibration below). We set the standard deviation of productivity innovations at 0.0068 to match the absolute volatility of Euro Area GDP, but leave the covariance of innovations at the standard 0.19 percent of Baxter (1995) and Backus, Kehoe, and Kydland (1992, 1994).[44]

[43] This yields a value for $\delta$ that is very close to the calibration (0.025) in BGM.

[44] Using the 0.73 percent standard deviation of innovations in Baxter (1995) and Backus, Kehoe, and Kydland (1992, 1994) does not alter any of our main results. Only the absolute volatility of GDP is affected and, as a consequence, the absolute magnitude of welfare costs of business cycles (for given regulation level). We also experimented with the bivariate productivity process for the Euro Area in Canzoneri, Cumby, Diba, and Mykhaylova (2006), which is roughly similar to that estimated for France and Germany by Collard and Dellas (2002). The key difference is that this process features less persistent productivity (0.76). While the performance of the model remains quite good, this parametrization results in excessively smooth consumption relative to the data and a less satisfactory match of international correlations. We settled on the Baxter calibration as benchmark given the stronger consensus for very

Finally, the parameter values in the historical rule for the ECB's interest rate setting are those estimated by Gerdesmeier and Roffia (2003). The inflation and GDP gap weights are 1.93 and 0.075, respectively, while the smoothing parameter is 0.87.

**Model Properties**

We begin our analysis by discussing the propagation mechanism of productivity shocks in the model. Since the purpose of the paper is to provide a quantitative characterization of optimal monetary policy following market deregulation, we validate the model by testing its ability to reproduce the cyclical behavior of key macroeconomic variables in the Euro Area.

*Impulse Responses*

Figure 1 (solid lines) shows impulse responses to a one-percent innovation to Home productivity under the historical rule for ECB interest rate setting.[45] Focus on the Home country first. Unemployment ($U_t$) does not respond on impact, but it falls in the periods after the shock. The higher expected return of a match induces domestic intermediate input producers to post more vacancies on impact, which results in higher employment in the following period. Firms and workers (costly) renegotiate nominal wages because of the higher surplus generated by existing matches, and wage inflation ($\pi_{w,t}$) increases. Wage adjustment costs make the effective firm's bargaining power procyclical, i.e., $\eta_t$ rises. To understand why this happens, recall equations (8), (9), and (11). Notice that $\partial J_t/\partial w_t$ is the change in firm surplus due to a change in nominal wages. The first term in the expression (8) for $\partial J_t/\partial w_t$ reflects the fact that, when the nominal wage increases by one dollar, the nominal surplus is reduced by the same amount (times the number of worked hours); the second term is the wage adjustment cost paid by the firm; and the last term represents the expected savings on future wage adjustments if wages are renegotiated today. When the first two effects are larger than the third one, the firm's bargaining share rises. Intuitively, $\eta_t$ shifts upward to ensure optimal sharing of the cost of adjusting wages between firms and workers. Other things equal, the increase in $\eta_t$ dampens the response of the renegotiated equilibrium wage, amplifying the response of job creation to the shock.

Employment and labor income rise in the more productive economy, boosting aggregate demand for final goods and household consumption ($C_t$). The larger present discounted value of future

persistent productivity processes in the literature.

[45] Dashed lines show responses under the Ramsey-optimal policy (discussed below). For comparability, all responses in the figure are computed around the Ramsey-optimal steady state.

profits generates higher expected return to product creation, stimulating producer entry ($N_{E,t}$) and investment ($I_t \equiv N_{E,t}e_t$) at Home. Price stickiness and increased substitutability across a larger number of available domestic varieties result in mildly countercyclical final producer markups ($\mu_t$).

Product creation falls temporarily in the Foreign country as resources are shifted to Home to finance increased entry in the more productive economy. Accordingly, Home runs a current account deficit in response to the shock ($CA_t$ falls on impact), as Home households borrow from abroad to finance higher investment in new products. Although Foreign households cannot hold shares in the mutual portfolio of Home firms (since only bonds are traded across countries), the return on bond holdings is tied to the return on share holdings in Home firms by no-arbitrage between bonds and shares within each country. Therefore, Foreign households share the benefit of higher Home productivity by shifting resources to Home via lending. Moreover, Home's terms of trade ($TOT_t \equiv p_{x,t}/p^*_{x,t}$) depreciate, i.e., Home goods become relatively cheaper. This shifts world demand toward Home goods (expenditure switching), but also generates a positive wealth effect for Foreign households, whose consumption rises. In contrast to the results of standard international real business cycle (IRBC) models, the combination of expenditure switching and resource shifting is not sufficient to imply negative comovement of GDP ($Y_t$) and employment across countries. The increase in aggregate demand at Home (which falls on both domestic and imported goods) is strong enough to ensure that trade linkages generate positive comovement of GDP and labor market variables. Interestingly, the adjustment in the Foreign economy takes place mostly along the intensive margin, as the reduction in Foreign product creation is short-lived and followed by a very mild increase as demand stimulates some entry in the Foreign final sector.

The historical policy rule yields muted responses of Home and Foreign producer price inflation ($\pi_{d,t}$ and $\pi^*_{d,t}$) to the shock. In fact, the adjustment of the economy closely mimics that under a policy of zero deviations of area-wide producer price inflation from its long-run target.[46]

*Second Moments*

Table 5 presents model-implied, HP-filtered second moments under the Baxter calibration of the bivariate productivity process (normal fonts) and the alternative BKK calibration (italics). Bold fonts denote data moments. Area-wide moments are computed from the AWM database; cross-country correlations are averages of bilateral correlations between the four largest euro area economies.

The model correctly reproduces the volatility of area-wide consumption, investment, and real

[46] Impulse responses for a policy of strict producer price stability are available upon request.

wages relative to GDP and generates first-order autocorrelations in line with the data. It also correctly captures the cyclicality of employment and is not far from its persistence.[47] This successful performance is a result of the model's strong propagation mechanism. Investment volatility is lowered relative to the excessive volatility generated by a standard IRBC framework because product creation requires hiring new workers. This process is time consuming due to search and matching frictions in the labor market, dampening investment dynamics. In contrast, consumption is more volatile than in traditional models as shocks induce larger and longer-lasting income effects.

With respect to the international dimension of the business cycle, the model successfully reproduces a ranking of cross-country correlations that is a challenge for standard IRBC models: Although lower than in the data, GDP correlation is larger than consumption correlation. This result depends both on model features and the parametrization of technology shocks. As shown in Figure 1, an increase in Home productivity generates Foreign expansion through trade linkages, as demand-side complementarities more than offset the effect of resource shifting to the more productive economy. Moreover, absent technology spillovers, Foreign consumers have weaker incentives to increase consumption on impact, which reduces cross-country consumption correlation.

As shown in Table 5, results are largely unaffected under the BKK calibration of exogenous shocks. The only exception is the magnitude and ranking of cross-country GDP and consumption correlations: The correlation of consumption is now higher than that of GDP. This result is explained by the Foreign permanent income effect of productivity spillovers, which induces Foreign households to increase consumption on impact in anticipation of future higher domestic productivity.[48]

## 6 Optimal Monetary Policy with High Market Regulation

We now characterize the Ramsey-optimal monetary policy in the presence of the high market regulation implied by our historical calibration. First, we study optimal monetary policy in the long run, then we turn to the Ramsey allocation over the business cycle.

[47] The absolute volatility of GDP and unemployment is matched by construction. The close match between data- and model-implied real wage moments provides indirect support for our calibration of the nominal wage adjustment cost.

[48] Importantly, however, the model generates positive and sizable GDP comovement regardless of the productivity parametrization. Standard IRBC models predict negative or negligible cross-country GDP correlation under the BKK calibration. Resource-shifting and the permanent income hypothesis dominate dynamics in those models.

**Optimal Monetary Policy in the Long Run**

First, it is immediate to verify that long-run inflation is always symmetric across countries regardless of symmetry or asymmetry of the calibration. This result follows from the presence of a common nominal interest rate in the monetary union and the steady-state Euler equations of households:

$$1 + \pi_d = 1 + \pi_C = \beta(1 + i) = 1 + \pi_C^* = 1 + \pi_d^*.$$

Moreover, wage inflation is always equal to producer price inflation: $\pi_d = \pi_{w.}$

Our interest in this section is in how the Ramsey central bank determines the optimal common inflation rate $\pi_d$ to address the distortions discussed in Section 4. To begin understanding long-run policy incentives, notice that a symmetric long-run equilibrium with constant endogenous variables eliminates some of these distortions: A constant markup removes the markup variation distortion from the product creation margin ($\Upsilon_\mu = 0$); Symmetry across countries removes the risk-sharing distortion of incomplete markets, and constant, zero net foreign assets eliminate the effect of asset adjustment costs; Finally, symmetry also eliminates the international relative price distortion of monetary union by implying $Q = 1$ (as a result of symmetry, $\Upsilon_Q = \Upsilon_a = \Sigma_{RS} = 0$).

Table 6 shows that the optimal long-run target for net inflation under the historically high regulation is positive and equal to 1.20 percent, in the range of the ECB's mandate. (All results in Table 6 and the following tables are annualized.) The finding of an optimal positive long-run inflation is in contrast with the prescription of near zero inflation delivered by the vast majority of New Keynesian models. While the costs of inflation outweigh the benefits of reducing other distortions in those models, this is no longer the case with a richer microfoundation of product and labor markets.[49]

To understand why the Ramsey allocation prescribes positive long-run inflation, observe first that all the remaining steady-state distortions but the costs of wage and price adjustment require a reduction of markups. As discussed in Bilbiie, Ghironi, and Melitz (2008b) and Bilbiie, Fujiwara, and Ghironi (2011), translog preferences imply that the steady-state, flexible-price markup is higher than the benefit of product variety to the consumer. *Ceteris paribus*, this results in suboptimal product creation. Smaller net markups contribute to realigning the firms' incentive for product

[49] Bilbiie, Ghironi, and Fujiwara (2011) obtain a similar result in a closed economy model with a Walrasian labor market and flexible wages. Cacciatore and Ghironi (2012) show that labor market frictions and sticky wages (but flexible prices) are sufficient to generate significant departures from zero optimal long-run inflation under flexible exchange rates.

creation and the consumers' benefit from variety. Moreover, a smaller markup narrows the wedge in labor supply and results in increased vacancy posting by firms. A decrease in markups can be achieved by means of positive net inflation. At the same time, since $\pi_d = \pi_w$, positive inflation implies a departure from the Hosios condition ($\eta > \varepsilon$). The Ramsey authority further stimulates job creation by increasing the bargaining power of firms. However, the Ramsey authority must trade the beneficial welfare effects of reducing these distortions against the costs of non-zero inflation implied by allocating resources to price and wage changes and by the departure from the Hosios condition. Compared to the zero inflation outcome, the Ramsey authority reduces the inefficiency wedges in product creation ($\Sigma_{PC}$), job creation ($\Sigma_{JC}$), and labor supply ($\Sigma_h$).

Table 6 also presents the welfare gain from implementing the long-run optimal policy relative to the ECB's historical behavior. To compute this welfare gain avoiding spurious welfare reversals, we assume identical initial conditions across different monetary policy regimes and include transition dynamics in the computation. Specifically, we assume that all the state variables are set at their steady-state levels under the historical policy at time $t = -1$, regardless of the monetary regime from $t = 0$ on. We compare welfare under the continuation of historical policy from $t = 0$ on (which implies continuation of the historical steady state) to welfare under the optimal long-run policy from $t = 0$ on (which implies a transition between the initial implementation at $t = 0$ and the Ramsey steady state). We measure the long-run welfare gains of the Ramsey policy in the two countries (which are equal by symmetry) by computing the percentage increase $\Delta$ in consumption that would leave the household indifferent between policy regimes. In other words, $\Delta$ solves:

$$\sum_{t=0}^{\infty} \beta^t u\left(C_t^{Ramsey}, h_t^{Ramsey} l_t^{Ramsey}\right) = \frac{u\left[\left(1+\frac{\Delta}{100}\right) C^{Hist}, h^{Hist} l^{Hist})\right]}{1-\beta}.$$

Table 6 shows that the welfare gains from the Ramsey-optimal policy amount to approximately 0.25 percent of annualized steady-state consumption.[50]

**Optimal Monetary Policy over the Business Cycle**

Stochastic fluctuations in aggregate productivity modify the policy tradeoffs facing the Ramsey authority by reintroducing the distortions eliminated by symmetry and absence of time variation in steady state. Moreover, Ramsey-optimal long-run policy does not close the steady-state inefficiency wedges. Thus, the Home and Foreign economies fluctuate around a steady state where markups

[50] Our results are not sensitive to the choice of (identical) initial conditions for the state variables.

and unemployment are inefficiently high. As a result, shocks trigger larger fluctuations in product and labor markets (in both economies) than in the efficient allocation: Both producer entry and unemployment are suboptimally volatile.

Figure 1 (dashed lines) shows impulse responses to a Home productivity increase under the Ramsey-optimal policy. Relative to the historical rule (i.e., a policy of near price stability, defined as zero deviation of inflation from trend), the Ramsey authority generates a smaller increase in wage inflation and a larger departure from price stability (disinflation) at Home. Instead, both prices and wages fall in Foreign. Unemployment falls at Home, but now it rises in Foreign.

To understand these results, it is instructive to characterize the policy tradeoffs facing the central bank over the business cycle. First, as in steady state, there is a tension between the beneficial effects of manipulating inflation and its costs. Second, there is a tradeoff between stabilizing price inflation (which contributes to stabilizing markups) and wage inflation (which stabilizes unemployment) at Home. Therefore, it is impossible to stabilize unemployment and markups jointly over the cycle. Third, there is a tension between stabilizing the Home and Foreign economies in response to asymmetric shocks.

These three policy tradeoffs explain why a policy of price stability is suboptimal: Wage inflation is too volatile, and markup stabilization correspondingly too strong, under this policy. Following fluctuations in aggregate productivity, sticky wages and positive unemployment benefits generate real wage rigidities, i.e., a positive (negative) productivity shock is not fully absorbed by the rise (fall) of the real wage, affecting job creation over the cycle. Higher Home productivity pushes the real wage above its steady-state level, as the real value of existing matches has increased. Under a policy of price stability, the effect of wage stickiness is magnified, since the real wage becomes even more rigid. Firms post too many vacancies and, in equilibrium, nominal wage adjustment costs are too large.[51] Finally, both historical ECB behavior and price stability result in positive employment comovement across countries. In contrast, the Ramsey authority pushes unemployment rates in opposite directions by engineering wage disinflation rather than inflation in the Foreign country and a reduction in Foreign firms' bargaining share. This results in higher unemployment in the relatively less productive economy. In the Home country, producers have a weaker incentive to post vacancies as more stable wage inflation implies that their effective bargaining power rises by less than under the historical policy. Lower job creation translates into smaller employment gains, which

[51] Notice, however, that a policy that completely stabilizes wage inflation is also suboptimal. In this case, there would be too much inflation and markup volatility, and the response of unemployment would be too small.

reduces domestic aggregate demand for Home and Foreign goods. Trade linkages and risk sharing still imply positive comovement of GDP and consumption across countries. While the standard New Keynesian prescription of price stability amounts to a prescription of procyclical monetary policy, with expansion in response to favorable productivity shocks to mimic the flexible-price equilibrium, optimal policy in our monetary union with multiple distortions is more countercyclical than historical behavior. The Ramsey central bank induces a larger drop in inflation (and markups) in both countries following an expansionary shock at Home, but it expands more aggressively in the opposite case of a contractionary shock.[52]

As for the long-run optimal policy, we compare policy regimes by computing the welfare gains for the two countries from optimal policy in the monetary union over the cycle. Specifically, we compute the percentage $\Delta$ of steady-state consumption that would make households indifferent between living in a world with uncertainty under monetary policy $m$, where $m = Ramsey$ or $Hist$, and living in a deterministic Ramsey world:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(C_t^m, h_t^m l_t^m) = \frac{u\left[\left(1 + \frac{\Delta}{100}\right) C^{Ramsey}, h^{Ramsey} l^{Ramsey})\right]}{1-\beta}.$$

First-order approximation methods are not appropriate to compute the welfare associated with each monetary policy arrangement. The solution of the model implies that the expected value of each variable coincides with its non-stochastic steady state. However, in an economy with a distorted steady state, volatility affects both first and second moments of the variables that determine welfare. Hence, we compute welfare by resorting to a second-order approximation of the policy functions. Table 7 shows that the welfare loss from not implementing optimal policy over the business cycle is 0.2 percent of annualized, steady-state consumption: Optimal departures from price stability lower the cost of business cycles from .95 percent of steady-state consumption under the historical policy to .75 percent. Overall, the implementation of optimal monetary policy over the cycle and in the long run increases welfare by approximately .5 percent of steady-state consumption under the market status quo.

[52] In the standard New Keynesian model, higher inflation is associated with a falling markup. The contemporaneous occurrence of falling inflation and markups in our model is a result of labor market frictions that induce marginal costs to rise in the impact period of expansionary shocks. It follows that markups must fall to ensure falling output prices.

## 7 Optimal Monetary Policy and Market Deregulation

How does market deregulation affect optimal monetary policy? Structural policy changes pose a set of challenges for the central bank. First, reforms have permanent effects that may alter the optimal long-run inflation target. Second, monetary policy can shape the dynamic adjustment to the new long-run equilibrium during the transition period. Third, deregulation affects the way economies respond to aggregate shocks, with consequences for the optimal conduct of monetary policy over the business cycle. Finally, new policy tradeoffs emerge for the central bank if deregulation is asymmetric across members of the monetary union, raising the question of desirability of coordinated reforms.

In our exercises, product market deregulation is interpreted as a permanent decrease of regulatory barriers to product creation, $f_R$. Labor market reform is instead a permanent reduction of unemployment benefits, $b$, and employment protection, $\eta$.[53] We assume that these policy parameters are lowered to the corresponding U.S. levels, a standard benchmark for flexible markets. Pissarides (2003) reports that it takes (on average) 9 days to fulfill entry requirements in the U.S. The implied value of $f_R$ is 0.16. Unemployment benefits, $b$, are tied to the average replacement rate $b/(wh)$. The U.S. replacement rate documented by OECD (2004) is 0.54. To pin down the change in workers' bargaining power $\eta$, we follow the procedure described in Cacciatore and Fiori (2011), who consider the ratio of indexes of employment protection legislation in the United States and Europe. The implied value of $\eta$ is 0.4, consistent with the estimates in Flinn (2006).

### Dynamic Adjustment and Long-Run Effects of Market Deregulation

We begin by studying the optimal monetary policy response to Home market deregulation during the transition dynamics and in the long run. Given the large size of the deregulation shocks, we do not rely on approximation methods. Instead, exploiting the absence of uncertainty, we solve the model exactly using a Newton-type algorithm first proposed by Laffargue (1990). The details of the algorithm can be found in Juillard (1996).

*Product Market Deregulation*

To understand the optimal monetary policy response to product market deregulation, it is useful first to inspect the dynamic adjustment and new long-run equilibrium under historical policy. As shown in Figure 2 (solid lines), a reduction in barriers to entry at Home generates profitable

[53] We follow Blanchard and Giavazzi (2003) in proxying a reduction in employment protection with a reduction in the workers' bargaining power parameter $\eta$.

investment opportunities and product creation. Under financial autarky, this would require households to cut consumption and increase savings to finance the expansion in entry.[54] With an open capital account, increased entry can also be financed by borrowing from abroad. As a result, the deregulating economy runs a current account deficit during the first part of the transition. Consumption rises on impact at Home as part of the external borrowing is used to increase current consumption in anticipation of higher permanent future income. Producer entry boosts job creation, lowering unemployment, and wages increase. The initial effect of a product market reform is inflationary, which erodes markups on impact. Financial and trade linkages imply significant spillovers to Foreign along the transition. As Foreign consumers invest at Home, Foreign consumption falls, and unemployment rises. Furthermore, Home's terms of trade appreciate in response to the deregulation, with a negative wealth effect abroad.

In the second part of the transition, the larger number of available domestic products lowers markups at Home, boosting GDP, consumption and job creation. In turn, the Foreign economy recovers due to increased demand for its products at Home.

How do the responses to deregulation change under the Ramsey-optimal policy? As before, we assume that initial conditions are given by the rigid steady state under the historical policy (which features zero inflation). Figure 2 (dashed lines) shows that the Ramsey policy generates higher consumption and lower unemployment in the first two years after the reform. The Ramsey allocation initially induces smaller product creation by increasing inflation, i.e., reducing the real present discounted value of entry. This happens because the economy starts from a situation in which markups are too high, $\Upsilon_N > 0$, and incumbents are too small, $\Upsilon_\varphi > 0$. However, the Ramsey planner anticipates that the new long-run equilibrium will feature lower markups and a larger number of producers of more significant size. Therefore, the optimal policy reduces markups, boosts incumbent firm size, and increases employment at Home in anticipation of these long-run effects. Employment, GDP, and consumption in the Foreign, rigid economy are also favorably affected by the Ramsey policy on impact due to the larger demand for Foreign goods in the deregulating economy.

As time passes, the differences between Ramsey policy and historical rule vanish, at least in the deregulating economy. Product market deregulation reduces inefficiencies wedges. The optimal long-run inflation target remains positive but is smaller than under high regulation.

[54] Since incumbents and new entrants are not more productive, expansion of entry after deregulation requires higher saving under financial autarky, as noted by Ghironi and Melitz (2005).

To understand this result, it is useful to inspect how deregulation affects inefficiency wedges in the long run. First, recall that the markup is constant in steady state, and so $\Upsilon_\mu = 0$. Moreover, under the historical long-run zero net inflation, the Hosios condition implied by our calibration ensures that $\eta = \varepsilon$ and $\Upsilon_\eta = \Upsilon_{\pi_w} = \Upsilon_{\pi_d} = 0$. Finally, product market regulation does not change the value of unemployment benefits, leaving $\Upsilon_b$ unaffected. Thus, three distortions remain: $\Upsilon_N = (\mu - 1) - 1/(2\sigma N)$, the misalignment between the consumers' benefit from variety and the profit incentives for new entrants; $\Upsilon_\varphi = (1/\mu) - 1$, measuring the monopoly power distortion on labor supply and job creation; and $\Upsilon_Q = (u_C^*/u_C) - Q$, the incomplete markets distortion.

As barriers to entry fall, the number of products in the economy increases. With zero net inflation, the fall in markups due to increased competition is larger than the reduction in the consumers' benefit from variety, since $\partial \Upsilon_N / \partial N = -1/\left(2\sigma N^2\right) < 0$. It follows that lower regulatory costs reduce the misalignment between benefit from variety and incentives for product creation. Moreover, the reduction in markups also reduces the distortion $\Upsilon_\varphi$,since $\partial \Upsilon_\varphi / \partial N = -1/\left(\sigma N^2\right) < 0$. Intermediate input producers have stronger incentives to post vacancies, households have stronger incentives to supply effort, and employment and hours get closer to the respective efficient levels. Finally, given the asymmetric nature of the reform, the incomplete markets wedge is wider by construction. Absent complete markets, the increase in Home consumption is not fully shared by Foreign.

Long-run responses under the Ramsey-optimal policy are very similar to those under the historical rule because the reduction in the first two distortions dominates the planner's incentives an results in lower steady-state optimal inflation (1.07 percent, as shown in Table 6, where $Asy\ PMR$ stands for asymmetric product market reform).

To measure the desirability of reform we compute the percentage $\Delta$ by which steady-state consumption should be increased relative to the status quo (no deregulation *and* historical policy) to leave households indifferent between implementing the reform or not:

$$\sum_{t=0}^{\infty} \beta^t u(C_t^m, l_t^m, h_t^m) = \frac{u\left[\left(1 + \frac{\Delta}{100}\right) C^{SQ}, h^{SQ} l^{SQ})\right]}{1 - \beta},$$

where $SQ$ stands for status quo and $m$ denotes the monetary regime ($m = Ramsey$ or $Hist$). Table 6 shows that product market reform is highly beneficial for the deregulating country already under the historical policy, as welfare gains amount to 5 percent of annualized consumption at Home. There is a modest prosper-thy-neighbor effect, as welfare rises by approximately 0.2 percent of

steady state consumption in Foreign.

Table 6 also reveals that the welfare gains from implementing the optimal policy response to deregulation are positive but not large, in particular for the reforming country (the relative gain is approximately 0.1 percent of steady state consumption). In other words, welfare gains from the optimal policy along the transition have little impact on the lifetime welfare effect of the reform, which is dominated by the reduction of long-run inefficiency wedges operated by the deregulation. The welfare gain from Ramsey policy is also reduced in Foreign, but to a smaller extent: Product market distortions in the rigid economy are still in place, and welfare gains from non-zero long-run inflation are more significant at 0.2 percent of steady-state consumption.

Before turning to the effects of labor market reform, it is worth briefly discussing a potential policy tradeoff posed by asymmetric deregulation in a monetary union. As noted above, long-run inflation rates are equalized across countries regardless of asymmetric regulation. This suggests that, in the presence of asymmetric reforms, the Ramsey authority faces—at least in principle—an additional tradeoff: While a flexible product market requires less inflation, the rigid member of the monetary union still benefits from a higher long-run inflation target. As a result, the optimal policy must strike a balance between these two opposing needs. Table 6 shows that the Ramsey central bank makes both countries better off. Even if Ramsey inflation is not as high as without any deregulation, Home's reform has positive international spillovers that reduce the need for inflation abroad.

*Labor Market Deregulation*

We now study the consequences of a Home labor market reform in which unemployment benefits, $b$, and employment protection legislation, $\eta$, are lowered to their corresponding U.S. levels. As before, we begin by describing the dynamic adjustment and the long-run equilibrium under the historical monetary policy. As shown by Figure 3 (solid lines), labor market reform immediately boosts aggregate consumption, since households immediately increase demand in anticipation of higher future income. Different from product market reform, producer entry drops in the aftermath of labor market deregulation. As vacancy posting increases, the expected cost of filling a vacancy rises, pushing up the equilibrium price of intermediate inputs. This makes producer entry more costly. In a sense, incumbent firms have a competitive advantage relative to potential entrants since they do not have to incur the sunk cost to benefit from the labor market reform.

The international adjustment to an asymmetric labor market reform also does not involve costs for the non-reforming trading partner. A larger increase in Home's aggregate demand generates

positive spillovers for Foreign consumption and employment. These positive effects are short-lived, however. As time passes, falling wages in the flexible economy lower marginal costs, and terms of trade depreciation induces expenditure switching toward Home goods.[55]

The adjustment under the Ramsey-optimal policy implies smaller markups and higher employment along the transition. The intuition mirrors that for product market reform. Regardless of the nature of deregulation, the Ramsey authority ensures that inflationary pressure stimulates job creation and reduces markups along the first part of the transition, before the positive effects of deregulation are fully materialized. The effects of Ramsey policy in the Foreign economy are large and positive during the transition, since consumption and employment comove positively with Home.

Table 6 shows that labor market reform is highly beneficial for the deregulating country, with a welfare gain of approximately 3.5 percent of steady-state consumption. Moreover, the reform generates some positive welfare effects also in the Foreign economy. To understand this result, notice that changes in labor market regulation directly affect two distortions: The reduction in unemployment benefits brings the workers' outside option closer to the (real) costs of labor effort, lowering real wages and stimulating vacancy posting. The increase in the firms' bargaining power, instead, implies that $\eta$ is now greater than the elasticity of matches to vacancies, $\varepsilon$, a departure from the Hosios condition. It turns out that the labor market reform is beneficial even if the Hosios condition is violated post-deregulation. In our second best environment, the rigid, distorted steady state features suboptimally low job creation: The increase in $\eta$ brings employment closer to the social optimum.

As before, the discrepancies between Ramsey and historical allocations vanish in the long run. As time passes, the need to stimulate vacancy posting and reduce markups is reduced since deregulation per se reduces inefficiency wedges. Table 6 shows that the optimal level of long-run inflation falls in response to asymmetric labor market deregulation. Mirroring product market deregulation, the welfare gain from implementing the optimal monetary policy in response to the labor market deregulation is not large for the reforming economy. The positive effects of smaller long-run distortions dominate results, narrowing the welfare gap between historical and Ramsey policy at Home. The Ramsey policy instead remains relatively more desirable in the Foreign country.

*Product and Labor Market Deregulation*

[55] Current account deficit in the first part of the transition allows Home households to sustain higher consumption in anticipation of the long-run increase in income.

Figure 4 presents the adjustment following joint deregulation in goods and labor markets. The dynamic adjustment qualitatively mirrors that to product market reform. Quantitatively, the positive effect on consumption and employment is reinforced on impact and in the long run. Table 6 shows that joint market reform is more beneficial than deregulation of product or labor market alone, even if there is some substitutability across reforms, since the welfare gain is smaller than the sum of the gains from individual reforms.[56] The relative gain from Ramsey policy (with respect to the historical rule) becomes even smaller for the reforming country since reform of both markets further reduces real distortions in the new long-run equilibrium.

**Deregulation and Optimal Monetary Policy over the Business Cycle**

Market deregulation affects domestic and international adjustment to aggregate shocks. As a result, it alters the policy tradeoffs facing the central bank over the business cycle. In this section, we study these effects and evaluate their consequences for policy.

*Product Market Deregulation*

Figure 5 contrasts the effects of a one percent Home productivity shock before and after Home product market deregulation under the historical policy rule. When barriers to entry are relaxed, the economy fluctuates around a steady state with a larger number of firms, smaller markups, and smaller producer-level profits. Therefore, the present discounted value of entry varies by less (in percentage of the steady state) in response to aggregate disturbances, dampening markup fluctuations and product market dynamics. This effect, combined with a tighter labor market after the deregulation, implies that the employment response to shocks is also muted.[57] Table 8 summarizes the business cycle implications of product market deregulation: Volatility and persistence of output and employment fall in the reforming country, but the effect on Foreign dynamics and international business cycles is very small.

The welfare cost of business cycles falls significantly in the more flexible economy—by approximately 20 percent (Table 7)—while it falls only slightly in the rigid country. This is explained by the fact that Home markups are less volatile with a flexible product market, resulting in less volatile employment. In contrast, the welfare costs of business cycles in the Foreign economy are not significantly affected since they remain dominated by domestic rigidities.

[56] See Cacciatore and Fiori (2010) for a detailed discussion of substitutability across reforms. The result is consistent with the empirical evidence in Fiori, Nicoletti, Scarpetta, and Schiantarelli (2012).

[57] Notice that productivity shocks put less pressure on nominal wage inflation after the deregulation, since the increase in the surplus from existing matches is smaller.

Turning to the Ramsey-optimal policy, Figure 6 shows that the Ramsey authority becomes less aggressive after the deregulation. Deregulation (even if asymmetric across countries and limited to product markets) ameliorates domestic and international policy trade-offs. At Home, a more flexible product market dampens volatility for the same reasons as under historical policy. Moreover, stabilization of cyclical fluctuations at Home requires less Foreign wage deflation because Home demand for Foreign goods is higher to begin with, and the resource switching effect of Ramsey policy is mitigated.

Table 7 shows that deregulation narrows the welfare gap between historical and Ramsey-optimal policy at Home as deregulation reduces the need for policy activism. The welfare gain from Ramsey policy increases slightly in the country that remains rigid.

*Labor Market Deregulation*

Home labor market reform affects the propagation of aggregate shocks through the cyclical behavior of the workers' outside option. As shown in Table 8, labor market flexibility makes job creation less responsive to shocks: Lower unemployment benefits and smaller worker bargaining power imply that adjustment takes place increasingly through the real wage, reducing job flows over the cycle. Table 7 shows that the welfare effects of the reform mimic those of product market deregulation. Under the historical policy rule, the welfare cost of business cycles falls by almost 50 percent. The rigid country (Foreign) benefits slightly more from optimal policy following deregulation, while the gain from optimal policy becomes significantly smaller for Home.

*Product and Labor Market Deregulation*

Table 7 shows that deregulation of both product and labor markets at Home has a larger welfare effect than individual reforms. Deregulation of both markets accomplishes the most significant moderation of Home's aggregate fluctuations (Table 8), and the welfare cost of business cycles under the historical policy is lowest at 0.54 percent of steady-state consumption. The welfare gain from Ramsey-optimal policy is correspondingly minimized. At the same time, however, the welfare gain from optimal policy is further magnified in the rigid country.

To summarize, across all scenarios, asymmetric deregulation across countries reduces the benefit from optimal policy in the country that deregulates but increases it in the country that remains rigid. The intuition is straightforward: The flexible economy has less need of an active policy that takes distortions explicitly into account. The focus of Ramsey-optimal activism correspondingly shifts toward the rigid country, which increases its gain from optimal policy.

## 8 International Coordination of Reforms

To what extent can coordination of market reforms improve welfare and how does it affect monetary policy? We have seen that asymmetric deregulation is beneficial for both members of our model monetary union. Reforms by one country alone are sufficient to improve domestic and international policy tradeoffs facing the Ramsey central bank. However, asymmetric deregulation translates in heterogeneous real rigidities across countries, posing, at least in principle, an additional challenge for the conduct of monetary policy. In the long run, the Ramsey authority targets a single union-wide inflation rate, trading off asymmetric needs of inflation across heterogenous countries. Over the cycle, optimal policy is relatively less aggressive for the flexible country compared to the rigid one. When the two economies are simultaneously hit by similar shocks, inflation stabilization may be too strong (weak) in the flexible (rigid) country. Symmetric market deregulation across countries could then further improve policy tradeoffs. To address this issue, we repeat the same policy experiments of Section 7 assuming that both countries undertake deregulation in goods and labor markets. Tables 7 and 8 summarize the results.[58]

We find that there are gains from international coordination of reforms due to improved stabilization of aggregate fluctuations. In particular, coordination of reforms eliminates the heterogeneous needs of inflation stabilization in rigid and flexible countries. In the long run, the reduction in inflation is larger with symmetric deregulation. From a welfare perspective, the addition of Foreign deregulation has a small impact on the gain from optimal monetary policy relative to historical behavior for Home, although Home benefits more significantly from Foreign deregulation for given monetary policy regime. Foreign gains significantly from deregulation for given monetary policy, with smaller gains from Ramsey-optimal policy relative to the historical policy, as expected.

## 9 Conclusions

We studied the implications of market deregulation for the conduct of optimal monetary policy in a monetary union. A key message of the paper is that high levels of regulation in goods and labor markets generate sizable static and dynamic distortions that call for active monetary policy in the long run and over the business cycle. A policy of strict price stability is costly in terms of welfare. Expansionary monetary policy can reduce transition costs by generating lower markups and stimulating job creation in the aftermath of market reforms. However, once the economies in

[58] For brevity, we do not present impulse responses. They are available upon request.

the monetary union have reached the new long-run equilibrium, real distortions in product and labor markets are reduced, and the need for inflation to correct market inefficiencies correspondingly mitigated. Finally, we showed that there is an international dimension of deregulation, as asymmetric product and labor market reforms can generate new policy tradeoffs for a welfare maximizing monetary authority. Coordination of reforms is desirable to mitigate these tradeoffs.

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TABLE 1: MODEL SUMMARY

| | |
|---|---|
| $1=(1-\alpha)\left[\rho_{d,t}\exp\left(\frac{\tilde{N}-N_t}{2\sigma\tilde{N}N_t}\right)\right]^{1-\phi}+\alpha\left[Q_t\rho^*_{d,t}\exp\left(\frac{\tilde{N}^*-N^*_t}{2\sigma\tilde{N}^*N^*_t}\right)\right]^{1-\phi}$ | (1) |
| $1=(1-\alpha)\left[\rho^*_{d,t}\exp\left(\frac{\tilde{N}^*-N^*_t}{2\sigma\tilde{N}^*N^*_t}\right)\right]^{1-\phi}+\alpha\left[\frac{\rho_{d,t}}{Q_t}\exp\left(\frac{\tilde{N}-N_t}{2\sigma\tilde{N}N_t}\right)\right]^{1-\phi}$ | (2) |
| $Z_t l_t h_t = N_t(y_{d,t}+y_{x,t})+\left(\frac{N_{t+1}}{1-\delta}-N_t\right)f_{E,t}$ | (3) |
| $Z^*_t l^*_t h^*_t = N^*_t(y^*_{d,t}+y^*_{x,t})+\left(\frac{N^*_{t+1}}{1-\delta}-N^*_t\right)f^*_{E,t}$ | (4) |
| $l_t=(1-\lambda)l_{t-1}+q_{t-1}V_{t-1}$ | (5) |
| $l^*_t=(1-\lambda)l^*_{t-1}+q^*_{t-1}V^*_{t-1}$ | (6) |
| $f_{E,t}=\beta(1-\delta)E_t\left(\frac{u_{C,t+1}}{u_{C,t}}\right)\frac{\rho_{d,t+1}}{\rho_{d,t}}\left[\frac{\mu_t}{\mu_{t+1}}f_{E,t}+\mu_t\left(1-\frac{1}{\mu_{t+1}}-\frac{\nu}{2}\pi^2_{d,t}\right)(y_{d,t+1}+y_{x,t+1})\right]$ | (7) |
| $f_{E,t}=\beta(1-\delta)E_t\left(\frac{u^*_{C,t+1}}{u^*_{C,t}}\right)\frac{\rho^*_{d,t+1}}{\rho^*_{d,t}}\left[\frac{\mu^*_t}{\mu^*_{t+1}}f^*_{E,t}+\mu^*_t\left(1-\frac{1}{\mu^*_{t+1}}-\frac{\nu}{2}\pi^{*2}_{d,t}\right)\left(y^*_{d,t+1}+y^*_{x,t+1}\right)\right]$ | (8) |
| $J_t=\eta_t\left[\varphi_t Z_t h_t-\frac{\vartheta}{2}\pi^2_{w,t}-\left(\frac{v(h_t)}{u_{C,t}}+b\right)\right]+E_t\beta_{t,t+1}J_{t+1}\left[(1-\lambda)\eta_t+(1-\lambda-\iota_t)(1-\eta_{t+1})\frac{\eta_t}{\eta_{t+1}}\right]$ | (9) |
| $J^*_t=\eta^*_t\left[\varphi^*_t Z^*_t h^*_t-\frac{\vartheta}{2}\pi^{*2}_{w,t}-\left(\frac{v(h^*_t)}{u^*_{C,t}}+b^*\right)\right]+E_t\beta_{t,t+1}J^*_{t+1}\left[(1-\lambda)\eta^*_t+(1-\lambda-\iota^*_t)(1-\eta^*_{t+1})\frac{\eta^*_t}{\eta^*_{t+1}}\right]$ | (10) |
| $\frac{\kappa}{q_t}=\beta E_t\left[\left(\frac{u_{C,t+1}}{u_{C,t}}\right)J_{t+1}\right]$ | (11) |
| $\frac{\kappa}{q^*_t}=\beta E_t\left[\left(\frac{u^*_{C,t+1}}{u^*_{C,t}}\right)J^*_{t+1}\right]$ | (12) |
| $v_{h,t}/u_{C,t}=\varphi_t Z_t$ | (13) |
| $v^*_{h,t}/u^*_{C,t}=\varphi^*_t Z^*_t$ | (14) |
| $\pi_{w,t}=\frac{w^r_t}{w^r_{t-1}}\pi_{C,t}$ | (15) |
| $\pi^*_{w,t}=\frac{w^{r*}_t}{w^{r*}_{t-1}}\pi^*_{C,t}$ | (16) |
| $1+i_{t+1}=(1+i_t)^{\varrho_i}\left[(1+i)\left(1+\tilde{\pi}^U_{C,t}\right)^{\varrho_\pi}\left(\tilde{Y}^U_{g,t}\right)^{\varrho_Y}\right]^{1-\varrho_i}$ | (17) |
| $1+\tau a_{t+1}=\beta\left(1+i_{t+1}\right)E_t\left(\frac{u_{C,t+1}}{u_{C,t}}\frac{1}{1+\pi_{C,t+1}}\right)$ | (18) |
| $1-\tau Q_t a_{t+1}=\beta\left(1+i_{t+1}\right)E_t\left(\frac{u_{C^*,t+1}}{u_{C^*,t}}\frac{1}{1+\pi^*_{C,t+1}}\right)$ | (19) |
| $\frac{Q_t}{Q_{t-1}}=\frac{1+\pi^*_{C,t}}{1+\pi_{C,t}}$ | (20) |
| $a_{t+1}=\frac{1+i_t}{1+\pi_{C,t}}a_t+N_t\rho_{d,t}y_{x,t}-N^*_t Q_t\rho^*_{d,t}y^*_{x,t}$ | (21) |

Note: $C, C^*, \rho_d, \rho^*_d, l, l^*, V, V^*, N, N^*, J, J^*, h, h^*, \pi_w, \pi^*_w, \pi_C, \pi^*_C, i, Q, a$ are the 21 endogenous variables determined by these equations. Other variables that appear in the table are determined as described in the text.

TABLE 2: SOCIAL PLANNER

| | |
|---|---|
| $1 = (1-\alpha)\left[\rho_{d,t}\exp\left(\frac{\tilde{N}-N_t}{2\sigma\tilde{N}N_t}\right)\right]^{1-\phi} + \alpha\left[Q_t\rho^*_{d,t}\exp\left(\frac{\tilde{N}^*-N^*_t}{2\sigma\tilde{N}^*N^*_t}\right)\right]^{1-\phi}$ | (1) |
| $1 = (1-\alpha)\left[\rho^*_{d,t}\exp\left(\frac{\tilde{N}^*-N^*_t}{2\sigma\tilde{N}^*N^*_t}\right)\right]^{1-\phi} + \alpha\left[\frac{1}{Q_t}\rho_{d,t}\exp\left(\frac{\tilde{N}-N_t}{2\sigma\tilde{N}N_t}\right)\right]^{1-\phi}$ | (2) |
| $Z_tL_th_t = N_t(y_{d,t}+y_{x,t}) + \left(\frac{N_{t+1}}{1-\delta} - N_t\right)f_{T,t}$ | (3) |
| $Z^*_tL^*_th^*_t = N^*_t(y^*_{d,t}+y^*_{x,t}) + \left(\frac{N^*_{t+1}}{1-\delta} - N^*_t\right)f^*_{T,t}$ | (4) |
| $l_t = (1-\lambda)l_{t-1} + \chi(1-l_{t-1})^{\varepsilon}V_{t-1}^{1-\varepsilon}$ | (5) |
| $l^*_t = (1-\lambda)l^*_{t-1} + \chi(1-l^*_{t-1})^{\varepsilon}V^{*1-\varepsilon}_{t-1}$ | (6) |
| $f_{T,t} = \beta(1-\delta)E_t\left\{\left(\frac{u_{c,t+1}}{u_{c,t}}\right)\frac{\rho_{d,t+1}}{\rho_{d,t}}\left[f_{T,t+1} + \frac{1}{2\sigma N_{t+1}}\left(y_{d,t+1}+y_{x,t+1}\right)\right]\right\}$ | (7) |
| $f^*_{T,t} = \beta(1-\delta)E_t\left\{\left(\frac{u^*_{c,t+1}}{u^*_{c,t}}\right)\frac{\rho^*_{d,t+1}}{\rho^*_{d,t}}\left[f^*_{T,t+1} + \frac{1}{2\sigma N^*_{t+1}}\left(y^*_{d,t+1}+y^*_{x,t+1}\right)\right]\right\}$ | (8) |
| $J_t = \varepsilon\left(\rho_{d,t}Z_th_t - \frac{v_{h,t}}{u_{C,t}}\right) + \left[1-\lambda-(1-\varepsilon)\,\iota_t\right]E_t\left(\beta_{t,t+1}J_{t+1}\right)$ | (9) |
| $J^*_t = \varepsilon\left(\rho^*_{d,t}Z^*_th^*_t - \frac{v^*_{h,t}}{u^*_{C,t}}\right) + \left[1-\lambda-(1-\varepsilon)\,\iota^*_t\right]E_t\left(\beta_{t,t+1}J^*_{t+1}\right)$ | (10) |
| $\frac{\kappa}{q_t} = \beta E_t\left[\left(\frac{u_{C,t+1}}{u_{C,t}}\right)J_{t+1}\right]$ | (11) |
| $\frac{\kappa}{q^*_t} = \beta E_t\left[\left(\frac{u^*_{C,t+1}}{u^*_{C,t}}\right)J^*_{t+1}\right]$ | (12) |
| $\frac{v_{h,t}}{u_{C,t}} = \rho_{d,t}Z_t$ | (13) |
| $\frac{v^*_{h,t}}{u^*_{C,t}} = \rho^*_{d,t}Z^*_t$ | (14) |
| $Q_t = \frac{u^*_{C,t}}{u_{C,t}}$ | (15) |

Note: $C, C^*, \rho_d, \rho^*_d, l, l^*, V, V^*, J, J^*, h, h^*, N, N^*, Q_t$ are the 15 endogenous variables determined by these equations. Other variables that appear in the table are determined as described in the text.

TABLE 3: DISTORTIONS

| | |
|---|---|
| $\Upsilon_{\mu,t} \equiv \frac{\mu_{t-1}}{\mu_t} - 1$ | time-varying markup*, product creation |
| $\Upsilon_{N,t} \equiv \mu_t \left(1 - \frac{\nu}{2}\pi_{d,t}^2\right) - 1 - \frac{1}{2\sigma N_t}$ | misalignment between markup and benefit from variety*, product creation |
| $\Upsilon_{R,t} \equiv f_{R,t}$ | regulation costs, product creation |
| $\Upsilon_{\varphi,t} \equiv \frac{1}{\mu_t} - 1$ | monopoly power and time-varying markup*, job creation and labor supply |
| $\Upsilon_{\eta,t} \equiv \eta_t - \varepsilon$ | failure of the Hosios condition**, job creation |
| $\Upsilon_{b,t} \equiv b$ | unemployment benefits, job creation |
| $\Upsilon_{Q,t} \equiv \frac{u_{c,t}^*}{u_{c,t}} - Q_t$ | incomplete markets, risk sharing |
| $\Upsilon_{a,t} \equiv \tau a_{t+1}$ | cost of adjusting bond holdings, risk sharing |
| $\Upsilon_{\pi_w,t} \equiv \frac{\vartheta}{2}\pi_{w,t}^2$ | wage adjustment costs, resource constraint and job creation |
| $\Upsilon_{\pi_d,t} \equiv \frac{\nu}{2}\pi_{d,t}^2$ | price adjustment costs, resource constraint |

* From translog preferences and sticky prices.

** From sticky wages and/or $\eta \neq \varepsilon$.

TABLE 4: CALIBRATION

| | Parameter | Value | Source/Target |
|---|---|---|---|
| Risk Aversion | $\gamma_C =$ | 2 | *Lit.* |
| Frisch Elasticity | $1/\gamma_h =$ | 0.2 | *Lit.* |
| Discount Factor | $\beta =$ | 0.99 | $r = 4\%$ |
| Elasticity Matching Function | $\varepsilon =$ | 0.5 | *Lit.* |
| Firm Bargaining Power | $\eta =$ | 0.5 | *Hosios* |
| Replacement Rate | $\psi_R =$ | 0.65 | *Data* |
| Exogenous separation | $\lambda =$ | 0.06 | *Lit.* |
| Vacancy Cost | $k =$ | 0.74 | $U = 9.8\%$ |
| Matching Efficiency | $\chi =$ | 0.62 | $q = 0.7$ |
| Elasticity across Home and Foreign goods | $\phi =$ | 3.8 | *Lit.* |
| Home Bias | $\alpha =$ | 0.2 | *Lit.* |
| Translog Shifter | $\sigma =$ | 0.60 | *Markup* |
| Plant Exit | $\delta =$ | .026 | $\frac{JD^{EXIT}}{JD} = .4$ |
| Regulation Cost | $f_R =$ | $0.69GDP^{SS}$ | *Data* |
| R&D Entry Cost | $f_D =$ | $0.18GDP^{SS}$ | *Lit.* |
| Rotemberg Adj Price | $\nu =$ | 80 | *Lit.* |
| Rotemberg Adj Price | $\vartheta =$ | 160 | $\frac{\sigma_U}{\sigma_{GDP}}$ |
| Taylor - Interest Rate Smoothing | $\varrho_i =$ | 0.87 | *Lit.* |
| Taylor - Inflation Parameter | $\varrho_\pi =$ | 1.93 | *Lit.* |
| Taylor - Output Gap Parameter | $\varrho_{GAP} =$ | .075 | *Lit.* |
| Bond Adjustment Cost | $\tau =$ | 0.0025 | *Lit.* |
| Std Productivity Shock | $\sigma_A =$ | 0.0068 | $\sigma_{GDP}$ |
| Persistence Productivity Shock | $\varrho_A =$ | 0.999 | *Lit.* |
| Correlation between Home and Foreign Shocks | | 0.253 | *Lit.* |

TABLE 5: BUSINESS CYCLE STATISTICS

| Variable | $\sigma_{X_R^U}$ | | | $\sigma_{X_R^U}/\sigma_{Y_R^U}$ | | | 1st Autocorr | | | $corr(X_{R,t}^U, Y_{R,t}^U)$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $Y_R^U$ | **1.32** | 1.32 | *1.30* | **1** | 1 | *1* | **0.91** | 0.76 | *0.74* | **1** | 1 | *1* |
| $C_R^U$ | **0.68** | 1.00 | *0.76* | **0.51** | 0.75 | *0.58* | **0.89** | 0.72 | *0.72* | **0.87** | 0.99 | *0.88* |
| $I_R^U$ | **3.30** | 3.09 | *4.13* | **2.50** | 2.34 | *3.18* | **0.89** | 0.76 | *0.76* | **0.94** | 0.64 | *0.71* |
| $l^U$ | **0.50** | 0.50 | *0.46* | **0.38** | 0.38 | *0.35* | **0.92** | 0.81 | *0.81* | **0.88** | 0.76 | *0.73* |
| $w_R^{Ur}$ | **0.50** | 0.54 | *0.49* | **0.38** | 0.41 | *0.38* | **0.85** | 0.94 | *0.91* | **0.16** | 0.62 | *0.71* |
| | | | | | | | | | | | | |
| $corr(C_{R,t}, C_{R,t}^*)$ | **0.55** | 0.29 | *0.97* | | | | | | | | | |
| $corr(Y_{R,t}, Y_{R,t}^*)$ | **0.86** | 0.36 | *0.41* | | | | | | | | | |

Bold fonts denote data moments, normal fonts denote moments for the Baxter calibration of productivity, and italics denote the BKK calibration.

TABLE 6: WELFARE EFFECTS OF REFORMS – NON STOCHASTIC STEADY STATE

| Market Reform | Δ Welfare – Historical | | Δ Welfare – Ramsey | | Ramsey Inflation |
|---|---|---|---|---|---|
| | Home | Foreign | Home | Foreign | |
| Status Quo | 0% | 0% | 0.21% | 0.21% | 1.20% |
| | | | | | |
| Asy PMR | 5.00% | 0.22% | 5.09% | 0.41% | 1.07% |
| Asy LMR | 3.32% | 0.21% | 3.44% | 0.39% | 1.00% |
| Asy GLOBAL | 7.38% | 0.38% | 7.41% | 0.55% | 0.96% |
| | | | | | |
| Sym PMR | 5.22% | 5.22% | 5.30% | 5.30% | 1.00% |
| Sym LMR | 3.51% | 3.51% | 3.61% | 3.61% | 0.85% |
| Sym GLOBAL | 7.72% | 7.72% | 7.76% | 7.76% | 0.76% |

TABLE 7: WELFARE EFFECTS OF REFORMS — STOCHASTIC STEADY STATE

| Market Reform | Welfare Cost – Historical | | Welfare Cost – Ramsey | |
|---|---|---|---|---|
| | Home | Foreign | Home | Foreign |
| Status Quo | 0.94% | 0.94% | 0.75% | 0.75% |
| Asy PMR | 0.78% | 0.93% | 0.65% | 0.72% |
| Asy LMR | 0.55% | 0.92% | 0.50% | 0.70% |
| Asy GLOBAL | 0.54% | 0.92% | 0.49% | 0.69% |
| Sym PMR | 0.77% | 0.77% | 0.62% | 0.62% |
| Sym LMR | 0.54% | 0.54% | 0.46% | 0.46% |
| Sym GLOBAL | 0.53% | 0.53% | 0.45% | 0.45% |

TABLE 8: BUSINESS CYCLE IMPLICATIONS OF DEREGULATION

| Variable X | $\sigma_X$ — Historical Rule | | | | | | |
|---|---|---|---|---|---|---|---|
| | Rigid | PMR asy | LMR asy | GLOBAL asy | PMR sym | LMR sym | GLOBAL sym |
| $Y_R$ | 1.32 | 1.28 | 1.21 | 1.20 | 1.27 | 1.21 | 1.19 |
| $C_R$ | 1.00 | 0.95 | 0.89 | 0.88 | 0.95 | 0.89 | 0.88 |
| $I_R$ | 3.09 | 3.17 | 2.60 | 2.77 | 3.17 | 2.60 | 2.77 |
| $L_R$ | 0.50 | 0.44 | 0.30 | 0.29 | 0.43 | 0.30 | 0.29 |
| $W_R$ | 0.54 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 |
| $Y_R^*$ | 1.32 | 1.32 | 1.32 | 1.31 | 1.27 | 1.21 | 1.19 |
| $C_R^*$ | 1.00 | 1.00 | 0.99 | 0.95 | 0.95 | 0.89 | 0.88 |
| $I_R^*$ | 3.09 | 3.08 | 3.08 | 3.08 | 3.17 | 2.60 | 2.77 |
| $L_R^*$ | 0.50 | 0.50 | 0.50 | 0.50 | 0.43 | 0.30 | 0.29 |
| $W_R^*$ | 0.54 | 0.54 | 0.54 | 0.54 | 0.55 | 0.55 | 0.55 |
| | | | | | | | |
| $corr(C_{R,t}, C_{R,t}^*)$ | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 |
| $corr(Y_{R,t}, Y_{R,t}^*)$ | 0.36 | 0.36 | 0.36 | 0.35 | 0.35 | 0.36 | 0.35 |
| Variable X | $\sigma_X$ — Ramsey Policy | | | | | | |
| | Rigid | PMR asy | LMR asy | GLOBAL asy | PMR sym | LMR sym | GLOBAL sym |
| $Y_R$ | 1.35 | 1.11 | 1.06 | 1.06 | 1.02 | 0.95 | 0.95 |
| $C_R$ | 1.59 | 1.06 | 0.87 | 0.87 | 0.87 | 0.72 | 0.72 |
| $I_R$ | 3.92 | 3.43 | 2.79 | 2.99 | 3.18 | 2.70 | 2.92 |
| $L_R$ | 0.38 | 0.34 | 0.28 | 0.27 | 0.29 | 0.19 | 0.19 |
| $W_R$ | 0.44 | 0.48 | 0.49 | 0.50 | 0.47 | 0.48 | 0.49 |
| $Y_R^*$ | 1.35 | 1.09 | 0.97 | 0.96 | 1.02 | 0.95 | 0.95 |
| $C_R^*$ | 1.59 | 1.09 | 0.90 | 0.89 | 0.87 | 0.72 | 0.72 |
| $I_R^*$ | 3.92 | 3.23 | 2.80 | 2.87 | 3.18 | 2.70 | 2.92 |
| $L_R^*$ | 0.38 | 0.31 | 0.24 | 0.23 | 0.29 | 0.19 | 0.19 |
| $W_R^*$ | 0.44 | 0.43 | 0.44 | 0.44 | 0.47 | 0.48 | 0.49 |
| | | | | | | | |
| $corr(C_{R,t}, C_{R,t}^*)$ | 0.72 | 0.42 | 0.19 | 0.21 | 0.16 | -0.09 | -0.07 |
| $corr(Y_{R,t}, Y_{R,t}^*)$ | 0.39 | 0.12 | 0.07 | 0.08 | 0.00 | -0.02 | 0.01 |

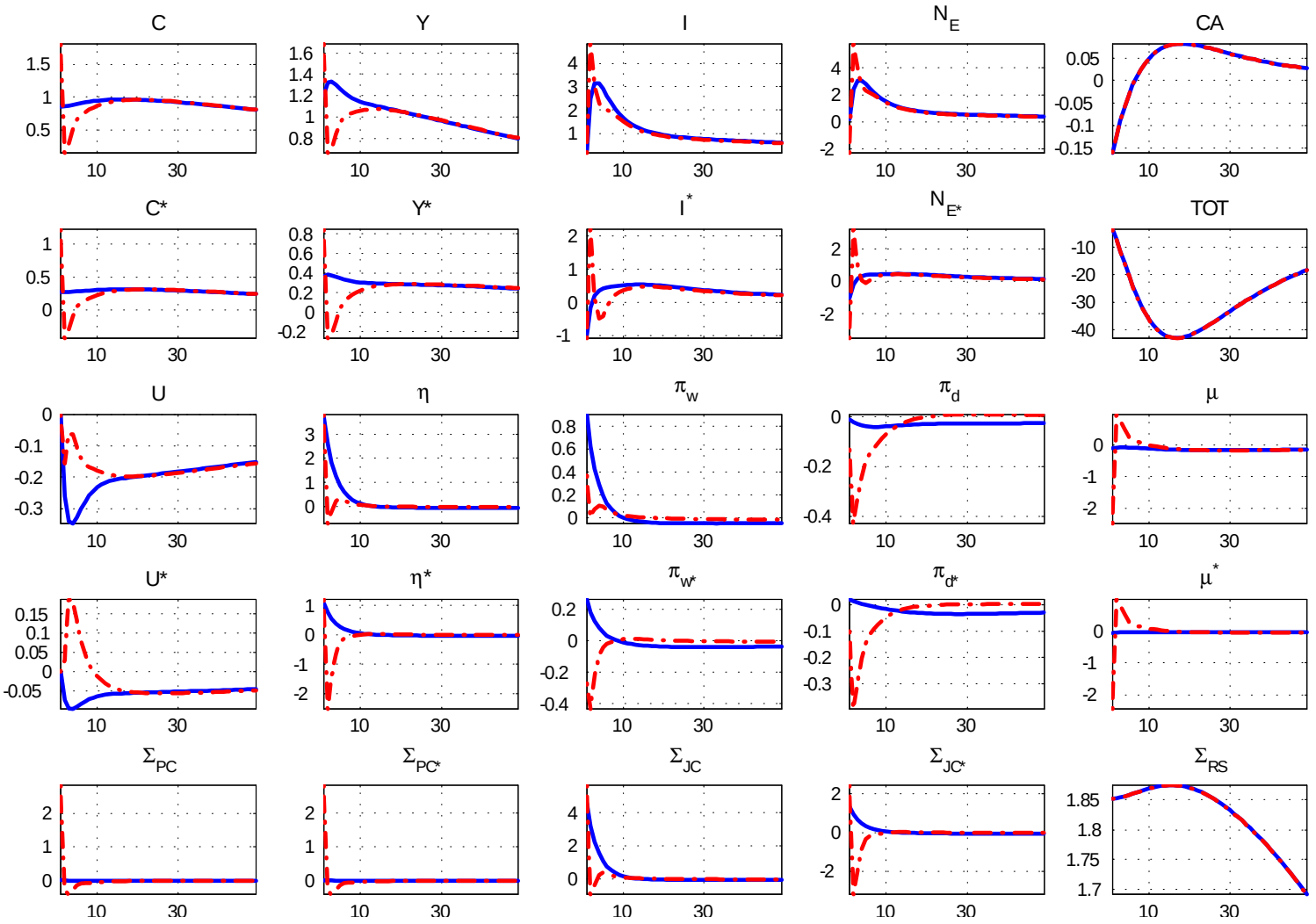



Figure 1: Home Productivity Shock, Taylor Rigid Economy (Solid Lines) versus Ramsey Rigid Economy (Dashed Lines).

Variables are in percentage deviations from the steady state. Unemployment and inflation are in deviations from the steady state.

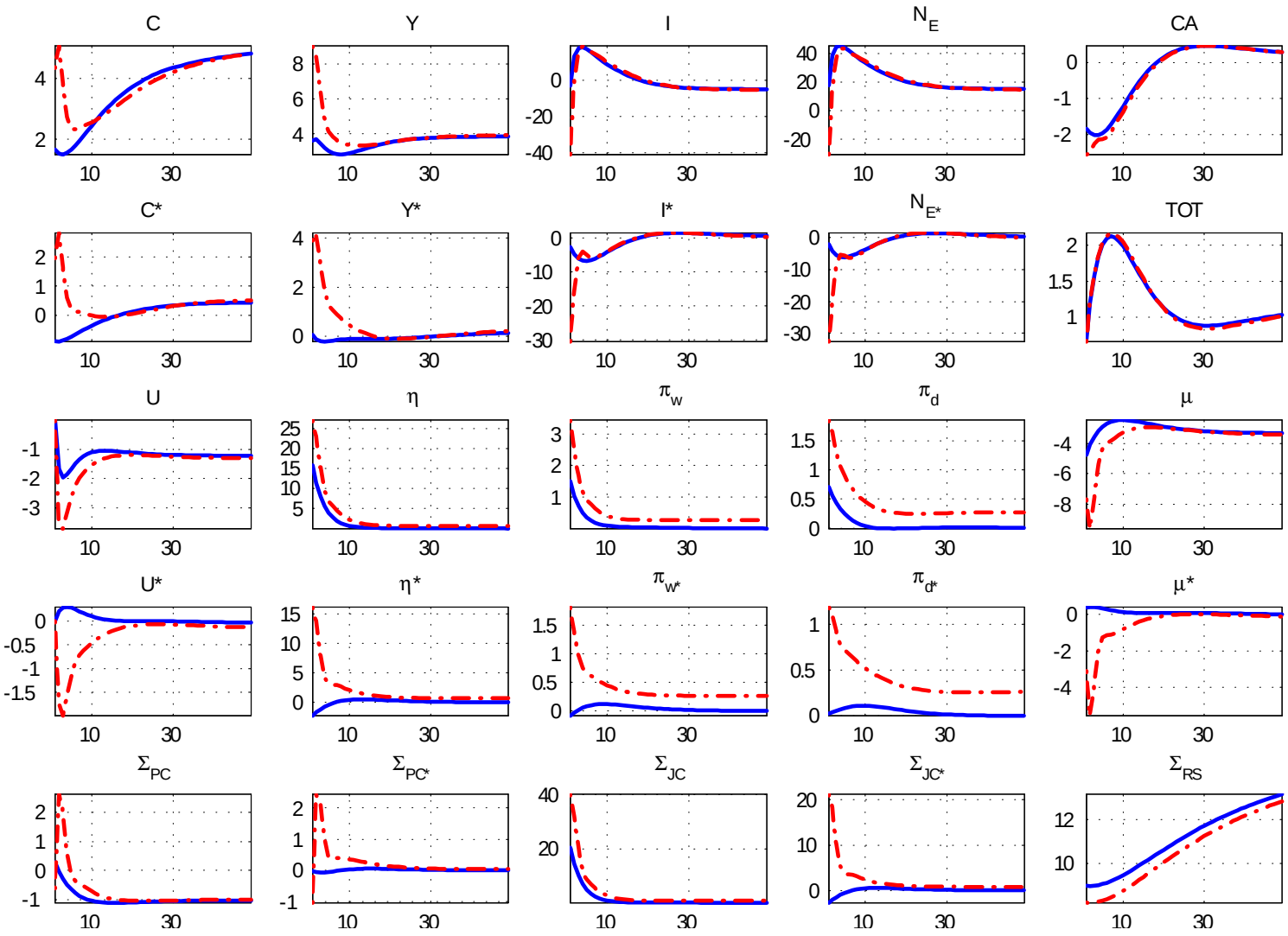



Figure 2: Home Product Market (PMR) Reform, Taylor Economy (Solid Lines) versus Ramsey Economy (Dashed Lines).

Variables are in percentage deviations from the Taylor rigid steady state. Unemployment and inflation are in deviations from the steady state.

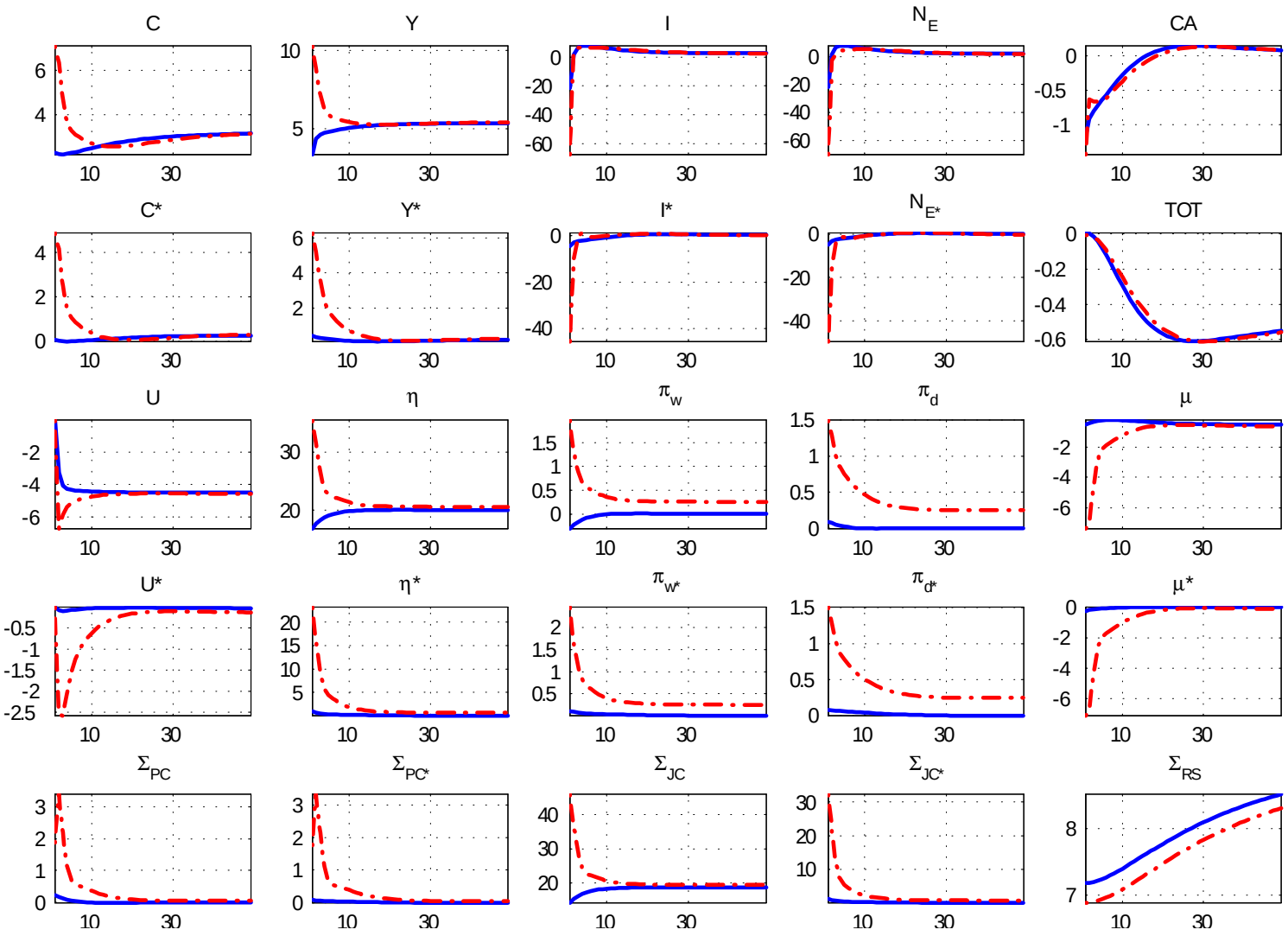



Figure 3: Home Labor Market (LMR) Reform, Taylor Economy (Solid Lines) versus Ramsey Economy (Dashed Lines).

Variables are in percentage deviations from the Taylor rigid steady state. Unemployment and inflation are in deviations from the steady state.

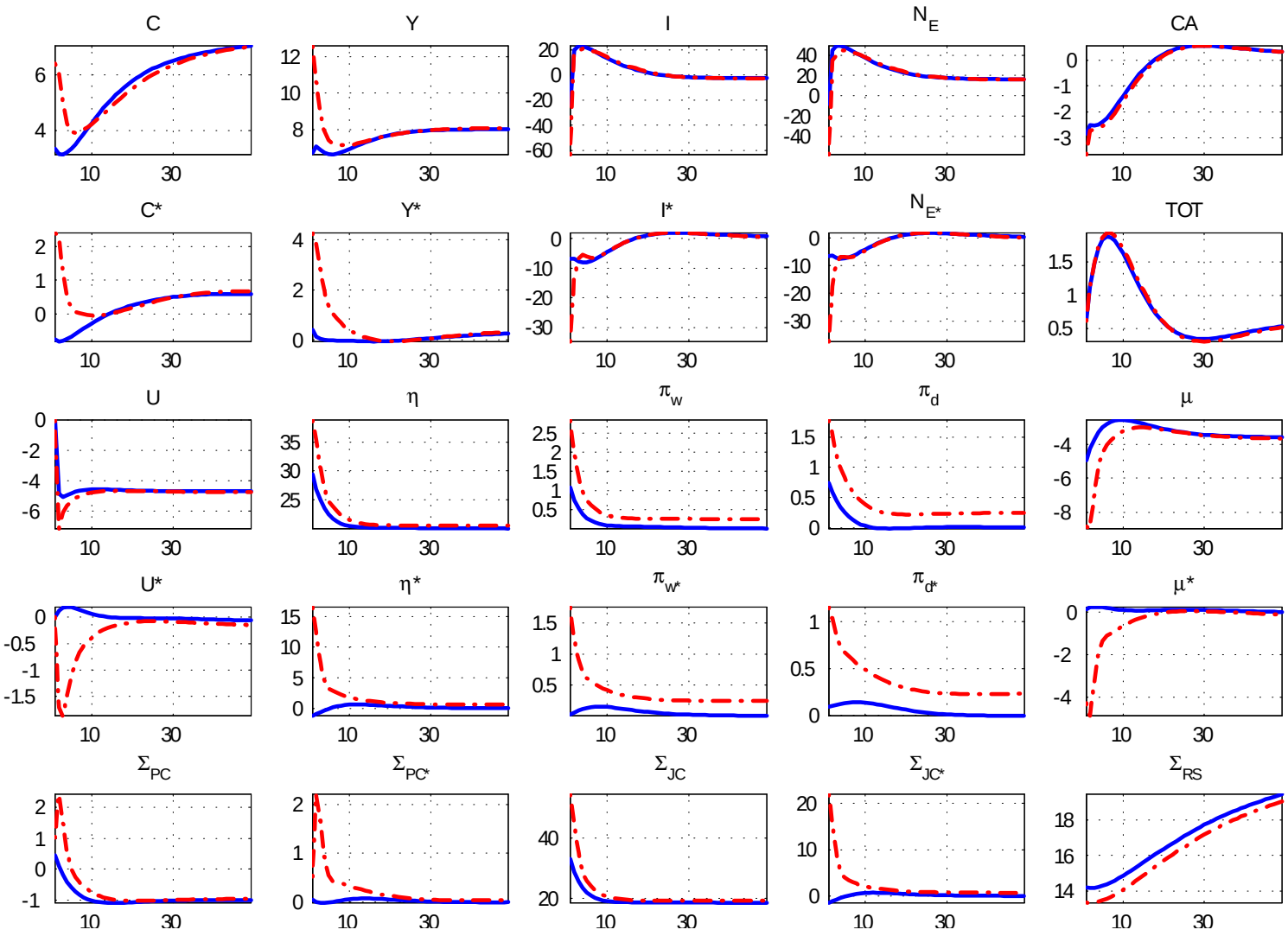



Figure 4: Home Global (joint PMR and LMR) Reform, Taylor Economy (Solid Lines) versus Ramsey Economy (Dashed Lines).

Variables are in percentage deviations from the Taylor rigid steady state. Unemployment and inflation are in deviations from the steady state.

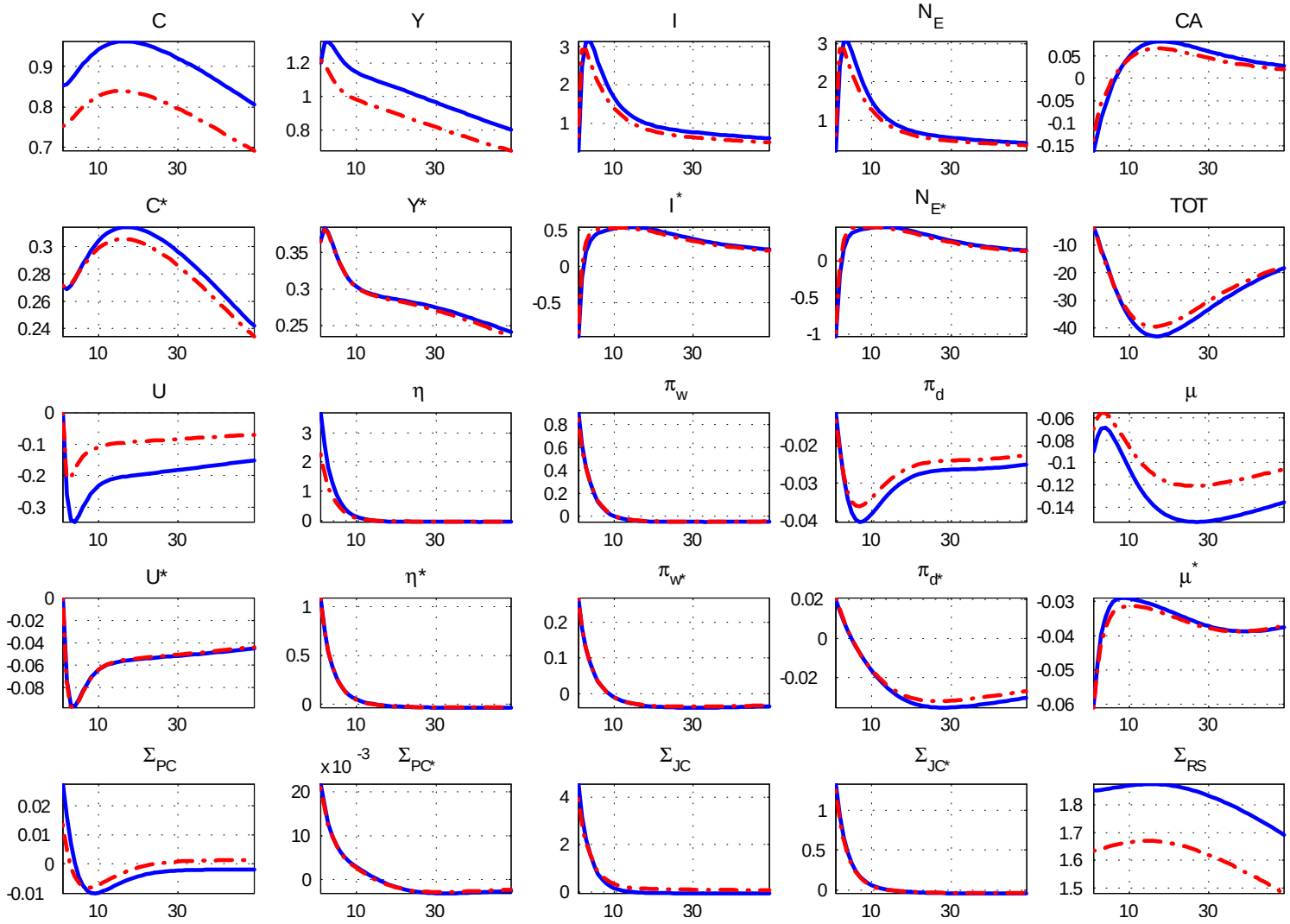



Figure 5: Home Productivity Shock, Taylor Rigid Economy (Solid Lines) versus Taylor Flexible Economy (Dashed Lines). Variables are in percentage deviations from the steady state. Unemployment and inflation are in deviations from the steady state.

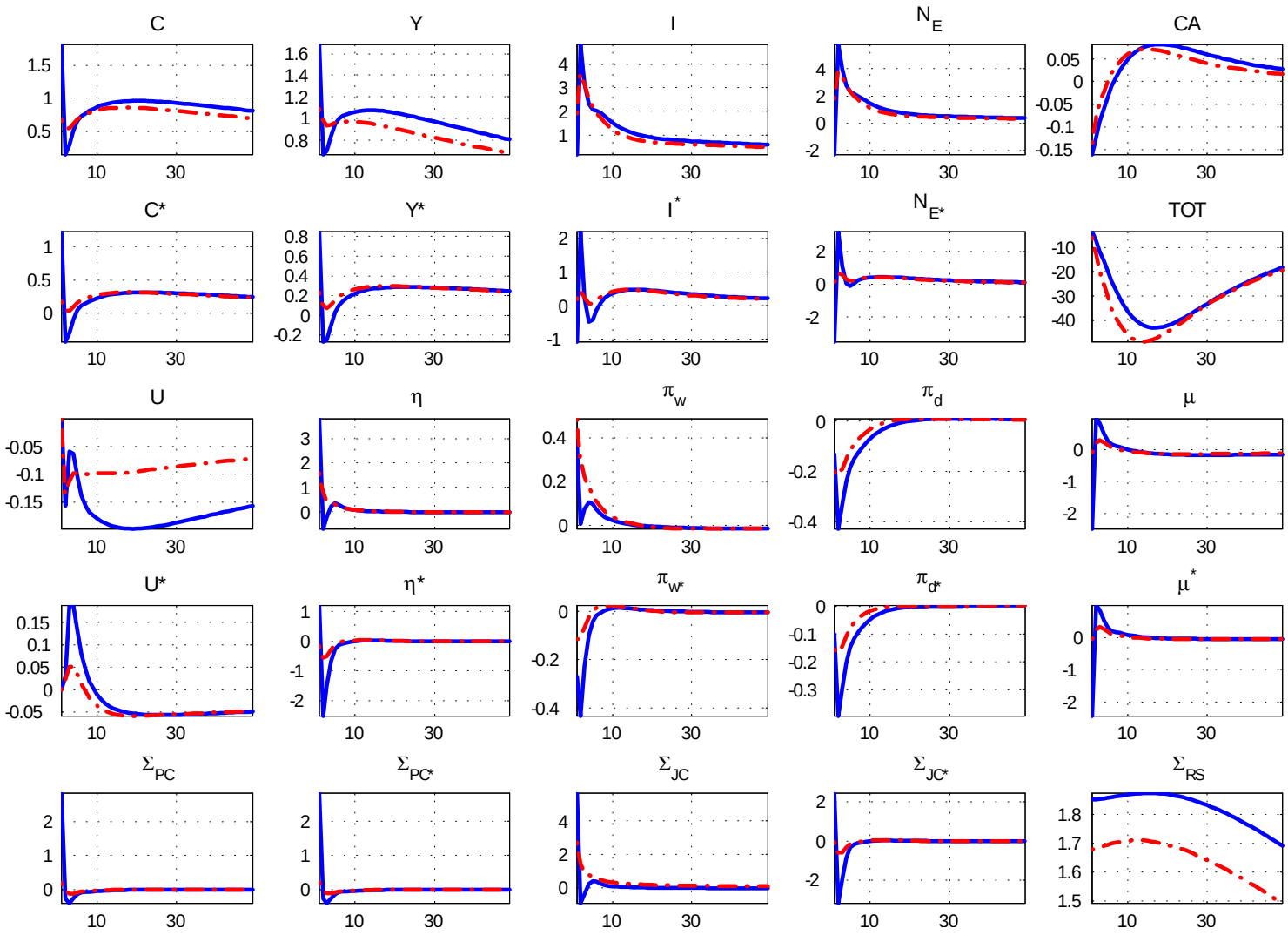



Figure 6: Home Productivity Shock, Ramsey Rigid Economy (Solid Lines) versus Ramsey Flexible Economy (Dashed Lines). Variables are in percentage deviations from the steady state. Unemployment and inflation are in deviations from the steady state.

# Appendix

## A No Pricing-to-Market

Focus first on the case of flexible prices. A Home firm selling at Home chooses $p_{d,t}(\omega)$ to maximize:

$$E_t \sum_{s=t}^{\infty} [\beta(1-\delta)]^{s-t} \frac{u_{C,s}}{u_{C,t}} \left( \frac{p_{d,t}(\omega)}{P_t} - \varphi_t \right) y_{d,t}(\omega),$$

subject to:

$$y_{d,t}(\omega) = (1-\alpha)\sigma \ln \left( \frac{\bar{p}_{d,t}}{p_{d,t}(\omega)} \right) \frac{P_{d,t}}{p_{d,t}(\omega)} \left( \frac{P_{d,t}}{P_t} \right)^{-\phi} Y_t^C.$$

The optimal price of domestic sales is determined by:

$$\frac{p_{d,t}(\omega)}{P_t} = \left[ 1 + \ln \left( \frac{\bar{p}_{d,t}}{p_{d,t}(\omega)} \right) \right] \varphi_t. \tag{A.1}$$

When selling abroad, the firm chooses $p_{x,t}(\omega)$ to maximize:

$$E_t \sum_{s=t}^{\infty} [\beta(1-\delta)]^{s-t} \frac{u_{C,s}}{u_{C,t}} \left( Q_t \frac{p_{x,t}(\omega)}{P_t^*} - \varphi_t \right) y_{x,t}(\omega),$$

subject to:

$$y_{x,t}(\omega) = \alpha\sigma \ln \left( \frac{\bar{p}_{x,t}}{p_{x,t}(\omega)} \right) \frac{P_{x,t}}{p_{x,t}(\omega)} \left( \frac{P_{x,t}}{P_t^*} \right)^{-\phi} Y_t^{C*},$$

and the optimal export price is determined by:

$$\frac{p_{x,t}(\omega)}{P_t} = \left[ 1 + \ln \left( \frac{\bar{p}_{x,t}}{p_{x,t}(\omega)} \right) \right] \varphi_t. \tag{A.2}$$

Pricing-to-market arises if $p_{d,t}(\omega) \neq p_{x,t}(\omega)$ in equilibrium, but the Armington form of the consumption aggregator implies that this never happens. To see this, recall first the definition of the reservation prices (the maximum prices that can be charged while still having positive market share):

$$\begin{aligned} \ln \bar{p}_{d,t} &= \frac{1}{\sigma N_t} + \frac{1}{N_t} \int_{\omega \in \Omega_{d,t}} \ln p_{d,t}(\omega) d\omega, \\ \ln \bar{p}_{x,t} &= \frac{1}{\sigma N_t} + \frac{1}{N_t} \int_{\omega \in \Omega_{x,t}} \ln p_{x,t}(\omega) d\omega. \end{aligned}$$

In the symmetric equilibrium, all firms that serve the Home market are also exporters. It follows that:

$$\ln \bar{p}_{d,t} = \frac{1}{\sigma N_t} + \ln p_{d,t}, \quad \text{and} \quad \ln \bar{p}_{x,t} = \frac{1}{\sigma N_t} + \ln p_{x,t}.$$

As a result:

$$\ln\left(\frac{\bar{p}_{d,t}}{p_{d,t}}\right) = \frac{1}{\sigma N_t} = \ln\left(\frac{\bar{p}_{x,t}}{p_{x,t}}\right).$$

Substituting this into the optimal price equations (A.1) and (A.2), we have:

$$\frac{p_{d,t}}{P_t} = \left(1 + \frac{1}{\sigma N_t}\right)\varphi_t = \frac{p_{x,t}}{P_t}.$$

Thus, there is no pricing-to-market under flexible prices. This happens because the Armington aggregator implies that the ratios of reservation prices to optimal prices for Home producers in the Home and Foreign markets depend only on the identical number of Home firms that serve domestic and export markets.

The extension to the sticky-price case is straightforward under the assumption that prices are sticky in the currency of producers, an assumption that is always satisfied in a monetary union.

## B The Law of Motion for Net Foreign Assets

Recall the representative household's budget constraint:

$$A_{t+1}+P_t\frac{\tau}{2}\left(\frac{A_{t+1}}{P_t}\right)^2+P_tC_t+x_{t+1}N_{E,t}e_t = (1+i_t)A_t+x_tP_tN_t(d_t+e_t)+w_tl_th_t+P_tb(1-l_t)+T_t^g+T_t^f+T_t^i. \tag{B.1}$$

In equilibrium, $x_t = x_{t+1} = 1$ for all $t$. The budget constraint of the government implies:

$$T_t^g = -P_tb(1-l_t).$$

Moreover,

$$T_t^f = P_t\frac{\tau}{2}\left(\frac{A_{t+1}}{P_t}\right)^2,$$

and:

$$T_t^i = P_t\left(\varphi_tZ_tl_th_t - \frac{w_t}{P_t}l_th_t - \kappa V_t - \frac{\vartheta}{2}\pi_{w,t}^2 l_t\right).$$

Therefore:

$$A_{t+1} + P_t C_t + N_{E,t} e_t = (1 + i_t) A_t + P_t N_t (d_t + e_t) + P_t \varphi_t Z_t l_t h_t - P_t \kappa V_t - P_t \frac{\vartheta}{2} \pi_{w,t}^2 l_t. \quad \text{(B.2)}$$

It is possible to simplify the consolidated budget constraint of the economy further. To begin, notice that:

$$d_t = \left(\rho_{d,t} - \varphi_t\right) \left(y_{d,t} + y_{x,t}\right) - \frac{\nu}{2} \pi_{d,t}^2 \left(y_{d,t} + y_{x,t}\right) \rho_{d,t}.$$

It follows that, after substituting and rearranging, equation (B.2) can be rewritten in real terms as:

$$a_{t+1} = \frac{1 + i_t}{1 + \pi_{C,t}} a_t + N_t \left(\rho_{d,t} - \varphi_t\right) \left(y_{d,t} + y_{x,t}\right) + \varphi_t Z_t l_t h_t - \left[ \begin{array}{c} C_t + N_{E,t} e_t + \kappa V_t + \frac{\vartheta}{2} \pi_{w,t}^2 l_t \\ + \frac{\nu}{2} \pi_{d,t}^2 \left(y_{d,t} + y_{x,t}\right) \rho_{d,t} N_t \end{array} \right]. \quad \text{(B.3)}$$

Next, recall the expression for Home's aggregate demand of the consumption basket:

$$Y_t^C = C_t + \kappa V_t + \frac{\vartheta}{2} \pi_{w,t}^2 l_t + \frac{\nu}{2} \pi_{d,t}^2 \rho_{d,t} (y_{d,t} + y_{x,t}) N_t.$$

Then, equation (B.3) becomes:

$$a_{t+1} = \frac{1 + i_t}{1 + \pi_{C,t}} a_t + N_t \left(\rho_{d,t} - \varphi_t\right) \left(y_{d,t} + y_{x,t}\right) + \varphi_t Z_t l_t h_t - \left(Y_t^C + N_{E,t} e_t\right).$$

Finally, recall that free entry implies $e_t = \varphi_t f_{E,t}$, and labor market clearing requires $N_t \varphi_t \left(y_{d,t} + y_{x,t}\right) + N_{E,t} \varphi_t f_{E,t} = \varphi_t Z_t l_t h_t$. It follows that home's net foreign assets entering period $t + 1$ are determined by the gross interest income on the asset position entering period $t$ plus the difference between home's total production and total demand (or absorption) of consumption:

$$a_{t+1} = \frac{1 + i_t}{1 + \pi_{C,t}} a_t + N_t \rho_{d,t} \left(y_{d,t} + y_{x,t}\right) - Y_t^C. \quad \text{(B.4)}$$

A similar equation holds in Foreign:

$$a_{t+1}^* = \frac{1 + i_t}{1 + \pi_{C,t}^*} a_t^* + N_t^* \rho_{d,t}^* \left(y_{d,t}^* + y_{x,t}^*\right) - Y_t^{C*}. \quad \text{(B.5)}$$

Now, multiply equation (B.5) by $Q_t$ and subtract the resulting equation from (B.4). Recall that $1 + \pi_{C,t} = (Q_{t-1}/Q_t) \left(1 + \pi_{C,t}^*\right)$ and use the bond market clearing condition $a_{t+1} + Q_t a_{t+1}^* = 0$ in

all periods. It follows that:

$$a_{t+1} = \frac{1+i_t}{1+\pi_{C,t}} a_t + \frac{1}{2}\left[N_t \rho_{d,t}\left(y_{d,t} + y_{x,t}\right) - N_t^* Q_t \rho_{d,t}^*\left(y_{d,t}^* + y_{x,t}^*\right)\right] - \frac{1}{2}\left(Y_t^C - Q_t Y_t^{C*}\right). \quad \text{(B.6)}$$

This is the familiar result that net foreign assets depend positively on the cross-country differential in production of final consumption output and negatively on relative absorption.

Notice next that home absorption of consumption must equal absorption of consumption output from home firms and output from foreign firms:

$$Y_t^C = N_t \rho_{d,t} y_{d,t} + N_t^* \rho_{x,t}^* y_{x,t}^* = N_t \rho_{d,t} y_{d,t} + N_t^* Q_t \rho_{d,t}^* y_{x,t}^*,$$

where we used the fact that $\rho_{x,t}^* = Q_t \rho_{d,t}^*$. Similarly,

$$Y_t^{C*} = N_t^* \rho_{d,t}^* y_{d,t}^* + N_t \rho_{x,t} y_{x,t} = N_t^* \rho_{d,t}^* y_{d,t}^* + N_t \frac{\rho_{d,t}}{Q_t} y_{x,t},$$

where we used $\rho_{x,t} = \rho_{d,t}/Q_t$. Substituting these results into equation (B.6) yields net foreign assets as a function of interest income on the initial asset position and the trade balance:

$$a_{t+1} = \frac{1+i_t}{1+\pi_{C,t}} a_t + N_t \rho_{d,t} y_{x,t} - N_t^* Q_t \rho_{d,t}^* y_{x,t}^*.$$

## C Inefficiency Wedges

The product creation inefficiency wedge is given by:

$$\Sigma_{PC,t} = -\Upsilon_{R,t} + (1-\delta) E_t \left\{ \beta_{t,t+1} \frac{\rho_{d,t+1}}{\rho_{d,t}} \left[ \begin{array}{c} \Upsilon_{\mu,t+1} f_{T,t+1} + (1+\Upsilon_{\mu,t+1}) \Upsilon_{R,t+1} \\ + \left(\Upsilon_{N,t+1} - \Upsilon_{\mu,t+1}\right)\left(y_{d,t+1} + y_{x,t+1}\right) \end{array} \right] \right\}. \quad \text{(C.1)}$$

To derive equation (C.1) start from the intertemporal equation characterizing product creation in the market economy:

$$\left(f_{R,t} + f_{R\&D}\right) = (1-\delta) E_t \left\{ \beta_{t,t+1} \frac{\rho_{d,t+1}}{\rho_{d,t}} \left[ \begin{array}{c} \frac{\mu_t}{\mu_{t+1}} \left(f_{R,t} + f_{R\&D}\right) \\ + \mu_t \left(1 - \frac{1}{\mu_{t+1}} - \frac{\nu}{2} \pi_{d,t}^2\right)\left(y_{d,t+1} + y_{x,t+1}\right) \end{array} \right] \right\}, \quad \text{(C.2)}$$

where we have used the fact that $f_{E,t} = (f_{R,t} + f_{R\&D})$.The intertemporal equation characterizing product creation in the planner economy is instead:

$$f_{R\&D} = (1-\delta)E_t\left\{\beta_{t,t+1}\frac{\rho_{d,t+1}}{\rho_{d,t}}\left[f_{R\&D} + \frac{1}{2\sigma N_{t+1}}\left(y_{d,t+1} + y_{x,t+1}\right)\right]\right\} \tag{C.3}$$

Define $\Sigma_{PC,t}$ as the difference between equation (C.2) and (C.3):

$$\Sigma_{PC,t} = -f_{R,t} + (1-\delta)E_t\left\{\beta_{t,t+1}\frac{\rho_{d,t+1}}{\rho_{d,t}}\left[\begin{array}{c}\left(\frac{\mu_t}{\mu_{t+1}} - 1\right)f_{R\&D} + \frac{\mu_t}{\mu_{t+1}}f_{R,t+1} \\ + \left(\mu_t\left(1 - \frac{\nu}{2}\pi^2_{d,t+1}\right) - \frac{1}{2\sigma N_{t+1}} - \frac{\mu_t}{\mu_{t+1}}\right)\left(y_{d,t+1} + y_{x,t+1}\right)\end{array}\right]\right\}$$

Given that $\Upsilon_{f_R,t} = f_{R,t}$, $\Upsilon_{\mu,t} \equiv \mu_{t-1}/\mu_t - 1$ and $\Upsilon_{N,t} \equiv \mu_{t-1}\left(1 - \nu\pi^2_{d,t}/2\right) - 1 - 1/(2\sigma N_t)$ we obtain equation (C.1).

The job creation inefficiency wedges is given by

$$\begin{aligned}\Sigma_{JC,t} &= \Upsilon_{\eta,t}\left(\Upsilon_{\varphi,t}\rho_{d,t}Z_t h_t - \frac{v_{h,t}}{u_{C,t}}\right) - \eta_t\left(\Upsilon_{\pi_w,t} + \Upsilon_{b,t}\right) \\ &\quad + E_t\left\{\beta_{t,t+1}\left[\left((1-\lambda)\eta_t + (1-\lambda-\iota_t)(1-\eta_{t+1})\frac{\eta_t}{\eta_{t+1}}\right) - \left(1-\lambda-(1-\varepsilon)\,\iota_t\right)\right]\Sigma_{JC,t+1}\right\}\end{aligned} \tag{C.4}$$

To derive expression (C.4), start from the equilibrium value of a match, $J_t$, in the market economy:

$$\begin{aligned}J_t &= \eta_t\left(\frac{\rho_{d,t}}{\mu_t}Z_t h_t - \frac{\vartheta}{2}\pi^2_{w,t} - \left(\frac{v(h_t)}{u_{C,t}} + b\right)\right) \\ &\quad + E_t\left\{\beta_{t,t+1}J_{t+1}\left((1-\lambda)\eta_t + (1-\lambda-\iota_t)(1-\eta_{t+1})\frac{\eta_t}{\eta_{t+1}}\right)\right\}.\end{aligned} \tag{C.5}$$

In the planner economy $J_t$ is instead given by:

$$J_t = \varepsilon\left(\rho_{d,t}Z_t h_t - \frac{v_{h,t}}{u_{C,t}}\right) + \left[1-\lambda-(1-\varepsilon)\,\iota_t\right]E_t\left(\beta_{t,t+1}J_{t+1}\right) \tag{C.6}$$

Define $\Sigma_{JC,t}$ as the the difference between equation (C.5) and equation (C.6):

$$\begin{aligned}\Sigma_{JC,t} &= (\eta_t - \varepsilon)\left[\left(\frac{1}{\mu_t} - 1\right)\rho_{d,t}Z_t h_t - \frac{v_{h,t}}{u_{C,t}}\right] - \eta_t\left(\frac{\vartheta}{2}\pi^2_{w,t} + b\right) \\ &\quad + E_t\left\{\beta_{t,t+1}\left[\left((1-\lambda)\eta_t + (1-\lambda-\iota_t)(1-\eta_{t+1})\frac{\eta_t}{\eta_{t+1}}\right) - \left(1-\lambda-(1-\varepsilon)\,\iota_t\right)\right]\Sigma_{JC,t+1}\right\}.\end{aligned}$$

Given that $\Upsilon_{\varphi,t} \equiv (1/\mu_t) - 1$, $\Upsilon_{\eta,t} \equiv \eta_t - \varepsilon$, $\Upsilon_{\pi_w,t} \equiv \vartheta \pi_{w,t}^2/2$ and $\Upsilon_{b,t} \equiv b$, we obtain equation (C.4).