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Fiscal Stabilization with Partial Exchange Rate Pass-Through*

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July 2009

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This paper examines the role of fiscal stabilization policy in a two-country framework that allows for a general degree of exchange rate pass-through. I derive analytical solutions for optimal monetary and fiscal policy which are shown to depend on the degree of pass-through. In the case of partial pass-through, an optimizing policy maker uses counter-cyclical fiscal stabilization in addition to monetary stabilization. However, in the extreme cases of complete or zero pass-through, the fiscal stabilization instrument is not employed. There is also no additional gain from the fiscal instrument in the case of coordination between the two countries. These results are due to the specific way the optimal fiscal policy rule affects marginal costs: Rather than being a substitute for monetary policy, fiscal policy complements it by increasing the correlation of the marginal cost terms within and across countries. This in turn makes monetary policy more effective at stabilizing them.

JEL codes: E52, E63, F41, F42

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Abstract

This paper examines the role of fiscal stabilization policy in a two-country framework that allows for a general degree of exchange rate pass-through. I derive analytical solutions for optimal monetary and fiscal policy which are shown to depend on the degree of pass-through. In the case of partial pass-through, an optimizing policy maker uses counter-cyclical fiscal stabilization in addition to monetary stabilization. However, in the extreme cases of complete or zero pass-through, the fiscal stabilization instrument is not employed. There is also no additional gain from the fiscal instrument in the case of coordination between the two countries. These results are due to the specific way the optimal fiscal policy rule affects marginal costs: Rather than being a substitute for monetary policy, fiscal policy complements it by increasing the correlation of the marginal cost terms within and across countries. This in turn makes monetary policy more effective at stabilizing them.

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1 Introduction

The extent to which fiscal policy can fulfill a stabilization role has been debated ever since Keynes proposed both monetary and fiscal policy as possible remedies for an economy stricken with an output-suppressing shock. Further fueling the debate, governments frequently resort to fiscal policy in addition to monetary policy in the hope of alleviating the consequences of recessions. Recent theoretical work

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on optimal policy in open macroeconomy models, however, has predominantly focused on monetary policy.

My paper contributes to filling this gap by examining optimal monetary and fiscal policy in a tractable two-country model. I introduce fiscal policy in the form of a labor tax that can be manipulated in response to observed shocks. Furthermore, I follow Sutherland (2005) and Corsetti and Pesenti (2005) in allowing for a general elasticity of exchange rate pass-through that includes the two most widely studied scenarios of Producer Currency Pricing (PCP) and Local Currency Pricing (LCP) as special cases. This generalization is highly desirable for two reasons. On a theoretical level, it has been shown that the degree of pass-through plays a crucial role in determining the optimal exchange rate policy.[1] On an empirical level, recent work has presented evidence that partial pass-through is most relevant.[2]

The way fiscal policy is introduced leaves the policy maker with two decisions. One concerns the average, or long-term, level of the labor tax, which has welfare implications in itself. The second decision concerns the determination of short-term deviations from the long-term rate, which are timed so as to be able to respond to contemporary shocks. These deviations play a potentially stabilizing role.

I find that the benefits from adding the fiscal stabilization instrument are highly dependent on the degree of exchange rate pass-through. The highest gains in welfare relative to the case without the second instrument are realized when the level of pass-through is partial. Interestingly, the fiscal instrument is not used at all under PCP and LCP: the optimal policy rule for setting the labor tax calls for the tax to be constant. This finding highlights the importance of considering partial exchange rate pass-through, while most of the previous literature has focused on the cases where pass-through is either complete or zero.

Interestingly, introducing the additional instrument does *not* eliminate the need for country-specific monetary policy as long as there are country-specific shocks. It also does not reduce fluctuations of the exchange rate. Instead, the welfare gains from the additional instrument are realized by further reducing fluctuations in consumption. Thus, the fiscal instrument acts as a complement to monetary policy. This result is especially relevant in light of the discussion of optimality of monetary unions (e.g. Corsetti (2006)), as fiscal instruments "taking over" for monetary ones are sometimes cited to be an answer to the stabilization deficit caused by surrendering monetary sovereignty (see Cooper and Kempf (2004)). The limited scope of the fiscal instrument is due to its distortionary effect on labor supply. While manipulations of the tax rate in response to shocks reduce fluctuations in consumption, they also affect the level of expected labor supply, which may be detrimental to welfare.

The optimal policy problem in this economy seeks to close the gap between the equilibrium allocations with fixed and flexible prices. Because of the presence of traded goods in the representative consumer's consumption basket, the policy maker minimizes the fluctuations of the two marginal cost terms that determine the prices of domestic and imported goods. Country-specific productivity shocks cause the policy maker to be generally unable to close both gaps using monetary policy.

The additional fiscal instrument increases welfare by aligning the two countries' objective functions. Fiscal policy in each country is optimally set to respond to both countries' productivity shocks. Because

[1] See Engel (2001), Devereux and Engel (2003) or Corsetti and Pesenti (2005)

[2] See, for example, Engel and Rogers (1996), Goldberg and Knetter (1997) or Campa and Goldberg (2005).

the labor tax is part of marginal costs, which form the basis for firms' pricing decisions, the effect of productivity shocks is distributed. Without the fiscal instrument, a positive productivity shock in the home country would only directly affect the marginal costs for the home firms. Now, fiscal policy both in the home and the foreign country react to the shock, which leads to a broader, more correlated change in marginal costs. As a result, optimal monetary policy is more successful at reducing marginal cost fluctuations due to the fiscal stabilizer. Intuitively, fiscal policy causes the two marginal cost terms to move with the shocks in a more correlated fashion. This in turn ensures that monetary policy, even though it is still only one instrument targeting two gaps, can achieve more stability.

This indirect way of fiscal policy complementing monetary policy is the reason for the lack of additional benefits from fiscal stabilization under PCP and LCP: With PCP, the alignment of marginal cost terms is unnecessary. The price of imports is outside of the control of the domestic policy maker, so there is only one target. But due to perfect pass-through, the marginal cost terms determining the price of goods for the domestic and the foreign market are identical. Optimal monetary policy set to keep marginal costs constant will therefore solve both countries' policy makers' problems perfectly. The result is the flex-price equilibrium for the global economy. It follows that there is no role for improvement through a fiscal instrument.

With LCP, the two countries' objective functions are *already* perfectly aligned. Domestic monetary policy has no impact on the foreign policy maker's targets and vice versa. Optimal monetary policy in the two countries results in identical rules, which in turn means that the exchange rate is constant. By eliminating any room for differences in the two countries' problems, LCP also removes the scope for improvement through a "smoothing" fiscal instrument.

This paper follows in the tradition of the New Open Economy Macroeconomics (NOEM) literature, which is usually traced to the pioneering work by Obstfeld and Rogoff (1995, 1996). Macroeconomic stabilization within this framework refers to closing gaps between the allocation that is obtained under fixed prices and the flex-price equilibrium. However, the treatment of fiscal policy in these models is considerably less developed and standardized than that of monetary policy. In general, fiscal policy is often introduced in the form of exogenous government expenditure which uses up goods, but fulfills no other role. In this context, government shocks are considered exogenous and introduced alongside technology or other shocks. Examples of this approach include the benchmark model in Obstfeld and Rogoff (1996, Ch. 10). Alternatively, Corsetti and Pesenti (2001) introduce fiscal policy via government expenditures which enter the consumer's utility function.

More recently, Lombardo and Sutherland (2004) study monetary and fiscal policies in a two-country model. They model fiscal policy in terms of government expenditure, which enters consumers' utility. One consequence of this modeling choice is that fiscal and monetary policy are set independently of each other, which is not the case in my design. Also, they focus exclusively on the case of producer currency pricing. Coutinho (2008) addresses questions that are similar to those I ask. She expands the framework used by Obstfeld and Rogoff (2002) by introducing sales taxes on firms. However, again only the case of perfect pass-through is considered, which, as I show below, is a somewhat special case, as it implies (counterfactually) that the Law of One Price holds at all times.

Introducing fiscal policy for stabilization purposes warrants some additional explanation. There are well-documented practical problems that arise if government expenditure is meant to fulfill stabilizing roles, including concern about both the inside and the outside lag. The inside lag refers to the time between recognizing the need to act and eventually passing the appropriate legislation. The outside lag refers to the time that it takes for this legislation to have a measurable effect on the economy. These observations led Alan Blinder (2004) to conclude *"If fiscal policy is to be used for stabilization purposes, taxes (and transfers) are probably the instrument of choice."* I therefore choose to insert nominal income taxes in the model, which turns out to provide a very direct way in which the government can influence prices, labor supply and output.

Keeping the model tractable necessitates some further assumptions. In order to focus on the real consequences of policy interaction, I the asset market is rendered irrelevant, in the sense that agents opt not to hold bonds in equilibrium. To this end, I assume log utility from consumption and unit elasticity of substitution between bundles of domestically and foreign produced goods. The resulting model therefore shares features with Corsetti and Pesenti (2001, 2005), Obstfeld and Rogoff (2000) and Devereux and Engel (2003). Benigno and Benigno (2003) have shown that assuming unit elasticity of substitution results in the flex price allocation being the best possible outcome, which is not generally the case under less specific assumptions. However, my framework generates interaction effects between the countries' policy choices in spite of the constant expenditure shares for domestic and imported goods, and tractability of the model buys me the advantage of transparence of the features driving my results.

Section two will introduce the model. Sections three and four provide its solution under the assumption of flexible prices and fixed prices, respectively. Section five derives the two countries' objective functions. Section six analyzes optimal monetary and fiscal policy rules in a Nash equilibrium before section seven turns to the case where the two countries coordinate policies. Section eight concludes.

2 The Model

2.1 The consumer side and consumption indexes

The model follows Devereux and Engel (2003), with the addition of income taxes and the option to allow for levels of pass-through that lie between the two extremes of PCP on one hand and LCP on the other. There are two countries, each populated by a continuum of agents with unit mass. Agents in the home country are indexed by j. Variables in the foreign country are denoted with an (*), so foreign agents are indexed by j^*.

Home agent's (j) lifetime expected utility is given by:[3]

$$U_t(j) = E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left[\ln C_\tau(j) + \chi \ln \frac{M_\tau(j)}{P_\tau} - \kappa l_\tau(j) \right] \tag{1}$$

There is a continuum of varieties of the final good, with each variety being produced by a specific monopolistic firm. The continuum is assumed to have unit mass. All goods are traded. Home produced goods are indexed by h and foreign produced goods are indexed by f. Agents maximize

[3] The assumption of log utility from consumption is not necessary for tractability. However, the loss of generality is minimal and the gain due to clarity of exposition considerable. For details regarding the derivations with a more general CRRA utility see Devereux and Engel (2003). Similarly, disutility from work is chosen to be linear for simplicity.

lifetime utility taking prices and wages as given. This results in consumption indexes for the two kinds of goods given by

$$C_{H,t}(j) = \left[\int_0^1 C_t(h,j)^{\frac{\lambda-1}{\lambda}} dh\right]^{\frac{\lambda}{\lambda-1}}$$

and

$$C_{F,t}(j) = \left[\int_0^1 C_t(f,j)^{\frac{\lambda-1}{\lambda}} dh\right]^{\frac{\lambda}{\lambda-1}}$$

λ represents the elasticity of substitution between different varieties of the home good and the foreign good. The elasticity of substitution between varieties is assumed to be strictly greater than the elasticity of substitution between the bundles of foreign and domestically produced goods, which in turn is unity. As a result, the home and foreign representative agent consumption basket is in the familiar Cobb-Douglas form:

$$C_t(j) \equiv \frac{C_{H,t}(j)^n C_{F,t}(j)^{1-n}}{n^n(1-n)^{(1-n)}} \qquad \text{and} \qquad C_t^*(j^*) \equiv \frac{C_{H,t}^*(j^*)^n C_{F,t}^*(j^*)^{1-n}}{n^n(1-n)^{(1-n)}}$$

n can be interpreted as a measure of the size of the economy, since it represents the prevalence of the home country's products in both countries' consumption baskets. It is not to be confused with a source for home bias, since it represents the weight for domestic goods in *both* baskets - so $n > \frac{1}{2}$ results in both countries spending more than half of their total nominal expenditure on goods from the home country. As is well known, the assumption of unit elasticity of substitution between foreign and domestic consumption bundles generates the result that the asset market is redundant, in the sense that it is not required for risk sharing across countries. Assuming an initially balanced current account, no country will be a net lender or borrower at the end of any period.

Solving the expenditure minimization problem results in the following home price indexes:

$$P_{H,t} = \left[\int_0^1 p_t(h)^{1-\lambda} dh\right]^{\frac{1}{1-\lambda}} \qquad \text{and} \qquad P_{F,t} = \left[\int_0^1 p_t(f)^{1-\lambda} df\right]^{\frac{1}{1-\lambda}}$$

P_H^* and P_F^* are defined accordingly.

In addition, the overall CPI for the home and the foreign country are given by

$$P_t = P_{H,t}^n P_{F,t}^{1-n} \qquad \text{and} \qquad P_t^* = (P_{H,t}^*)^n (P_{F,t}^*)^{1-n}$$

2.2 Technology and Resource Constraints

Output is linear in labor. A productivity disturbance θ_t represents the amount of output produced by one period of labor.

$$Y_t(h) = \theta_t l_t(h)$$

θ_t and θ_t^* thus represent technology shocks, which hit both countries independently every period. They are governed by the following processes:

$$\ln\theta_t = \ln\theta_{t-1} + u_t$$

$$\ln \theta_t^* = \ln \theta_{t-1}^* + u_t^*$$

u_t and u_t^* are assumed to be i.i.d. normally distributed random variables with zero mean.

The resource constraint for any domestic variety h is given by:

$$Y_t(h) \leq \int_0^1 C_t(h,j)dj + \int_0^1 C_t^*(h,j^*)dj^*$$

The nominal marginal cost is determined only by the common wage rate W_t and the productivity factor:

$$MC_t(h) = MC_t = \frac{W_t}{\theta_t}$$

A home firm's nominal profits Π_t are then given by:

$$\Pi_t(h) = (p_t(h) - MC_t)\int_0^1 C_t(h,j)dj + (\varepsilon_t p_t^*(h) - MC_t)\int_0^1 C_t^*(h,j^*)dj^* \quad (2)$$

Finally there is a resource constraint for labor:

$$\int_0^1 l_t(j)dj \geq \int_0^1 l_t(h)dh$$

This condition simply states that the aggregate amount of labor supplied by all individuals in the home country needs to be equal or greater than the aggregate amount of labor demanded by all of the domestic firms.

2.3 Budget Constraints and Consumer Optimization

Consumers hold money balances M_t and two kinds of bonds B_t and B_t^*, one denoted in each currency. Their income consists of interest receipts on the bonds, money carried over from last period, wages on labor and profits from the firms. The uses consist of holding assets to carry over to the next period, consumption, and lump-sum taxes payable to the government denoted by Φ_t. Proportional nominal taxes τ_t have to be paid on labor income.

$$\begin{aligned} M_t(j) + B_{t+1}(j) + \varepsilon_t B_{t+1}^*(j) \quad \leq \quad & M_{t-1}(j) + (1+i_t)B_t(j) + (1+i_t^*)\varepsilon_t B_t^*(j) \\ & +(1-\tau_t)W_t l_t(j) - \Phi_t(j) + \int_0^1 \Pi_t(h)dh \\ & - \int_0^1 p_t(h)C_t(h,j)dh - \int_0^1 p_t(f)C_t(f,j)df \end{aligned} \quad (3)$$

The timing convention is taken from Corsetti and Pesenti (2005), or Obstfeld and Rogoff (1996, ch.10): $M_t(j)$ represents agent j's nominal balances accumulated during period t and carried over into period $t+1$. However, $B_t(j)$ and $B_t^*(j)$ denote agent j's bonds accumulated during period $t-1$ and carried over into period t.

The consumers maximize (1) subject to (3) with respect to consumption, labor effort, money and bond holdings. They take wages and prices as given. The optimality conditions can be used to find expressions for the demands for home and foreign goods:

$$C_t(h,j) = \left[\frac{p_t(h)}{P_{H,t}}\right]^{-\lambda} C_{H,t}(j)$$

$$C_t(f,j) = \left[\frac{p_t(f)}{P_{F,t}}\right]^{-\lambda} C_{F,t}(j)$$

The Cobb-Douglas aggregation also gives us the result that spending on home and foreign goods is just a constant fraction of overall spending given by n and $1-n$, respectively:

$$P_t C_t(j) = \frac{1}{n} P_{H,t} C_{H,t}(j) = \frac{1}{1-n} P_{F,t} C_{F,t}(j)$$

The government budget constraint is given by

$$\int_0^1 (M_t(j) - M_{t-1}(j))dj + \int_0^1 \Phi_t(j)dj + \int_0^1 \tau_t W_t l_t(j)dj \geq 0$$

M_t denotes the money supply set by the monetary authority. The rules for monetary and fiscal policy will be discussed in more detail below. Clearly, any kind of fiscal and monetary policy can be financed by the government by choosing the appropriate transfer Φ_t. Government revenue from taxation plays no further role. Parallel to seigniorage revenue, which is commonly assumed to be redistributed to the consumers in a lump-sum fashion, income taxes do nothing beyond providing the fiscal policy maker with a policy instrument. This assumption of fiscal policy operating through the 'revenue side' is common in the optimal taxation literature, as noted by Coutinho (2008).

The availability of lump-sum transfers to the government eliminates the possibility of addressing questions concerning different effects of expansionary fiscal policy depending on the source of financing the government chooses. Ganelli (2005) combines a New Open Economy Macroeconomics framework with an overlapping generations setup to generate an environment in which Ricardian Equivalence is violated and different financing choices by the fiscal authority have different effects on the economy. However, his work falls into the category of papers that introduce fiscal policy as an additional shock to the economy rather than a potential stabilization instrument. Since the stabilization interaction between fiscal and monetary policy is at the core of this paper, the government is assumed to have lump-sum transfers at its disposal.

2.4 Price Setting by domestic firms

Firms set their prices one period in advance, and the assumption of monopolistic competition results in a markup over marginal cost. However, since there is a continuum of varieties, each producer is too small to have an impact on the aggregate price indices P_H and P_F.

Firms are assumed to maximize the utility of their owners, resulting in next period's profits being discounted using a subjective discount factor. More formally, firms maximize $E_{t-1}Q_{t-1,t}\Pi_t$, where Π_t is given by (2) and $Q_{t-1,t}$ is the stochastic discount rate $Q_{t-1,t} \equiv \beta \frac{P_t C_t}{P_{t-1}C_{t-1}}$. The optimal price chosen by domestic firms for the domestic market is given by

$$p_t(h) = \frac{\lambda}{\lambda - 1} \frac{E_{t-1}(Q_{t-1,t} p_t(h)^{-\lambda} P_{H,t}^{\lambda} C_{H,t} MC_t)}{E_{t-1}(Q_{t-1,t} p_t(h)^{-\lambda} P_{H,t}^{\lambda} C_{H,t})} \tag{4}$$

Using the conditions

$$P_t C_t(j) = \frac{1}{n} P_{H,t} C_{H,t}(j) = \frac{1}{1-n} P_{F,t} C_{F,t}(j)$$

along with

$$Q_{t,t+1}(j) \equiv \beta \frac{P_t C_t(j)}{P_{t+1} C_{t+1}(j)}$$

and

$$Q_{t,t+1}(j) = Q_{t,t+1}$$

we can write (4) as

$$p_t(h) = P_{h,t} = \frac{\lambda}{\lambda - 1} E_{t-1}\left[MC_t\right]$$

The pricing in the export market is more complicated, since it depends on the degree of pass-through of the exchange rate on export prices. Firms are assumed to be able to price-discriminate between home and foreign markets. As in Sutherland (2005), there are separate pricing contracts at home and abroad. The structure of contracts is assumed to be an institutional feature that is fixed.[4] It is optimal for firms to engage in this kind of price discrimination in spite of identical elasticities of substitution in the two countries due to the stochastic nature of home and foreign demand. Following Corsetti and Pesenti (2005), and defining the pass-through elasticity $\eta = \partial \ln p_t^*(h) / \partial \ln(1/S_t)$, the foreign-currency price of home varieties is:[5]

$$p_t^*(h) = \frac{\widetilde{p}_t(h)}{S_t^{\eta}} \qquad 0 \leq \eta \leq 1$$

The two standard scenarios for exchange rate pass-through are producer currency pricing (PCP) and local currency pricing (LCP). The former assumes that producers set export prices $\widetilde{p}(h)$ in their own currency, which means that the price faced by foreign consumer fluctuates 1:1 with the exchange rate but the profits to the firm are stable. This case is given by $\eta = 1$ and can also be described as complete pass-through. In contrast, if the exporter sets the price in the local currency of the country she exports to, the price does not react at all to fluctuations in the exchange rate, but profits fluctuate. This scenario is obtained if $\eta = 0$.

Home firms choose $\widetilde{p}_t(h)$ in $t-1$ to maximize the expected discounted profit in t. The actual export price p^* is dependent on the realization of the exchange rate at time t.

$$P_{h,t}^* = \frac{\lambda}{\lambda - 1} \frac{1}{S_t^{\eta}} E_{t-1}\left[\frac{MC_t}{S_t^{1-\eta}}\right]$$

[4] As mentioned in Devereux and Engel (2003), it is crucial for this assumption that the aforementioned bonds result in payoffs denominated in currency, as opposed to goods. This forces consumers to buy goods at prices set for their country.

[5] One would ultimately want to model exchange rate pass-through as being determined endogenously, as it is the result of decisions taken at the firm-level (see Corsetti and Pesenti (2002)). However, this is beyond the scope of this paper and is left for future research.

The prices chosen by foreign firms are given by

$$P_{f,t}^{*} = \frac{\lambda}{\lambda - 1} E_{t-1}\left[MC_t^{*}\right]$$

and

$$P_{f,t} = \frac{\lambda}{\lambda - 1} S_t^{\eta} E_{t-1}\left[S_t^{1-\eta} MC_t^{*}\right]$$

2.5 Monetary and Fiscal Policy

The money supply evolves according to the following process

$$m_t = m_{t-1} + \mu_t$$

where $m_t = \ln M_t$. Similarly,

$$m_t^{*} = m_{t-1}^{*} + \mu_t^{*}$$

The nominal tax rates τ_t and τ_t^{*} are set as follows

$$\ln(1 - \tau_t) = \ln(1 - \overline{\tau}) + T_t$$

$$\ln(1 - \tau_t^{*}) = \ln(1 - \overline{\tau}^{*}) + T_t^{*}$$

Monetary and fiscal policy rules consist of rules for μ_t and T_t, or μ_t^{*} and T_t^{*} for the foreign country. These policy rules respond to unanticipated shocks to productivity, so that $E_{t-1}\mu_t = E_{t-1}T_t = 0$. The analogue conditions hold for the foreign country.

Fiscal policy consists of a constant benchmark tax rate and time-varying deviations. As a consequence, setting optimal fiscal policy consists of two parts. The first part is finding the optimal level for the benchmark tax rate, which can also be interpreted as the long-term tax rate. The long-term level influences the steady-state allocations independent of whether prices are flexible or fixed. When I study welfare in an economy with fixed prices relative to the flex-price case later on, the long-run level of the labor tax consequently drops out.

The second part of the fiscal decision is concerned with finding an optimal rule for setting T_t. When studying optimal policy below, I will focus mainly on the short-term stabilization decisions, implicitly assuming that the long-term rate has been set and remains at its level. However, the level of the long-term rate will be different depending on the specific scenario under investigation.

3 Solution with Flexible Prices

It is helpful to first study the equilibrium under flexible prices. With flexible prices, the assumption of various degrees of pass-through does not affect the results, since firms do not need to form expectations regarding next period's marginal costs. Marginal cost are given by

$$MC_t = \frac{W_t}{\theta_t} = \frac{\kappa P_t C_t}{\theta_t(1 - \tau_t)}$$

(due to $W_t = \frac{\kappa P_t C_t}{(1-\tau_t)}$) and

$$MC_t^* = \frac{\kappa^* P_t^* C_t^*}{\theta_t^*(1-\tau_t^*)}$$

Flex price consumption is given by

$$C_t = \frac{\lambda - 1}{\lambda \kappa} \theta_t^n \theta_t^{*1-n} (1-\tau_t)^n (1-\tau_t^*)^{1-n}$$

and employment is given by

$$L_t = \frac{\lambda - 1}{\lambda \kappa}(1-\tau_t)$$

The terms of trade are given by

$$\frac{P_{ht}}{S_t P_{ft}^*} = \frac{\theta_t^*(1-\tau_t^*)}{\theta_t(1-\tau_t)}$$

Monetary policy has no effect in a world with flexible prices. However, the tax rate on labor income directly influences output in this economy. In addition, it generates a possibility for gains from coordination, since consumption depends on both countries' fiscal policy, whereas the labor supply only depends on domestic labor taxes. Assuming that the government maximizes consumer welfare, its problem becomes

$$\max_{1-\tau_t} \ln(\frac{\lambda-1}{\lambda\kappa}) + n \ln\theta_t + (1-n)\ln\theta_t^* + n\ln(1-\tau_t) + (1-n)\ln(1-\tau_t^*) - \frac{\lambda-1}{\lambda}(1-\tau_t)$$

The optimal tax rate $(1-\tau) = \frac{n\lambda}{\lambda-1}$. We obtain the standard result that the nominal tax should be used to subsidize labor, with the additional factor representing the share of the country's goods in the consumption basket. In a country which contributes relatively little to the consumption basket, the negative effects from taxation due to higher prices are not as significant because most goods in the consumption basket are produced abroad. However, the full benefits in terms of less disutility from labor due to taxes are reaped. This offers scope for improvement through international cooperation. The factor $\frac{\lambda}{\lambda-1}$ compensates for the distortion caused by monopolistic competition, setting $L_t = \frac{n}{\kappa}$ and output at $\frac{n\theta_t}{\kappa}$.

In the following analysis, I will assume the mean tax rate in a fixed-price scenario to be set to the same level that would obtain in an otherwise identical flex-price scenario. For example, a global planner maximizing a measure of world welfare will set long-term tax rates to their optimal levels $\frac{n}{g}\frac{\lambda}{\lambda-1}$ and $\frac{(1-n)}{(1-g)}\frac{\lambda}{\lambda-1}$. In a Nash equilibrium, on the other hand, the two countries' average tax rates will be given by $n\frac{\lambda}{\lambda-1}$ and $(1-n)\frac{\lambda}{\lambda-1}$. This is of consequence because the level of the subsidies determines the marginal welfare effect of a change in the expected labor supply.

3.1 Optimal Fiscal Policy with a Global Welfare Function

This section shows that the introduction of a tax on labor leads to gains from policy coordination. To that end, I examine optimal policy from a global perspective, that is I assume tax rates for both countries are chosen by a decision maker who is concerned with the welfare of all citizens. Let us assume that there are some weights applied to the two countries, given by g and $1-g$, respectively.

Note that the weights do not necessarily have to equal n and $1-n$.[6] In that case, a global decision maker maximizes

$$\max_{1-\tau_t,1-\tau_t^*}(g+(1-g))n\ln(1-\tau_t)+(g+(1-g))(1-n)\ln(1-\tau_t^*)-g\frac{\lambda-1}{\lambda}(1-\tau_t)-(1-g)\frac{\lambda-1}{\lambda}(1-\tau_t^*)+X$$

where X represents all of the terms independent of the choice of $1-\tau_t$ and $1-\tau_t^*$. The optimal choices for the tax rates are given by $(1-\tau_t)=\frac{n}{g}\frac{\lambda}{\lambda-1}=(1-\overline{\tau})$ and $(1-\tau_t^*)=\frac{(1-n)}{(1-g)}\frac{\lambda}{\lambda-1}=(1-\overline{\tau}^*)$. The chosen tax rates are constant. In addition, the global decision maker chooses lower tax rates (or higher subsidies) in both countries than the national policy maker. The intuition behind this result stems from the fact that the national decision maker only considers domestic consumption when weighing costs and benefits of taxation. For example, when the domestic policy maker lowers the tax rate on labor, the benefits of that decision accrue to both countries, in form of lower prices for domestically produced goods. However, the costs of that tax cut accrue only to the home country in form of more disutility from the work that is required to produce more of those goods. Optimal policy from a global perspective internalizes the benefits of higher consumption in the other country and chooses higher subsidies.

This spillover of long-run fiscal policy to the other country's welfare generates the scope for gains from cooperation between the two countries even in the case of flexible prices. Indeed, it can be shown that each country is unambiguously better off when decisions on long-run tax policy are made by the global decision maker rather than the national ones.[7]

4 Solution with Fixed Prices

I am now ready to study the optimal policy problem with nominal rigidities. Allowing for a general level of pass-through implies that the law of one price will generally not hold. In addition, consumption in the two countries will generally not be the same (as is the case with $\eta=1$) and the exchange rate will generally not be fixed (as it is with $\eta=0$). In what follows, I will present expressions for the price index and consumption that provide some intuition for the effects of policy.

Denoting lower case letters in logs, I can find expressions for the innovations (or unexpected changes) in the domestic price level and consumption:

$$p_t - E_{t-1}p_t = (1-n)\eta(s_t - E_{t-1}s_t) - K \tag{5}$$

Here K is some constant. (See appendix for details and derivations.) The only part of the domestic price level that is not pre-set stems from the price for imported goods. However, the extent to which imported goods enter the domestic CPI is given by $1-n$, and the extent to which exchange rate fluctuations affect the price of imported goods is given by η. So (5) shows that unexpected changes in the exchange rate translate into unexpected changes in the domestic CPI to a larger extent when pass-through is high and the share of foreign goods in the domestic consumption basket is large.

[6] Which needs not to be the case, because n and $1-n$ do not represent the countries' relative size but rather the relative amount of goods produced by either country.

[7] Assuming, of course, somewhat 'reasonable' weights in the global welfare function. Weights that will support this result are for example $g=n$ or $g=1/2$.

Innovations to consumption in the home and the foreign country are given by

$$c_t - E_{t-1}c_t = (1-n)(1-\eta)(s_t - E_{t-1}s_t) + \widetilde{\mu}_t \tag{6}$$

and

$$c_t^* - E_{t-1}c_t^* = -n(1-\eta)(s_t - E_{t-1}s_t) + \widetilde{\mu}_t \tag{7}$$

where $\widetilde{\mu}_t = n\mu_t + (1-n)\mu_t^*$. These two expressions collapse to the results reported by Devereux and Engel (2003) in the special cases of $\eta = 0$ or $\eta = 1$. The presence of $\widetilde{\mu}$ in both equations means that both countries' levels of consumption are affected by domestic as well as foreign monetary policy. Monetary policy turns out to be a tool for the policy maker to directly "set" nominal expenditures. In fact, the appendix shows that $\mu_t = (p_t + c_t) - E_{t-1}(p_t + c_t)$, implying that a passive monetary stance ($\mu = 0$) will result in no "surprises" in nominal expenditures, whereas an increase in the domestic monetary supply results in higher nominal expenditures by domestic consumers. Since prices are (largely) pre-set, the increase in $P * C$ must come in form of higher consumption. Monetary policy also affects foreign consumption due to the fixed share of nominal expenditure that goes towards purchasing inputs ($(1-n)PC$ in the case of the home country).

The exchange rate enters the price of imported goods, which explains the remaining term on the right hand sides of equations (6) and (7). Unexpected changes in home country consumption depend more heavily on exchange rate movements if the share of foreign goods in the consumption basket is high and if the degree of pass-through is low.

The exchange rate is determined exclusively by the relative monetary stances of the two countries:

$$s_t - E_{t-1}s_t = \mu_t - \mu_t^*$$

If the domestic monetary authority increases money supply μ_t, an unexpected depreciation (rise in s_t) is the result. Or, putting it a different way, if there are changes to nominal expenditures in the home country, the only way for the exchange rate to stay constant is if there were exactly offsetting changes in foreign nominal expenditures. For future reference, note at this point that perfect symmetry between the foreign and the domestic monetary policy rule will always result in a constant exchange rate.

5 Welfare Analysis

Prices adjust fully after one period, so changes to the money supply prior to time t do not have an effect on $E_{t-1}U_t$. The problem of the policy maker is reduced to maximizing the consumer's utility on a period-by-period basis. Following the literature, I abstract from the direct welfare effects of holding real balances. The inclusion of nominal income taxes, however, makes the term depicting disutility from labor policy-dependent. Expected utility is given by

$$E_{t-1}U_t = E_{t-1}\left[\ln C_t - \kappa L_t\right]$$

The appendix shows the derivations leading to the complete objective function for the home country:

$$\begin{aligned} E_{t-1}W_t &= -\frac{n}{2}E_{t-1}(\mu_t - u_t - T_t)^2 - \frac{(1-n)}{2}E_{t-1}(\eta\mu_t^* + (1-\eta)\mu_t - u_t^* - T_t^*)^2 \\ & -n\left(\left[n \exp E_{t-1}\left[(\mu_t - u_t)T_t - T_t^2\right] + (1-n)\exp E_{t-1}\left[(\eta\mu_t + (1-\eta)\mu_t^* - u_t)T_t - T_t^2\right]\right] - 1\right) \end{aligned} \quad (8)$$

The first two terms of (8) correspond to the marginal cost terms relevant to the price setting for goods in the domestic CPI. They represent the gaps the policy maker strives to close in order to reach the flex-price equilibrium. In effect, the stabilization task consists of keeping marginal costs as close to constant as possible: in case of a positive productivity shock (increase in u_t), the policy maker can counter this increase by raising μ_t. The first term of the objective function could be held constant in this fashion, but clearly this is not optimal due to the second term, which represents fluctuations in the marginal costs of a foreign firm setting prices for the domestic market. The foreign firm takes the exchange rate into account, which explains the presence of μ_t in the second term. Optimal setting of domestic monetary policy will therefore also depend on the foreign productivity shock u_t^*.

The objective function (8) differs from versions in the literature (for example Corsetti and Pesenti (2005)) for two reasons: the addition of the fiscal policy instrument T and the trade-off between marginal cost stabilization (the first two terms) and reducing disutility from labor, which is represented by the second line of the equation. The last two terms enter the policy maker's objective function because a positive covariance between the innovation to the tax rate T_t and the monetary policy instrument μ_t weakens any effect monetary policy alone has on output. If, for example, monetary policy is expansionary but T_t rises at the same time (a rise in T corresponds to a decrease in the tax rate τ), the increase in marginal costs due to the rise in μ_t is alleviated to some degree by the simultaneous rise in $(1-\tau_t)$. This is detrimental to welfare because lower marginal costs imply higher disutility from labor due to higher output. Following the same logic, a negative covariance between μ_t and T_t will be welfare enhancing. In addition, volatility in fiscal policy has a welfare increasing component now, as well. Examining (21) reveals that higher variance of $(1-\tau_t)$ increases the marginal cost terms $E_{t-1}[\frac{P_tC_t}{\theta_t(1-\tau_t)}]$ and $E_{t-1}[\frac{P_tC_t}{S_t^{1-\eta}\theta_t(1-\tau_t)}]$, thereby decreasing overall expected labor supply.

Note that the addition of the fiscal instrument seems at first glance to provide the policy maker with another viable way to close the marginal cost gaps. However, the analysis below shows that this is misleading. Due to the impact of the fiscal policy rules on expected labor supply, reflected by the second line of (8), T_t is not optimally set to counter movements in u_t. Instead, monetary policy will still fulfill the stabilization role, while fiscal policy manipulates the marginal cost terms so as to make monetary policy more effective.

In the following section I will study the effect of the introduction of the fiscal instrument in a Nash equilibrium setting, as well as examine the welfare effects of coordination with and without fiscal policy. Throughout the analysis I will assume the two countries to be symmetric, so that $n = 1/2$.

6 Optimal Policy

Assuming that both domestic and foreign policy makers can set μ_t and T_t and μ_t^* and T_t^* freely in response to the productivity disturbances, the problem becomes a simple maximization of (8) and its foreign equivalent with respect to the policy variables. Foreign welfare is given by

$$\begin{aligned} E_{t-1}W_t^* &= -\frac{n}{2}E_{t-1}(\eta\mu_t + (1-\eta)\mu_t^* - u_t - T_t)^2 - \frac{(1-n)}{2}E_{t-1}(\mu_t^* - u_t^* - T_t^*)^2 \\ &\quad -(1-n)\left(n \exp E_{t-1}((\eta\mu_t^* + (1-\eta)\mu_t - u_t^*)T_t^* - T_t^{*2}\right) + (1-n)\exp E_{t-1}((\mu_t^* - u_t^*)T_t^* - T_t^{*2}) - 1) \end{aligned} \tag{9}$$

In order to be able to arrive at a closed-form solution without having to resort to numerical simulation, I approximate the exponential terms in the welfare functions by linear expressions. For example, $\exp((\mu_t^* - u_t^*)T_t^* - T_t^{*2})$ is approximated by $1 + (\mu_t^* - u_t^*)T_t^* - T_t^{*2}$. This is valid due to the nature of the AR(1) processes in this model, μ_t, μ_t^*, u_t, u_t^*, T_t and T_t^* are all innovations to log-linear expressions; they can be interpreted to be denoting percentage values. Note also that we are analyzing the case of national policy makers maximizing only their respective country's welfare function while taking the policy decisions of the other country as given. In this setting $1 - \overline{\tau}$ is set to equal $n\frac{\lambda+1}{\lambda}$ and $1 - \overline{\tau}^*$ is equal to $(1-n)\frac{\lambda+1}{\lambda}$ (see the results of section 3 above).

6.1 Monetary Policy

In a Nash equilibrium, domestic monetary policy is given by

$$\mu_t = \frac{1}{2}\left[u_t \frac{3\eta^2 - 2\eta + 3}{3\eta^2 - 4\eta + 3} + u_t^* \frac{3\eta^2 - 6\eta + 3}{3\eta^2 - 4\eta + 3}\right]$$

It is not surprising that the optimal policy rule takes on the form $\mu_t = au_t + bu_t^*$, given the log-linear nature of the model. The expressions representing a and b are both strictly positive. Optimal monetary policy is accommodating: in the case of a positive productivity shock monetary authorities react by increasing the money supply. This holds for both domestic and foreign productivity shocks, although the magnitude of the response crucially depends on the degree of pass-through. Figure 1 depicts the weight on foreign and domestic productivity shocks in the setting of domestic monetary policy graphically, as a function of η.

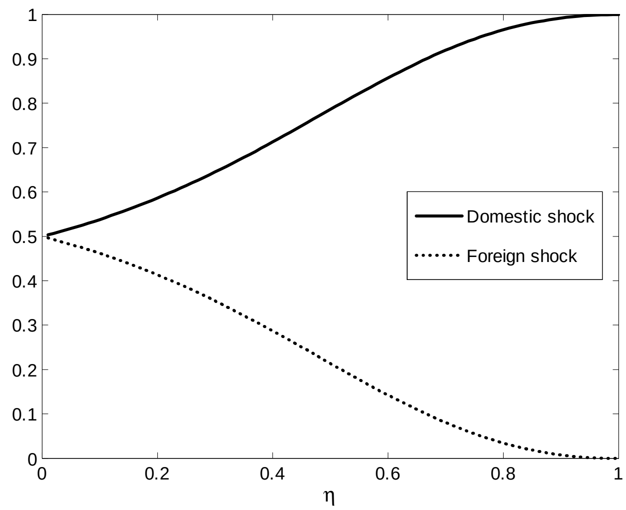

Figure 1: Monetary policy weights on productivity shocks

When pass-through is zero, the origin of productivity shocks is irrelevant and both countries respond identically to either shock (formally, $\mu_t = \mu_t^* = \frac{1}{2}u_t + \frac{1}{2}u_t^*$). Recall that this also means that there is no movement in the exchange rate. If pass-through is perfect, on the other hand, the optimal monetary policy focuses solely on the domestic productivity shock and monetary supply changes one-for-one with productivity. As one moves away from those two special cases, the weight on the foreign shock increases monotonically as the pass-through decreases from one to zero. From the policy maker's perspective, a decrease in observed pass-through should thus cause a shift in the priorities of monetary policy. If, for example, pass-through were to decline from an initial level near unity, monetary policy should start putting more weight on the foreign productivity shock when deciding on the domestic monetary stance.

6.2 Fiscal Policy

As soon as I analyze cases of partial pass-through, fiscal policy plays a role. The optimal domestic fiscal policy rule is given by

$$T_t = (u_t - u_t^*)\,\frac{\eta(\eta - 1)}{3\eta^2 - 4\eta + 3}$$

Figure 2 shows the factor multiplying the relative productivity disturbance $(u_t - u_t^*)$ for fiscal policy as a function of η. Note that fiscal policy is counter-cyclical - a positive shock (corresponding to an increase in u_t) is countered by a decrease in T_t, which represents an increase in the tax rate. This dampens the effect of shocks on marginal costs, and thus on prices, consumption and welfare.

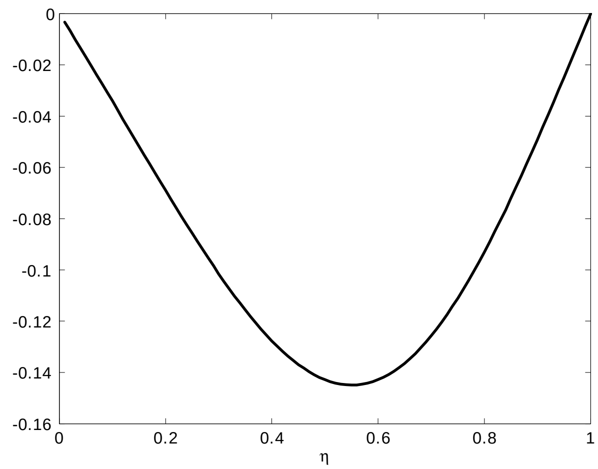

Figure 2: Reaction of domestic fiscal policy to relative productivity shocks

Fiscal policy is a function of the *relative* global productivity shocks; only a difference between the two countries' productivity disturbances calls for a fiscal reaction. In the case of just one global shock, fiscal policy is optimally set to be constant.

The optimal rules for monetary and fiscal policy suggest how the weights on the two countries' productivity shocks should change as the policy maker faces a changing exchange rate transmission environment. For example, in a scenario of declining pass-through, both the weight on foreign productivity shocks in the optimal monetary policy rule and the extent to which optimal fiscal policy reacts to the difference between the productivity shocks of the two countries increase.[8]

Optimal fiscal policy T_t can also be written as

$$\begin{aligned} T_t &= \frac{1}{2}(\eta - 1)(s_t - E_{t-1}s_t) \\ &= \frac{1}{2}(\eta - 1)(\mu_t - \mu_t^*) \end{aligned} \tag{10}$$

Both of these expressions hint at the way fiscal stabilization works in this framework. The instrument becomes active when there are differences - differences in the two countries' monetary stances or differences in the productivity shocks. Figure 1 shows that monetary policy stances in the two countries are different at high degrees of pass-through and become more similar as pass-through decreases. At the same time, it is at high degrees of pass-through that the fiscal instrument's impact is limited because the marginal cost terms for domestic goods sold at home and abroad (the first terms in (8) and (9), respectively) resemble each other (giving rise to the factor $(\eta - 1)$ in (10). Combining these two effects gives the result that the biggest impact from aligning the marginal cost terms occurs at medium levels of pass-through.

6.3 Welfare Effects of Fiscal Policy

To examine the welfare effects of introducing the additional fiscal instrument, I will first compare my results thus far with optimal monetary policy in the absence of the fiscal instrument. This will clarify

[8]Campa and Goldberg (2002) and Gagnon and Ihrig (2004) have presented empirical evidence showing a decline in pass-through in industrialized countries for recent years.

the channels through which fiscal policy has an impact on the two countries' welfare. Without fiscal policy as an available option, and still assuming equally sized countries ($n = 1/2$), optimal monetary policy choices in a Nash equilibrium are given by

$$\mu_t = u_t \frac{(\eta^2 - \eta + 1)}{2\eta^2 - 3\eta + 2} + u_t^* \frac{(\eta^2 - 2\eta + 1)}{2\eta^2 - 3\eta + 2}$$

and

$$\mu_t^* = u_t \frac{(\eta^2 - 2\eta + 1)}{2\eta^2 - 3\eta + 2} + u_t^* \frac{(\eta^2 - \eta + 1)}{2\eta^2 - 3\eta + 2}$$

Figure 3a depicts the weights monetary policy places on the two productivity shocks as a function of η. Figure 3b depicts the monetary policy weights just on the domestic productivity shock with and without an available fiscal instrument.

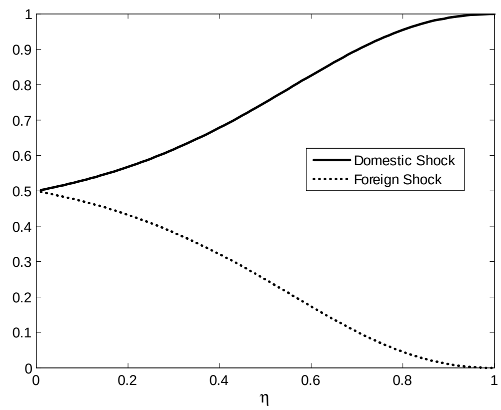

Figure 3a: Monetary policy weights on productivity shocks in the absence of a fiscal instrument

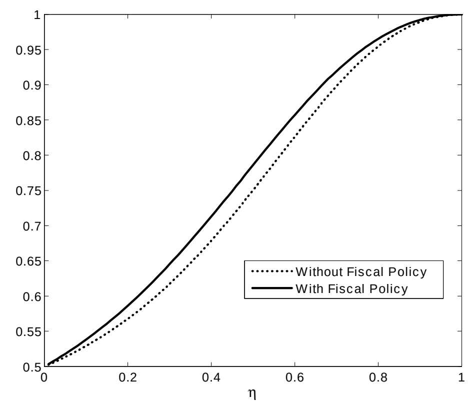

Figure 3b: Weights on domestic productivity shock with and without fiscal instrument

Perhaps surprisingly, the introduction of the fiscal instrument does not change optimal monetary policy rules significantly (compare Figures 1 and 3a). As noted before, the welfare gains from using the fiscal instrument are indirect: Instead of taking over a stabilization role by counteracting the productivity shocks directly, fiscal policy modifies the marginal cost terms so that the monetary policy rule, even though it is very similar to the one-instrument case, proves to be more effective. To demonstrate this, Figures 4a and 4b show the change in the fluctuations of marginal costs that are the basis for the prices faced by domestic consumers as we include the fiscal instrument. Figure 4a depicts $E_{t-1}[\mu_t - u_t]^2$ and $E_{t-1}[\mu_t - u_t - T_t]^2$ by graphing the factor multiplying the variance term $(\sigma_u^2 + \sigma_{u^*}^2)$, where σ_u^2 is the variance of u_t. Figure 4b depicts $E_{t-1}\left[\eta\mu_t^* + (1-\eta)\mu_t - u_t^*\right]^2$ and $E_{t-1}\left[\eta\mu_t^* + (1-\eta)\mu_t - u_t^* - T_t^*\right]^2$ in the same fashion.

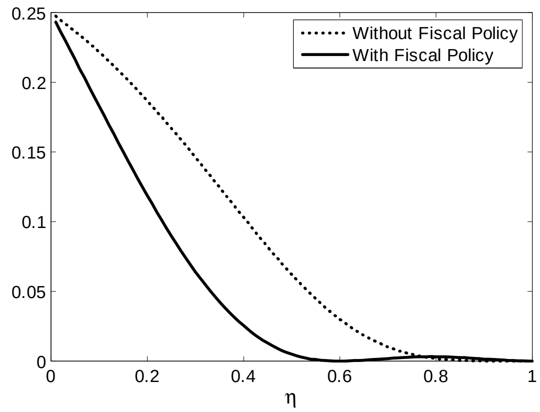

Figure 4a: Marginal cost fluctuations relevant to the domestic market price of the domestically produced good

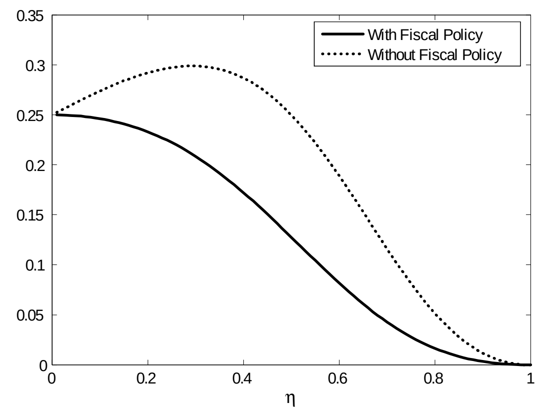

Figure 4b: Marginal cost fluctuations relevant to the domestic market price of the foreign produced good

In understanding the graphs, it helps to recall that prices are constant markups over expected marginal costs, so price fluctuations are equivalent to fluctuations in firms' marginal costs. The domestic marginal costs are given by $\frac{PC}{\theta(1-\tau)}$. and the appendix shows that the variance of this term can be written as $E[\mu - (u+T)]^2$. With optimal policy setting, T reacts counter-cyclically to u, which 'stabilizes' the sum $u+T$. In fact, $var(u+T) = var((u_t - u_t^*)\,\frac{\eta(\eta-1)}{3\eta^2-4\eta+3} + u) = \left(\frac{4\eta^2-5\eta+3}{3\eta^2-4\eta+3}\right)^2 \sigma_u^2 - \left(\frac{\eta(\eta-1)}{3\eta^2-4\eta+3}\right)^2 \sigma_{u^*}^2$. Because fiscal policy modifies taxes based on *relative* productivity shocks, the variance of the sum $(u+T)$ is a function of the variances of both shocks.

To further help with intuition, let us examine the case where $\sigma_u^2 = \sigma_{u^*}^2$. In that case, $var(u+T) = \frac{3-6\eta+5\eta^2}{3-4\eta+3\eta^2}\sigma_u^2$. Figure 5 plots the coefficient.

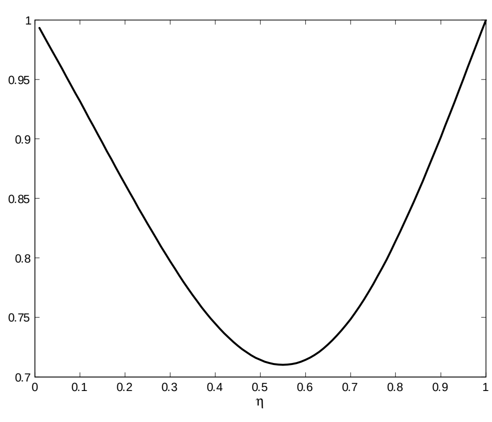

Figure 5: Factor of productivity shock variance passed on to $(u+T)$

For medium levels of pass-through, the use of fiscal policy achieves a variance reduction of the term $(u+T)$ of almost 30% relative to the case of constant fiscal policy (if $T=0$, the variance will clearly just be σ_u^2, independent of the level of pass-through). It is this reduction in variance that is ultimately responsible for the drop in variance of domestic prices for domestic consumers depicted in Figure 4a, since monetary policy, and thus the variance of μ, is very similar in both scenarios.[9]

The volatility of the price of imported goods depends on the volatility of foreign marginal costs and the volatility of the exchange rate. However, as we saw above, $s_t = \mu_t - \mu_t^*$, so that import price volatility can be written as $[\eta\mu_t^* + (1-\eta)\mu_t - u_t^* - T_t^*]^2$. The introduction of fiscal policy results in a decrease in the variance of $(u_t^* + T_t^*)$, analogous to the case of domestic prices. Figure 4b depicts the effect of this decrease on the overall import price volatility as a function of the pass-through parameter η.

In addition to each of the two marginal cost terms being less volatile due to the fiscal component of marginal costs, they are also more highly correlated. This is the key effect of fiscal policy that enables the monetary instrument to achieve a higher level of stabilization. The correlation between the terms $[\mu - u]$ and $[\eta\mu^* + (1-\eta)\mu - u^*]$ is given by $\frac{1}{ab}$, where a and b are given by the values on the y-axis in Figures 4a and 4b for the dotted line (for a given value of η). With fiscal policy, the correlation between $[\mu - u - T]$ and $[\eta\mu^* + (1-\eta)\mu - u^* - T^*]$ is given by $\frac{1}{cd}$, with c and d representing the values taken from the solid line for the same value of η in the Figures 4a and 4b. Clearly, $c \leq a$ and $d \leq b$ with equality at $\eta = 0$ and $\eta = 1$. It follows that fiscal policy increases the correlation of the marginal cost terms relevant to the domestic policy maker. As a consequence, trying to close both gaps with monetary policy is more successful, resulting in less fluctuations and in turn lower prices.

In the Nash equilibrium, the two countries' policy makers make use of fiscal policy to bring down fluctuations in firms' marginal costs. However, using fiscal policy in this way also moves expected labor supply away from its (constant) flex-price level. The welfare losses caused by higher expected disutility from labor are very small and the gains due to reduced price volatility are larger in magnitude. Figure 6a shows the gains in welfare due to the availability of the fiscal instrument by plotting the factors multiplying $(\sigma_u^2 + \sigma_{u^*}^2)$ for total welfare in both cases, and Figure 6b plots the welfare gains from having the fiscal instrument. Note that the scope for improvement through the use of fiscal policy in addition to monetary policy is most pronounced in the mid-range of the pass-through parameter. Furthermore, examining the neighborhood of the two extreme cases, there is more scope for welfare gains from fiscal stabilization for near-zero pass-through than in the case of near-perfect pass-through.

[9] Of course, the third candidate for an explanation of the drop in $var(\ln \frac{PC}{\theta(1-\tau)})$ is the covariance between $\ln PC$ and $\ln(\theta(1-\tau))$. In fact, that covariance decreases slightly with the introduction of fiscal policy, which by itself would result in an increase in $var(\ln \frac{PC}{\theta(1-\tau)})$.

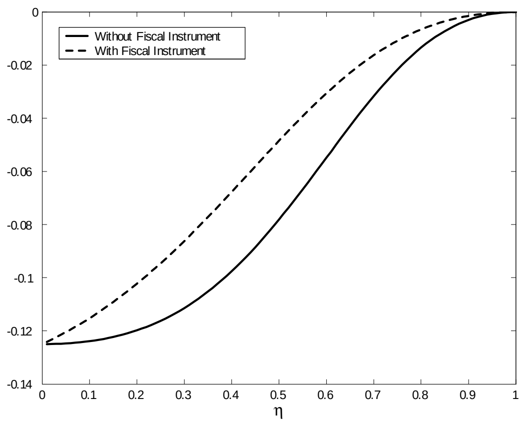

Figure 6a: Welfare as mutliple of the variance term $(\sigma_u^2 + \sigma_{u^*}^2)$

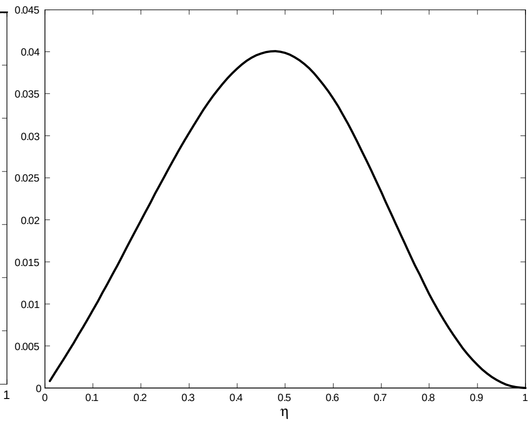

Figure 6b: Gain in welfare from using the fiscal instrument as a multiple of $(\sigma_u^2 + \sigma_{u^*}^2)$

Finally, it is instructive to compare the implications of the availability of an additional fiscal instrument on the volatility of the exchange rate. Corsetti and Pesenti depict the policy maker's problem in an open economy with imperfect pass-through as facing a trade-off between complete domestic price stabilization on the one hand and perfect synchronization of the two countries' monetary stances (which results in a fixed exchange rate) on the other. In this model, the policy decisions with LCP and PCP are identical to their results - the exchange rate is still fixed when $\eta = 0$ and firm marginal costs are still held constant when $\eta = 1$. However, is fiscal policy used to reduce exchange rate fluctuations for mid-range values of the elasticity of pass-through? Because exchange rate volatility is given by $E_{t-1}(\mu_t - \mu_t^*)^2$, the slightly stronger response to the domestic productivity shock and the weaker response to the foreign shock result in larger exchange rate fluctuations in the scenario with fiscal policy. The second instrument is not used to achieve a more stable exchange rate.

The addition of a fiscal instrument does not lead the two countries to choose more similar monetary stances. The only case where the exchange rate ends up being constant is the case of LCP.

Instead, as (10) indicates, fiscal policy provides a buffer between exchange rate fluctuations and marginal costs facing exporters. Instead of reducing the fluctuations in the exchange rate directly, optimally set labor taxes reduce their impact on marginal costs, instead.

7 Policy Coordination

7.1 Policy Coordination: Solution to a Global Planner's problem

In this class of two-country models it is well known that there are no gains from monetary policy coordination when the focus is only on the cases of LCP and PCP (Benigno and Benigno (2003), Benigno (2004)). In other words, a Global Planner that were to maximize a weighted sum of the two countries' welfare functions would choose exactly the same policies as the countries choose independent of each other. Even without fiscal policy, there are gains from cooperation as soon as we allow for general degrees of pass-through. Without time-varying taxes and focusing on the symmetric case of

$n = \frac{1}{2}$ and equal country weights in the Global Planner's objective function, labor supply is constant and global welfare can thus be written as

$$\begin{aligned} W^{GL} &= E\Bigg[\frac{1}{2}\left(-\frac{1}{4}(\mu - u - T)^2 - \frac{1}{4}(\eta\mu^* + (1-\eta)\mu - u^* - T^*)^2\right) \\ &\quad + \frac{1}{2}\left(-\frac{1}{4}(\eta\mu + (1-\eta)\mu^* - u - T)^2 - \frac{1}{4}(\mu^* - u^* - T^*)^2\right)\Bigg] \end{aligned} \tag{11}$$

The optimal monetary policy rules set by the Global Planner are given by

$$\mu = \frac{1-\eta+2\eta^2}{2-4\eta+4\eta^2}u + \frac{1-3\eta+2\eta^2}{2-4\eta+4\eta^2}u^*$$

and

$$\mu^* = \frac{1-3\eta+2\eta^2}{2-4\eta+4\eta^2}u + \frac{1-\eta+2\eta^2}{2-4\eta+4\eta^2}u^*$$

Due to symmetry, there are only two terms that can be manipulated by the policy maker, fluctuation in the price index for domestic goods and the price index for imported goods. Figures 7a and 7b show the effect of policy coordination on these indices; Figure 7c shows the net gain in welfare due to coordination. Again, the figures show the factors multiplying the variance term $(\sigma_u^2 + \sigma_{u^*}^2)$.

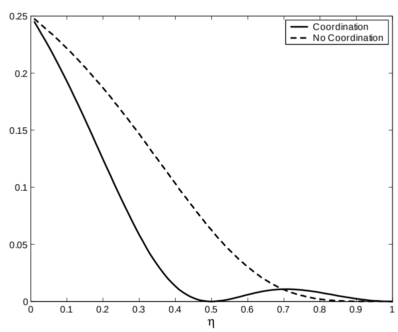

Figure 7a: Marginal cost fluctuations relevant to the price for domestically produced goods

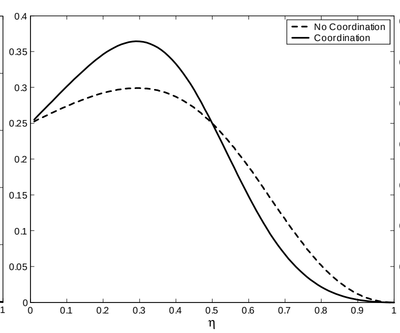

Figure 7b: Marginal cost fluctuations relevant to the price of imported goods

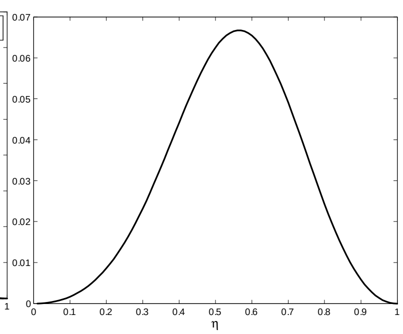

Figure 7c: Welfare gain from monetary policy coordination

The benefits from coordination depend strongly on the degree of pass-through. Interestingly, the increases in welfare relative to the Nash case are generated exclusively by reducing fluctuations in the price index for *domestically* produced goods for low degrees of pass-through ($\eta < 1/2$). Another look at the objective function (11) delivers an explanation. When setting the monetary stance μ, the domestic country's policy maker balances the two conflicting objectives of choosing a value that compensates for the domestic productivity shock u and one that compensates for the foreign productivity shock u^*, because μ enters the exchange rate and thus also the pricing decision of the foreign exporting firms. The global planner, however, includes one more price in the stabilization problem - the price of domestic goods that are exported to the foreign country. But this also involves counter-acting the swings of u rather than u^*. This generates the somewhat counter-intuitive result that a more global perspective leads to domestic monetary policy reacting more strongly to the domestic productivity shock. The result is a decrease in the squared difference $[\mu - u]^2$ for almost all values of η, as we can see in Figure 7a. But for high degrees of pass-through, fluctuations in export prices $[\eta\mu - (1-\eta)\mu^* - u]^2$ approach those of the domestic index - and thus the higher emphasis on the domestic productivity shock starts 'paying off' in terms of lower price fluctuations as the elasticity of pass-through exceeds 0.5, as can be seen in Figure 7b.

Allowing for a general level of pass-through results in gains from coordination. Interestingly, those gains are realized due to the fact that countries react too *strongly* to foreign productivity shocks in the absence of coordination, rather than too little. Note that the introduction of the fiscal instrument in a Nash equilibrium above has also led to a stronger reaction of optimal monetary policy to domestic productivity shocks.

Next I will turn to the question of gains from coordination with fiscal policy as an additional instrument.

What turns out to be of significance in this approach is the assumption regarding each country's choice for the steady state labor tax rate. Assuming that the global planner determines both aspects of fiscal policy, average labor subsidies in both countries will be raised, as discussed above. As a result, the first-best allocation becomes achievable, because the labor subsidy compensates for the markup chosen by the monopolistic producers. In the simplest case, assuming that $n = g = \frac{1}{2}$, the global objective function is given by

$$\begin{aligned} W^{GL} &= E\Bigg[\frac{1}{2}\Bigg(-\frac{1}{4}(\mu - u - T)^2 - \frac{1}{4}(\eta\mu^* + (1-\eta)\mu - u^* - T^*)^2 \\ &\quad -\frac{1}{2}((\mu - u)T - T^2) - \frac{1}{2}((\eta\mu + (1-\eta)\mu^* - u)T - T^2)\Bigg) \\ &\quad +\frac{1}{2}\Bigg(-\frac{1}{4}(\eta\mu + (1-\eta)\mu^* - u - T)^2 - \frac{1}{4}(\mu^* - u^* - T^*)^2 \\ &\quad -\frac{1}{2}((\eta\mu^* + (1-\eta)\mu - u^*)T^* - T^{*2}) - \frac{1}{2}((\mu^* - u^*)T^* - T^{*2})\Bigg)\Bigg] \end{aligned} \tag{12}$$

Lines one and three of the welfare function correspond to stabilizing the CPIs of the two countries, as we saw before. Lines two and four capture the effect of variations in fiscal policy on the expected labor supply. Assuming the Global Planner can optimally set all four policies after observing the productivity shocks in both countries, the interior solution to the program calls for the following policies:

$$\begin{aligned} \mu &= \frac{1-\eta+2\eta^2}{2-4\eta+4\eta^2}u + \frac{1-3\eta+2\eta^2}{2-4\eta+4\eta^2}u^* \\ \mu^* &= \frac{1-3\eta+2\eta^2}{2-4\eta+4\eta^2}u + \frac{1-\eta+2\eta^2}{2-4\eta+4\eta^2}u^* \\ T &= 0 \\ T^* &= 0 \end{aligned}$$

The introduction of the fiscal instrument does not change the planner's policies at all. Mathematically, the reason for the constant tax rate lies in the marginal effect of an increase in labor subsidies on global welfare:

$$
\begin{aligned}
\frac{\partial W^{GL}}{\partial T} &= \frac{1}{4}(\mu - u - T) - \frac{1}{4}(\mu - u) + \frac{1}{2}T - \frac{1}{4}(\eta\mu + (1-\eta)\mu^* - u) + \frac{1}{2}T \\
&\quad + \frac{1}{4}(\eta\mu + (1-\eta)\mu^* - u - T) \\
&= \frac{1}{2}T
\end{aligned}
$$

Clearly, an interior solution must have the property that $T = 0$.[10] The comparison between cooperation and Nash scenarios with fiscal policy is thus made difficult by the different treatment of the average tax rate which in turn has implications for the marginal effect of a change in the labor tax on the expected disutility from work. In particular, the cooperative scenario does not support interior solutions with tax rates reacting to relative productivity shocks as in the non-cooperative case. The reason lies in the two ways that fiscal policy uncertainty enters this model: On the one hand, fiscal policy rules can decrease CPI fluctuations by making marginal costs depend on a linear combination of both countries' productivity shocks as is the case in the Nash equilibrium solution. On the other hand, both fluctuations in the tax rate itself and a negative covariance between T and $\frac{PC}{\theta}$ are welfare enhancing by unambiguously raising expected marginal costs, thereby raising prices, decreasing quantities demanded and thus decreasing disutility from work. The Global Planner's problem weighs these two effects against each other and the result is a fiscal policy that is independent of the choices for either country's monetary stance. This severs the link between fiscal and monetary policy and results in non state-contingent fiscal policy being the only equilibrium.

Concerning the reduction of volatility in consumption, there are thus no further gains from cooperation once we take into account fiscal policy. However, due to the higher level of subsidies reflected in larger values for $(1-\overline{\tau})$ and $(1-\overline{\tau}^*)$, the level of global welfare will still be higher with fiscal policy through the subsidies to labor that overcome the artificially low level of output due to monopolistic competition.

Intuitively, policy coordination effects are similar to the fiscal policy effects discussed above. Since both policy makers are now focusing on all four of the gaps which are relevant for the countries' welfare, the result is a monetary policy which causes the marginal cost terms to be less volatile and more correlated, just as the fiscal instrument did in the Nash equilibrium.

7.2 Optimal Policy in a Monetary Union

In this section I will assume that the union policy maker has the same objective function as the Global Planner in the previous section (12). The issue at stake is optimal policy given the constraint of a monetary union.

[10] An examination of a corner solution is not helpful at this point. A budget constraint motivated upper bound on T depends on the support of the productivity shocks. In addition, for very large absolute values of T the approximation $\exp((\mu - u)T - T^2) \approx 1 + ((\mu - u)T - T^2)$ will not hold.

Knowing that $\mu = \mu^*$ will hold, the optimal fiscal policy stance for the home country is given by

$$\begin{aligned} T_t &= (\mu_t - u_t)\left[1 - (1-n) - n\right] \\ &= 0 \end{aligned}$$

Independent of the relative country size and the degree of pass-through, countries will opt not to use their fiscal instruments in the case of a monetary union. The intuition is exactly the same as for the case of LCP: Because the two countries have identical monetary policy rules, there are no further gains from smoothing differences between the two countries policy problems. Any stabilization gains cannot outweigh the losses due to higher expected labor supply. μ_t now describes the policy stance chosen by the centralized monetary authority. The optimal decision rule for μ_t is given by

$$\mu_t = nu_t + (1-n)u_t^*$$

The effect of a monetary union is thus to eliminate the dependence of the policy choices on the parameter η as well as the deactivation of the use of fiscal instruments. How do fluctuations in the marginal cost compare to the non-union case? Simple algebra reveals that the fluctuations in domestic market prices are now equal for domestically and foreign produced goods. In both cases, the fluctuations are equal to $\frac{1}{4}(u_t - u_t^*)^2$. Taking a look back at Figure 4a shows that with regard to prices of domestically produced goods, a monetary union results in a more volatile price index in all cases except LCP, in which case all of the scenarios examined thus far arrive at the same policy prescriptions. However, Figure 8 shows the sense in which the use of fiscal policy is a substitute for forming a monetary union (with the y-axis again depicting the factor multiplying $(\sigma_u^2 + \sigma_{u^*}^2)$).

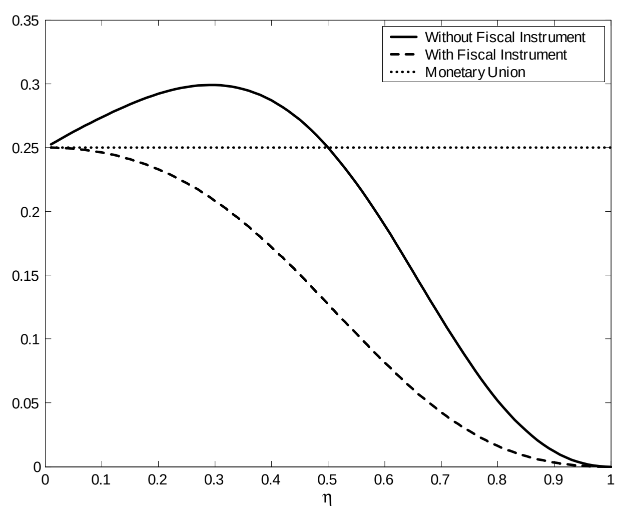

Figure 8: Fluctuation in the domestic price index for imported goods under different regimes

For low degrees of pass-through (in fact, for $\eta < 0.5$), a monetary union setting a joint monetary stance for both countries causes lower fluctuations in the price index for imported goods than those obtained when the two countries decide on monetary policy in a Nash equilibrium. However, this result ceases to hold once we allow for countries using fiscal stabilization instruments in addition to monetary policy. In summary, allowing for fiscal policy does not move two countries closer to forming a monetary union in this kind of model, instead it further magnifies the loss in welfare caused by forming one in the first place. The reason is that fiscal policy is optimally used to increase the correlation between the marginal cost terms that are targeted for stabilization, which is the same effect coordinated decision making would have.

To illustrate this point more strongly, Figure 9 shows total expected global welfare in the three scenarios of Monetary Union, Nash equilibrium with an available fiscal instrument and Nash equilibrium without the fiscal instrument.

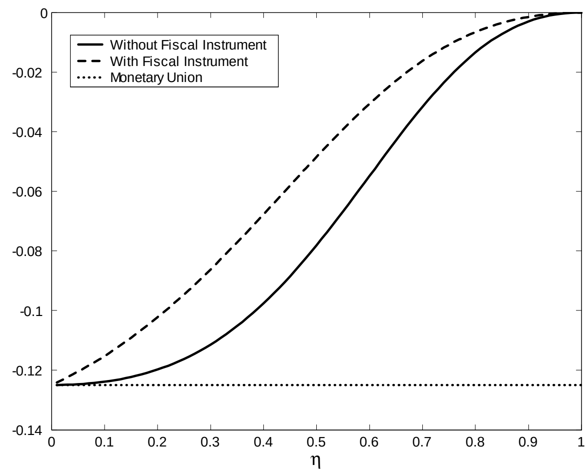

Figure 9: Welfare under three different regimes (multiplier of $(\sigma_u^2 + \sigma_{u^*}^2)$)

In the case of Local Currency Pricing, all three scenarios result in the same welfare. However, as soon as pass-through is positive, the monetary union results in fluctuations in expected consumption which are avoided in the case of country-specific monetary policy that is sensitive to the degree of pass-through. Furthermore, introducing fiscal policy, which also reacts to the productivity shocks in a way that depends on the degree of pass-through, increases welfare further.

Summarizing, the fiscal stabilization instrument provides no benefits in settings where coordination or merging of monetary policy takes place. This reflects the specific role played by the fiscal instrument: it reacts to fluctuations in the exchange rate and brings domestic monetary policy closer to internalizing the effects it has on the pricing of exports sold in the foreign market. Once I assume coordination of policies, domestic monetary policy already takes into account all of the marginal cost gaps. In a monetary union, as in the case of LCP, there are no exchange rate fluctuations, so the fiscal instrument is no longer beneficial.

8 Conclusions

The addition of fiscal stabilization instruments in form of labor income taxes in a Neo-Keynesian two-country model affects policy decisions in a non-cooperative Nash equilibrium. This result depends critically on allowing for a general elasticity of pass-through, since stabilizing fiscal policy does not lead to welfare gains at the two extremes of zero pass-through (LCP) and perfect pass-through (PCP). This finding provides further motivation for studying implications of partial pass-through, especially in light of recent empirical work showing prevalence of partial pass-through in most of the countries studied. When facing declining levels of pass-through, optimal monetary policy becomes more responsive to foreign productivity shocks and optimal fiscal policy starts playing a more active stabilization role.

Interestingly, the additional fiscal instrument does not free up monetary policy to stabilize the exchange rate - in fact monetary policy reacts more strongly to domestic productivity shocks in the scenario with fiscal instruments, thereby increasing exchange rate variance. Fiscal policy reacts counter-cyclically to relative productivity shocks (that is taxes are temporarily lowered in response to a decrease in domestic productivity, but raised in response to a decrease in foreign productivity). This specific fiscal policy rule both decreases the volatility and increases the correlation of the marginal cost terms that determine the prices of goods in the domestic consumers' CPI. As a consequence, monetary policy aiming to stabilize the marginal cost terms is more successful. The lower fluctuations in the marginal cost terms lead to lower prices set by the monopolistically competitive firms. This in turn increases welfare.

Fiscal policy is found to be a complement to monetary policy - enhancing the latter's effectiveness rather than being a substitute. This supporting role is most effective when there are discrepancies within and between the two countries' objective functions. As a consequence, fiscal policy matters especially at partial levels of pass-through. Another consequence of this indirect role of fiscal policy is the lack of further gains from its inclusion in the cases of policy coordination between the two countries or a monetary union.

The addition of a fiscal instrument that systematically responds to domestic and foreign shocks can move purely domestically minded policy makers to set monetary policy rules that are closer to the rules that are optimal from a global perspective. In this sense, the additional instrument represents a substitute for policy coordination. One interpretation of this result is that the addition of international policy spill-over effects (in this case through state-dependent labor taxes) will result in more globally desirable outcomes.

For tractability, the model was built making several strong assumptions. In future work, it would be interesting to study the impact of labor income taxes on a non-trivial financial sector, that is allowing countries to borrow or lend in equilibrium. In addition, and not unrelated, it would be interesting to relax the assumption of availability of lump-sum transfers to the government, which essentially lets the fiscal policy maker use taxes as stabilization instruments without any concern about the government budget constraint.

Another interesting avenue for future research is the assumed exogeneity of pass-through. In this paper, I assume pass-through to be a strictly microeconomic phenomenon whose determination is outside the model and, most importantly, independent of policy. This is a simplification, as there is some evidence linking pass-through to macroeconomic aggregates such as inflation. The incorporation of a more detailed treatment of pass-through may result in additional channels connecting optimal policy to degree of pass-through. I leave these extensions for future work.

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A Appendix

A.1 Derivation of $c_t - E_{t-1}c_t$ and $c_t^* - E_{t-1}c_t^*$

In order to arrive at the domestic welfare function, I begin with finding expressions for the innovation in logged variables, especially $c_t - E_{t-1}c_t$ and $p_t - E_{t-1}p_t$ (and the foreign country analogues), where lower case letters refer to variables in logs.

$$p_t = n \ln P_{h,t} + (1-n) \ln P_{f,t}$$

$$\begin{aligned}
p_t &= np_h + (1-n)p_f \\
&= \ln\frac{\lambda}{\lambda-1} + n\ln(\frac{EP_tC_t}{\theta_t(1-\tau_t)}) + (1-n)\eta\ln(S_t) + (1-n)\ln(\frac{EP_t^*C_t^*S_t^{1-\eta}}{\theta_t^*(1-\tau_t^*)}) \\
&= \ln\frac{\lambda}{\lambda-1} + E_{t-1}p_t(n+(1-n)(1-\eta)) + E_{t-1}c_t(n+(1-n)(1-\eta)) \\
&\quad +\eta(1-n)E_{t-1}p_t^* + \eta(1-n)E_{t-1}c_t^* + (1-n)\eta\left[p_t + c_t - p_t^* - c_t^*\right] \\
&\quad -n(\ln\theta_{t-1} + \ln(1-\overline{\tau})) - (1-n)(\ln\theta_{t-1}^* + \ln(1-\overline{\tau}^*)) + K
\end{aligned}$$

Here K encompasses all of the variance and covariance terms that are constant. Using above results, we get

$$p_t - E_{t-1}p_t = \frac{(1-n)\eta}{[1-(1-n)\eta]}\left[c_t - E_{t-1}c_t - (p_t^* - E_{t-1}p_t^*) - (c_t^* - E_{t-1}c_t^*)\right]$$

or

$$p_t - E_{t-1}p_t = (1-n)\eta(s_t - E_{t-1}s_t) - K \tag{13}$$

Intuitively, the "unpredictable" component of the domestic price level is the price of imported goods, since only that price varies with the exchange rate, depending on the degree of pass-through. This is why the deviation from the price level from its expected level is only due to the deviation of the nominal exchange rate from its expected level - and the higher the share of imported goods $(1-n)$ in the consumption bundle and the higher the degree of pass-through η, the stronger is the connection.

A similar approach starting with p_t^* yields

$$p_t^* - E_{t-1}p_t^* = \frac{-\eta n}{1-n\eta}\left[c_t - E_{t-1}c_t + p_t - E_{t-1}p_t - (c_t^* - E_{t-1}c_t^*)\right]$$

or

$$p_t^* - E_{t-1}p_t^* = -\eta n(s_t - E_{t-1}s_t) - K' \tag{14}$$

The money market equilibrium condition yields

$$\mu_t = \frac{1+i}{i}(c_t - E_{t-1}c_t) + \frac{1+i}{i}(p_t - E_{t-1}p_t) - \frac{1}{i}\left[E_tp_{t+1} - E_{t-1}p_{t+1} + (E_tc_{t+1} - E_{t-1}c_{t+1})\right] \tag{15}$$

for the home country and

$$\mu_t^* = \frac{1+i}{i}(c_t^* - E_{t-1}c_t^*) + \frac{1+i}{i}(p_t^* - E_{t-1}p_t^*) - \frac{1}{i}\left[E_tp_{t+1}^* - E_{t-1}p_{t+1}^* + \left(E_tc_{t+1}^* - E_{t-1}c_{t+1}^*\right)\right] \tag{16}$$

for the foreign one. Combining (15) with (16) yields

$$\mu_t - \mu_t^* = \frac{1+i}{i}(s_t - E_{t-1}s_t) - \frac{1}{i}\left[E_ts_{t+1} - E_{t-1}s_{t+1}\right]$$

Guess and verify offers

$$s_t = m_t - m_t^*$$

as solution, which is the familiar result that the exchange rate only depends on the relative monetary stances of the two countries. This in turn implies

$$s_t - E_{t-1}s_t = \mu_t - \mu_t^*$$

Unexpected fluctuations in the exchange rate and the price level are exclusively due to unexpected changes in monetary policy. Furthermore, the degree to which monetary policy can cause the price level to be different from its expected value hinges crucially on the degree of pass-through. With LCP there is no effect, and $p_t - E_{t-1}p_t$ will always be equal to zero. Combining (13) and (14) yields

$$(c_{t+1} - E_t c_{t+1}) - (c^*_{t+1} - E_t c^*_{t+1}) = (1-\eta)[\mu_t - \mu^*_t] \tag{17}$$

In addition, we can find another expression involving $(c_t - E_{t-1}c_t)$ and $(c^*_t - E_{t-1}c^*_t)$:

Starting again with the expressions for the prices chosen by domestic firms, we can further derive:

$$\begin{aligned}
P_H^n P_F^{*1-n} &= \frac{\lambda}{\lambda-1}\left(E_{t-1}\left[\frac{P_t C_t}{\theta_t(1-\tau_t)}\right]\right)^n \left(E_{t-1}\left[\frac{P^*_t C^*_t}{\theta^*_t(1-\tau^*_t)}\right]\right)^{1-n} \\
1 &= \frac{\lambda}{\lambda-1}\left(\frac{E_{t-1}[C_t]}{E_{t-1}[\theta_t]E_{t-1}\left[1-\tau_t\right]}\right)^n \left(\frac{E_{t-1}[C^*_t]}{E_{t-1}[\theta^*_t]E_{t-1}[1-\tau^*_t]}\right)^{1-n} \\
&\quad * \exp(n(1-n)\eta(\eta-1)\sigma_s^2 - (1-\eta)(1-n)n\sigma_{su^*} - (1-\eta)(1-n)n\sigma_{sT^*}) \\
&\quad * \exp(n(1-n)(\eta^2-\eta+1)\sigma_s^2 - n(1-n)(1-\eta)\sigma_{su} - n(1-n)(1-\eta)\sigma_{sT}) \\
&\quad * \exp(-n\sigma_{cu} - n\sigma_{cT} - (1-n)\sigma_{c^*u^*} - (1-n)\sigma_{c^*T^*})
\end{aligned}$$

where $\sigma_{c\tau}$ represents the covariance between the log of consumption and the fiscal policy parameter T[11]. This in turn yields

$$\begin{aligned}
& nE_{t-1}c_t + (1-n)E_{t-1}c^*_t \\
\equiv\; & E_{t-1}\widetilde{c}_t = -\ln\left(\frac{\lambda}{\lambda-1}\right) + n\ln\theta_{t-1} + (1-n)\ln\theta^*_{t-1} \\
& + n\ln(1-\overline{\tau}) + (1-n)\ln(1-\overline{\tau}^*) + K
\end{aligned} \tag{18}$$

This term shows the way that fiscal policy is playing a role in the world economy. While the levels of the base tax rates $\overline{\tau}$ and $\overline{\tau}^*$ lower or raise expected world consumption, the covariance between the temporary tax innovation T_t and T^*_t and consumption and productivity shocks also play a role.

From the money market equation we get

$$\widetilde{m}_t - \widetilde{p}_t = \widetilde{c}_t - \frac{1}{i}(E_t\widetilde{c}_{t+1} - \widetilde{c}_t) - \frac{1}{i}(E_t\widetilde{p}_{t+1} - \widetilde{p}_t) \tag{19}$$

where $\widetilde{p}_t = np_{H,t} + (1-n)p^*_{F,t}$ and $\widetilde{m}_t = nm_t + (1-n)m^*_t$. Taking expectations at time $t-1$ and solving for $\widetilde{p}_t$ we get

$$\widetilde{p}_t = \widetilde{m}_{t-1} - E_{t-1}\widetilde{c}_t + \frac{1}{i}(E_{t-1}\widetilde{c}_{t+1} - E_{t-1}\widetilde{c}_t) - \frac{1}{i}(E_{t-1}\widetilde{p}_{t+1} - \widetilde{p}_t)$$

But a close look at expression (18) shows that the first term in brackets must be zero, since the only terms with a time index are $\ln\theta_t$ and $\ln\theta^*_t$, and given the AR(1) process we have assumed for the

[11] since we have $covar(\ln C_t, \ln(1-\tau_t)) = (c_t - E_{t-1}c_t)(\ln(1-\tau_t) - \ln(1-\overline{\tau})) = (c_t - E_{t-1}c_t)\,T_t$

evolution of the productivity disturbance, $E_{t-1}\ln\theta_{t+1} = E_{t-1}\ln\theta_t = \ln\theta_{t-1}$. So we get

$$\begin{aligned}\widetilde{p}_t &= \widetilde{m}_{t-1} - E_{t-1}\widetilde{c}_t - \frac{1}{i}(E_{t-1}\widetilde{p}_{t+1} - \widetilde{p}_t)\\ \widetilde{p}_t &= \widetilde{m}_{t-1} - (n\ln\theta_{t-1} + (1-n)\ln\theta^*_{t-1}) + \Gamma\end{aligned}$$

Here Γ is a constant and I use 'guess and verify' to confirm that $E_{t-1}\widetilde{p}_{t+1} = \widetilde{p}_t$. This in turn implies

$$\widetilde{p}_{t+1} - \widetilde{p}_t = \widetilde{\mu}_t - \widetilde{u}_t$$

where $\widetilde{u}_t = nu_t + (1-n)u^*_t$. So (19) becomes

$$\begin{aligned}\widetilde{m}_t - \widetilde{p}_t &= \widetilde{c}_t - \frac{1}{i}(E_t\widetilde{c}_{t+1} - \widetilde{c}_t) - \frac{1}{i}(\widetilde{\mu}_t - \widetilde{u}_t)\\ &\iff \widetilde{m}_t - (\widetilde{m}_{t-1} - (n\ln\theta_{t-1} + (1-n)\ln\theta^*_{t-1}) + \Gamma) = \widetilde{c}_t - \frac{1}{i}(E_t\widetilde{c}_{t+1} - \widetilde{c}_t) - \frac{1}{i}(\widetilde{\mu}_t - \widetilde{u}_t)\\ &\iff \widetilde{\mu}_t + n\ln\theta_{t-1} + (1-n)\ln\theta^*_{t-1} + \Gamma = \widetilde{c}_t - \frac{1}{i}(E_t\widetilde{c}_{t+1} - \widetilde{c}_t) - \frac{1}{i}(\widetilde{\mu}_t - \widetilde{u}_t)\end{aligned}$$

Recall that

$$E_t\widetilde{c}_{t+1} = n\ln\theta_t + (1-n)\ln\theta^*_t + K$$

Solving for $\widetilde{c}_t$ yields

$$\begin{aligned}\frac{1+i}{i}\widetilde{c}_t &= \frac{1}{i}(\widetilde{\mu}_t - \widetilde{u}_t) + \frac{1}{i}(n\ln\theta_t + (1-n)\ln\theta^*_t) + \widetilde{\mu}_t + n\ln\theta_{t-1} + (1-n)\ln\theta^*_{t-1} + \Gamma'\\ &\iff \widetilde{c}_t = \frac{1}{1+i}(\widetilde{\mu}_t - \widetilde{u}_t) + \frac{1}{1+i}(n\ln\theta_t + (1-n)\ln\theta^*_t)\\ &\quad + \frac{i}{1+i}\widetilde{\mu}_t + \frac{i}{1+i}(n\ln\theta_{t-1} + (1-n)\ln\theta^*_{t-1}) + \Gamma'\end{aligned}$$

which in turn implies

$$\begin{aligned}\widetilde{c}_t - E_{t-1}\widetilde{c}_t &= \frac{1}{1+i}(\widetilde{\mu}_t - \widetilde{u}_t) + \frac{1}{1+i}(n\ln\theta_t + (1-n)\ln\theta^*_t) + \frac{i}{1+i}\widetilde{\mu}_t - \frac{1}{1+i}(n\ln\theta_{t-1} + (1-n)\ln\theta^*_{t-1})\\ &= \widetilde{\mu}_t\end{aligned}$$

So we established that

$$c^*_t - E_{t-1}c^*_t = \frac{n}{1-n}\mu_t + \mu^*_t - \frac{n}{1-n}\left[c_t - E_{t-1}c_t\right] \tag{20}$$

Combining (20) with (17) yields the expressions in the main text.

A.2 Derivation of $E_{t-1}W_t$

As commonly done in the literature, I focus on expressing welfare in terms of the deviation from the deterministic equilibrium.[12] Let

$$E[\widehat{C}_t] \equiv E \ln\left(\frac{C_t}{\overline{C}}\right)$$

where $\overline{C}$ depicts the consumption level in the deterministic, flex-price equilibrium. The only nominal rigidity in the model is due to the price-setting, so the deviation of the consumption level from its flex-price level is a direct function of the deviation of the prices.

$$\widehat{C}_t = -\left(n\widehat{P}_{H,t} + (1-n)\widehat{P}_{F,t}\right)$$

but

$$\begin{aligned}
E_{t-1}\widehat{P}_{H,t} &= E_{t-1}\ln\left(\frac{E_{t-1}\left[\frac{P_tC_t}{\theta_t(1-\tau_t)}\right]}{\frac{P_tC_t}{\theta_t(1-\tau_t)}}\right) = \frac{1}{2}E_{t-1}var\left(\ln\left(\frac{P_tC_t}{\theta_t(1-\tau_t)}\right)\right) \\
&= E_{t-1}(p_t - E_{t-1}p_t + c_t - E_{t-1}c_t - (\ln\theta_t - \ln\theta_{t-1}) - (\ln(1-\tau_t) - \ln(1-\overline{\tau}))^2 \\
&= \frac{1}{2}E_{t-1}(\mu_t - u_t - T_t)^2
\end{aligned}$$

where I used the results from the previous section. Similarly

$$E_{t-1}\widehat{P}_{F,t} = \frac{1}{2}E_{t-1}(\eta\mu_t^* + (1-\eta)\mu_t - u_t^* - T_t^*)^2$$

The term $E_{t-1}L_t$ depends on fiscal policy:

$$E_{t-1}L_t = \frac{\lambda-1}{\lambda\kappa}E_{t-1}\left[n\frac{\frac{P_tC_t}{\theta_t}}{E_{t-1}[\frac{P_tC_t}{\theta_t(1-\tau_t)}]} + (1-n)\frac{\frac{P_t^*C_t^*S_t^{\eta}}{\theta_t}}{E_{t-1}[\frac{P_tC_t}{S_t^{1-\eta}\theta_t(1-\tau_t)}]}\right] \tag{21}$$

[12] The deterministic equilibrium coincides with the solution for the flex-price model given in the previous section, comibined with the assumption that the productivity disturbances are given and constant at $\theta = \theta^* = 1$. This is the same notion of deterministic equilibrium as in Sutherland (2005).

using the assumption of log-normality in the disturbances and consequently in all of the model variables, this expression can be written as

$$
\begin{aligned}
E_{t-1}L_t &= \frac{\lambda-1}{\lambda\kappa}\left[1-\overline{\tau}\right]\left[n\exp\left[cov(\ln\left(\frac{P_tC_t}{\theta_t}\right),\ln(1-\tau_t)) - var(\ln(1-\tau_t))\right]\right. \\
&\quad \left. +(1-n)\exp\left[cov(\ln\left(\frac{P_tC_t}{S_t^{1-\eta}\theta_t}\right),\ln(1-\tau_t)) - var(\ln(1-\tau_t))\right]\right] \\
&= \frac{n}{\kappa} n\exp\left[E_{t-1}\left[\left[(p_t - E_{t-1}p_t) + (c_t - E_{t-1}c_t) - (\ln\theta_t - \ln\theta_{t-1})\right]\right.\right. \\
&\quad \left.\left. * \left[\ln(1-\tau_t) - \ln(1-\overline{\tau})\right]\right] - E_{t-1}\left[\ln(1-\tau_t)-\ln(1-\overline{\tau})\right]^2\right] \\
&\quad + \frac{n}{\kappa}(1-n)\exp\left[E_{t-1}\left[\left[(p_t - E_{t-1}p_t) + (c_t - E_{t-1}c_t) - (1-\eta)(s_t - E_{t-1}s_t)\right.\right.\right. \\
&\quad \left.\left.\left. -(\ln\theta_t - \ln\theta_{t-1})\right]\left[\ln(1-\tau_t)-\ln(1-\overline{\tau})\right]\right] - E_{t-1}\left[\ln(1-\tau_t)-\ln(1-\overline{\tau})\right]^2\right] \\
&= \frac{n}{\kappa}\left[n\exp E_{t-1}\left[(\mu_t - u_t)T_t - T_t^2\right] + (1-n)\exp E_{t-1}\left[(\eta\mu_t + (1-\eta)\mu_t^* - u_t)T_t - T_t^2\right]\right] \quad (22)
\end{aligned}
$$

Where I again made use of several of the results from the previous section. Similarly, we can obtain for the foreign country:

$$
E_{t-1}L_t^* = \frac{(1-n)}{\kappa}\left[(1-n)\exp E_{t-1}\left[(\mu_t^* - u_t^*)T_t^* - T_t^{*2}\right] + n\exp E_{t-1}\left[(\eta\mu_t^* + (1-\eta)\mu_t - u_t^*)T_t^* - T_t^{*2}\right]\right]
$$