The Welfare Effect of Monetary Shocks in an Economy with Internationalized Production

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Abstract

This paper investigates the role of internationalized production in determining the welfare effect of monetary shocks. Internationalized production occurs when firms hire domestic as well foreign labor services. It is shown that whether a monetary shock is beggar-thyself and/or beggar-thy-neighbor depends on the extent of internationalized production which also determines whether a welfare-maximization monetary shock is large enough to stimulate production to its potential.

Key words: internationalized production, nominal wage rigidity, monetary shocks

JEL classification: *F3, F4*

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1 Introduction

The purpose of this paper is to investigate how internationalized production affects welfare effects of monetary shocks in a framework of the "new open macroeconomics".[1] An advantage of this framework is that the microfoundations of this framework provide a convenient welfare evaluation of both domestic policies and responses to foreign policies in terms of consumer utility. Contributions in this line of research suggest that whether the welfare effect of a monetary innovation to the trading partners is adverse or beneficial depends on various characteristics of the world economy under consideration, such as elasticity of substitution between goods, deviation from the law of one price, and introducing nontraded goods.[2] The mixed conclusions of these works in part reflects the complexity of this problem and thus warrants further investigations.

In this paper we consider the implication of a prevalent feature into the "new open macroeconomics" in which firms hire both domestic and foreign inputs in production. This feature, so called internationalized production, meaning that part of the output in one country is made by firms based in another country (Lipsey (1998)), can arise from direct foreign investment by source country firms in operations in a host country. The literature of foreign direct investment, for example, Dixit and Grossman (1986), Levinsohn (1989) and Glass and Saggi (1999) has discussed the welfare impact of trade policy in the presence of internationalized production. However, as far as we know, the welfare effect of monetary policy has not been analyzed in the presence of internationalized production.

A related work that is close to this paper is Devereux and Engel (2000). They show that the floating exchange rate system is more preferred in an economy with internationalized production than without. Under the floating exchange rate system, when there is a monetary shock abroad that reduces foreign demand for the home good, foreign employment absorbs some effect from the reduction of output. Thus, domestic employment is sheltered from the foreign shock. This mechanism directly results from internationalized

[1] For a comprehensive survey of the literature see Lane (2001).

[2] For example, based on the benchmark model of Obstfeld and Rogoff (1995), Tille (2001) shows that the the relation between the elasticity of substitution between goods produced in a country and the elasticity of substitution between goods produced in different countries is critical; Betts and Devereux (2000) show that deviation from the law of one price by assuming pricing to the market is critial; and Hau (2000) adds nontraded goods in the model derive different welfare implications, as well.

production which leads to differential welfare impacts among agents of the same country. However, instead of tackling the issue of beneficial effect versus adverse effect from monetary policies such as devaluation, they focus on the optimal choice of exchange-rate regime.

We embed the feature of internationalized production and the above mentioned mechanism of monetary shocks into the model of Corsetti and Pesenti (2001) to discuss the welfare effect of monetary shocks. Corsetti and Pesenti's framework can be solved in closed-form and therefore provides a clear explanation of the monetary transmission mechanism.

The paper is structured as follows. Section 2 presents a model with internationalized production. Section 3 derives closed-form solutions of the model. Section 4 analyzes the welfare effect of a monetary shock. We conduct the closed-form welfare analysis of small and large monetary shocks. Section 5 concludes.

2 Environment

Time is discrete. There are a Home country and a Foreign country in the economy. The two countries are symmetric in all respects unless specified. There are two traded consumption goods, x and y. The good markets are perfectly competitive. There is no trade barrier. Firms of the Home country specialize in the production of x and firms of the Foreign country specialize in producing y.

Labor is the only input of production. There are two types of labor in the world. Type-x and type-y labor are specific to manufacture x and y, respectively. Each country has a continuum of agents, with population size normalized to one. At each date, an agent monopolizes one unit of homogeneous labor services which can be offered to firms of any country. The labor market exhibits nominal wage rigidity. All agents are identical in other respects. Governments issue money, collect taxes and maintain balanced budgets in each date.

In the following, a notation $N^j_{k,t}(z)$ refers to the value of a variable N at time t attached to an individual z with type-k labor services in a country j, for $k = x$, y and $j = h$(home), f(foreign).

2.1 Technology

A fraction θ_k^j of the labor force is type-k in a country j. Each firm can hire domestic labor services as well as labor services abroad. The aggregate production function of the Home country at date t is given by

$$x_t = \left(\int_0^{\theta_x^h} l_{x,t}^h(z)^{\frac{\phi-1}{\phi}} dz + \int_0^{\theta_x^f} l_{x,t}^f(z)^{\frac{\phi-1}{\phi}} dz \right)^{\frac{\phi}{\phi-1}}, \phi > 1,$$

where x is the aggregate output; $l_x^h(z)$ and $l_x^f(z)$ are the amounts of labor services employed from a type-x agent z of the Home and the Foreign country, respectively; and ϕ denotes the elasticity of input substitution. Similarly, the production technology in the foreign country is given by

$$y_t = \left(\int_{\theta_y^h}^1 l_{y,t}^h(z)^{\frac{\phi-1}{\phi}} dz + \int_{\theta_y^f}^1 l_{y,t}^f(z)^{\frac{\phi-1}{\phi}} dz \right)^{\frac{\phi}{\phi-1}}.$$

In each country there is nominal rigidity that is introduced in the form of one-period nominal wage contracts.[3] That is, nominal wages in period t are predetermined by contracts signed at the end of period $t-1$. It is assumed that nominal wages are contracted in terms of the currency of the producer.

Since firms act competitively and there is no market segmentation, the law of one price holds for consumption goods. Let p_k^j denote the unit price of good k in a country j and E denote the exchange rate. Then, the law of one price implies

$$p_k^h = E p_k^f.$$

Each firm chooses the amounts of domestic as well as foreign labor services to maximize its profit. The labor demand function is derived as

$$l_k^j(z) = \left(\frac{w_k^j(z)}{p_k^j} \right)^{-\phi} k, \qquad (1)$$

and

$$l_k^h(z) = l_k^f(z).$$

[3]Recent open-economy models with nominal wage rigidities include Corsetti and Pesenti (2001), Hau (2000), Obstfeld and Rogoff (1996).

2.2 Consumers

The lifetime utility of an agent z with type-k labor in a country j is represented by

$$U_k^j(z) = E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{c_{k,t}^j(z)^{1-\rho}}{1-\rho} + \chi \ln \frac{m_{k,t}^j(z)}{p_t^j} - \frac{a}{2} l_{k,t}^j(z)^2 \right],$$

where $0 < \beta < 1$, $0 < \rho < 1$, and χ, $a > 0$. Here β is the discount rate, $1/\rho$ is the elasticity of intertemporal substitution, $m_{k,t}^j(z)$ is money holdings , $l_{k,t}^j(z)$ is the amounts of labor supplied, and $c_{k,t}^j(z)$ is the consumption index. The consumption index is defined by the consumption of good x, $x_k^j(z)$, and the consumption of good y, $y_k^j(z)$ according to

$$c_k^j(z) \equiv x_k^j(z)^{\gamma} y_k^j(z)^{1-\gamma}, \quad 0 < \gamma < 1.$$

The corresponding consumption-based price indexes p^j are determined as a function of the price of good x, p_x^j, and the price of good y, p_y^j:

$$p^j = \frac{1}{\gamma^{\gamma}(1-\gamma)^{1-\gamma}} \left(p_x^j\right)^{\gamma} \left(p_y^j\right)^{1-\gamma}.$$

Agents hold two assets, national money m and an international bond b. An individual's budget constraint is

$$\begin{aligned} & b_{k,t+1}^j(z) + m_{k,t}^j(z) - m_{k,t-1}^j(z) \\ \leq \; & \left(1 + i_t^j\right) b_{k,t}^j(z) + w_{k,t}^j(z)\, l_{k,t}^j(z) - p_t^j \tau_t(z) - p_t^j c_{k,t}^j(z), \end{aligned}$$

where i is the nominal yield of b and $\tau(z)$ is the lump sum taxes per capita. Given the labor demand function (1), the agent's labor income equals to $p_k^j \left(l_k^j(z)\right)^{1-\frac{1}{\phi}} k^{\frac{1}{\phi}}$. Plugging $p_{k,t}^j \left(l_{k,t}^j(z)\right)^{1-\frac{1}{\phi}} k_t^{\frac{1}{\phi}}$ into above budget constraint to replace $w_k^j(z)\, l_k^j(z)$, the agent chooses $x_{k,t}^j$, $y_{k,t}^j$, $c_{k,t}^j$, $m_{k,t}^j$, $b_{k,t+1}^j$, and $l_{k,t}^j$ to maximize his utility.

When nominal wage rates are predetermined, agents make their labor-supply decisions, taking the nominal wages and the prices of consumption goods as given.[4] In any case, no agent will supply labor services to an extent that the marginal benefit from working is less than the marginal cost from working. Accordingly, a participation constraint

[4] The critical impact of nominal wage rigidity on prices of consumption goods is that only p_x^h and p_y^f are unadjustable in the short run. Since $p_x^f = p_x^h/E$ and $p_y^h = Ep_y^f$, variations in the exchange rate will cause variations in p_x^f and p_y^h , in spite of the rigidity of p_x^h and p_y^f.

is derived[5] as

$$\frac{w^j_{k,t}}{p^j_t} = \frac{\left(\theta^h_k + \theta^f_k\right)^{\frac{1}{\phi-1}} p^j_{k,t}}{p^j_t} \geq a l^j_{k,t} c^{j\rho}_{k,t}. \tag{2}$$

2.3 Government and Resource Constraints

Each government implements a balanced budget by way of equating the increment of nominal money stock issued and the nominal government transfers. Then, the government's budget is given by

$$\int_0^{\theta^j} m^j_{x,t}(z)dz + \int_{\theta^j}^1 m^j_{y,t}(z)dz - \left(\int_0^{\theta^j} m^j_{x,t-1}(z)dz + \int_{\theta^j}^1 m^j_{y,t-1}(z)dz\right) + p^j_t \tau_t = 0.$$

The world resource constraints require that the aggregate output is no less than the world consumption for any good k:

$$k_t \geq \int_0^{\theta^h} k^h_{x,t}(z)dz + \int_{\theta^h}^1 k^h_{y,t}(z)dz + \int_0^{\theta^f} k^f_{x,t}(z)dz + \int_{\theta^f}^1 k^f_{y,t}(z)dz. \tag{3}$$

In addition, the international bond is in zero-net supply at date t:

$$b^h_t + E_t b^f_t = 0, \tag{4}$$

where $b^j_t = \theta^j_x b^j_{x,t} + \theta^j_y b^j_{y,t}$.

3 Equilibrium

In the equilibrium, all consumers and firms solve their maximization problems; all resource constraints and government constraints are satisfied; the participation constraints of the workers are not violated. The world economy is initially in an equilibrium where neither country is a net debtor. The initial equilibrium is indexed by the subscript 0. The short-run equilibrium is not indexed, where the economy experiences an unanticipated monetary shock and nominal wages are predetermined. The long-run equilibrium is indexed by upperbars, where all variables are free to adjust.

[5]To derive the constraint we use the results that the production technology implies $\left(\theta^h_k + \theta^f_k\right)^{\frac{\phi}{\phi-1}} l^j_k = k$ and the zero profit condition of perfect competition yields $w^j_k(z) = \left(\theta^h_k + \theta^f_k\right)^{\frac{1}{\phi-1}} p^j_k$.

In the following, we denote a subscript k to be such that $k = x, y$, $k' = x, y$ and $k \neq k'$; a superscript j to be such that $j = h, f$, $j' = h, f$ and $j \neq j'$. In addition, let $\gamma_x \equiv \gamma$, $\gamma_y \equiv 1 - \gamma$, $\Phi \equiv \frac{\phi - 1}{a\phi}$, $\Upsilon \equiv \frac{\gamma}{1-\gamma}$, $\Theta \equiv \frac{\theta_y^h + \theta_y^f}{\theta_x^h + \theta_x^f}$, $a_3 = \frac{a_4}{a_5}$, $a_4 = \left(\theta_x^f + \theta_y^f (\Upsilon\Theta)^{-\rho}\right)$ and $a_5 = \left(\theta_x^h + \theta_y^h (\Upsilon\Theta)^{-\rho}\right)$. For a variable N, define $N_R \equiv N^h / N^f$ and $N_w \equiv \left(N^h\right)^{\gamma} \left(N^f\right)^{1-\gamma}$.

It is shown in the Appendix I that we can denote i, c_k, x_k, y_k, such that

$$i \equiv i^j, c_k \equiv c_k^j, x_k \equiv x_k^j,\ y_k \equiv y_k^j,\ \overline{c}_k \equiv \overline{c}_k^j, \overline{x}_k \equiv \overline{x}_k^j, \text{ and } \overline{y}_k \equiv \overline{y}_k^j.$$

That is, the two countries have the same nominal rate of returns in bonds and agents with the same type of labor consume the same amounts of goods.

Appendix II derives the short-run and the long-run equilibrium, which are summarized in Table 1.

Table 1: The Equilibrium

$\frac{\overline{p}_x^j}{\overline{p}_y^j}$	$= \Upsilon^{\frac{1+\rho}{2}} \Theta^{\frac{1}{2}\left(\rho - \frac{1+\phi}{1-\phi}\right)}$
$\overline{k}$	$= \left(\frac{\overline{p}_k^j}{\overline{p}_{k'}^j}\right)^{\gamma_{k'} \frac{1-\rho}{1+\rho}} \Phi^{\frac{1}{1+\rho}} \gamma_w^{\frac{1-\rho}{1+\rho}} \left(\theta_k^h + \theta_k^f\right)^{\left(\frac{\phi+1}{\phi-1} + \rho\right)\frac{1}{1+\rho}}$
$\overline{c}_k$	$= \left(\frac{\overline{p}_k^j}{\overline{p}_{k'}^j}\right)^{\gamma_{k'} \frac{2}{1+\rho}} \Phi^{\frac{1}{1+\rho}} \gamma_w^{\frac{2}{1+\rho}} \left(\theta_k^h + \theta_k^f\right)^{\frac{2}{(\phi-1)(1+\rho)}}$
$\frac{\overline{m}_k^j}{\overline{p}^j}$	$= \chi \frac{1+\delta}{\delta} \overline{c}_k^{\rho}$
$\overline{E}$	$= \overline{M}_R a_3$
$\overline{p}^h$	$= \overline{M}^h a_3^{1-\gamma} \chi^{-1} \frac{\delta}{1+\delta} a_4^{\gamma-1} a_5^{-\gamma} \left(\overline{c}_x\right)^{-\rho}$
c_k	$= \overline{M}_w^{\frac{1}{\rho}} M_{w0}^{\frac{-1}{\rho}} \overline{c}_k$
x	$= \overline{M}_R^{1-\gamma} M_{R0}^{\gamma-1} \overline{M}_w^{\frac{1}{\rho}} M_{w0}^{\frac{-1}{\rho}} \frac{\left(\theta_x^h + \theta_x^f\right)}{\gamma_w} \left(\frac{\overline{p}_x^j}{\overline{p}_y^j}\right)^{\gamma-1} \overline{c}_k$
y	$= \overline{M}_R^{-\gamma} M_{R0}^{\gamma} \overline{M}_w^{\frac{1}{\rho}} M_{w0}^{\frac{-1}{\rho}} \Upsilon^{-1} \frac{\left(\theta_x^h + \theta_x^f\right)}{\gamma_w} \left(\frac{\overline{p}_x^j}{\overline{p}_y^j}\right)^{\gamma} \overline{c}_k$
$\frac{\overline{m}_k^j}{p^j}$	$= \overline{M}_w M_{w0}^{-1} \chi \frac{1+\delta}{\delta} \overline{c}_k^{\rho}$
$1 + r$	$= \overline{M}_w^{-1} M_{w0} \beta^{-1}$
E	$= \overline{M}_R a_3$

4 Welfare Analysis

4.1 Welfare Effects of Small Shocks

We assume that each individual shares an equal weight in the social welfare function. The Home country's social welfare level U^h is determined by the following equation,

$$U^h = \sum_{k=x,y} \theta_k^h \left(\frac{c_k^{1-\rho}}{1-\rho} - \frac{a}{2}k^2 + \frac{1}{\delta}\left(\frac{\overline{c}_k^{1-\rho}}{1-\rho} - \frac{a}{2}\overline{k}^2 \right) \right),$$

where the real balance terms are dropped by assuming χ is sufficiently small. Thus, the impact of an unanticipated monetary shock on the welfare of the home country is determined as follows,

$$\frac{\partial U^h}{\partial \overline{M}^h} = \theta_x^h \frac{\gamma}{\overline{M}^h} \left(\frac{c_x^{1-\rho}}{\rho} - ax^2 \left(\frac{1}{\rho} + \frac{1-\gamma}{\gamma} \right) \right) + \theta_y^h \frac{\gamma}{\overline{M}^h} \left(\frac{c_y^{1-\rho}}{\rho} - ay^2 \left(\frac{1}{\rho} - 1 \right) \right).$$

It is easy to verify that

$$sign \left(\frac{\partial U^h}{\partial \overline{M}^h} \right) = sign \left(c_x^{1-\rho} - ax^2 V^h \right), \tag{5}$$

where

$$V^h = \left(\theta_x^h \left(1 + \rho \Upsilon^{-1}\right) + \theta_y^h (1-\rho) \left(\frac{M_{R0}}{\overline{M}_R} \right)^2 \Upsilon^{\rho-1} \Theta^{\left(\rho - \frac{1+\phi}{1-\phi}\right)} \right) \left(\theta_x^h + \theta_y^h \left(\Upsilon\Theta\right)^{\rho-1} \right)^{-1}.$$

Since the participation constraint (2) and equation (20) imply that

$$c_x^{1-\rho} \geq ax^2 \left(\theta_x^h + \theta_x^f \right)^{\frac{2\phi}{1-\phi}},$$

we then obtain the following result.

Result 1.

If $\left(\theta_x^h + \theta_x^f \right)^{\frac{2\phi}{1-\phi}} \geq V^h$ then a positive monetary shock is prosper-thyself;
if $\left(\theta_x^h + \theta_x^f \right)^{\frac{2\phi}{1-\phi}} < V^h$ then a positive monetary shock *can be* beggar-thyself.

In particular, suppose $\Upsilon = \Theta = 1$ then

if $\frac{1}{\phi - 1} \geqslant \rho(\theta_x^h - \theta_y^h)$ then a positive monetary shock is prosper-thyself;
if $\frac{1}{\phi - 1} < \rho(\theta_x^h - \theta_y^h)$ then a positive monetary shock is beggar-thyself.

The impact of a monetary shock originating abroad on domestic welfare is measured by

$$\frac{\partial U^h}{\partial \overline{M}^f} = \theta_x^h \frac{1-\gamma}{\overline{M}^f}\left(\frac{c_x^{1-\rho}}{\rho} - ax^2\left(\frac{1}{\rho}-1\right)\right) + \theta_y^h \frac{1-\gamma}{\overline{M}^f}\left(\frac{c_y^{1-\rho}}{\rho} - ay^2\left(\frac{1}{\rho}+\frac{\gamma}{1-\gamma}\right)\right).$$

Therefore,

$$sign\left(\frac{\partial U^h}{\partial \overline{M}^f}\right) = sign\left(c_x^{1-\rho} - ax^2 V^f\right), \tag{6}$$

where

$$V^f = \left(\theta_x^h(1-\rho) + \theta_y^h\left(1+\rho\Upsilon\right)\left(\frac{M_{R0}}{\overline{M}_R}\right)^2 \Upsilon^{\rho-1}\Theta^{\left(\rho - \frac{1+\phi}{1-\phi}\right)}\right)\left(\theta_x^h + \theta_y^h\left(\Upsilon\Theta\right)^{\rho-1}\right)^{-1}.$$

Thus, we reach the following conclusion.

Result 2.

If $\left(\theta_x^h + \theta_x^f\right)^{\frac{2\phi}{1-\phi}} \geq V^f$ then a positive monetary shock is prosper-thy-neighbor;
if $\left(\theta_x^h + \theta_x^f\right)^{\frac{2\phi}{1-\phi}} < V^f$ then a positive monetary shock *can be* beggar-thy-neighbor.

In particular, suppose $\Upsilon = \Theta = 1$ then

if $\frac{1}{\phi-1} \geqslant \rho(\theta_y^h - \theta_x^h)$ then a positive monetary shock is prosper-thy-neighbor;
if $\frac{1}{\phi-1} < \rho(\theta_y^h - \theta_x^h)$ then a positive monetary shock is beggar-thy-neighbor.

In contrast to the result by Corsetti and Pesenti (2001) that an expansionary monetary shock is always prosper-thy-neighbor, our model shows that an expansionary monetary shock can be beggar-thy-neighbor

Basically, the monetary transmission mechanism is similar to that points out by Corsetti and Pesenti (2001). An expansionary monetary shock from the Home country raises the demand for good x and deteriorates its terms of trade. Since the elasticity of intratemporal substitution in the consumption index is one in equilibrium, type-x agents' nominal incomes increase relative to type-y agents but their purchasing power declines proportionally. Since the intertemporal elasticity $\frac{1}{\rho}$ is larger then the intratemporal elasticity, the demand for good y also increases. Therefore, type-y agents benefit from the monetary shock for sure. The welfare of type-x agents increases if their monopoly power is sufficiently large and/or the world expenditure share of the good x is large enough. The former condition leads to a substantial output boost in the Home country after an expansionary monetary shock; the latter condition ensures that most of the increased purchasing power of the world is allocated on the Home good x. Thus, for type-x agents, the disadvantage on their purchasing powers can be overcome by the advantage on aggregate demand for good x.

Therefore, if we assume that the relative size of type-x agents to type-y agents is one in the world and the two goods have the same expenditure share, i.e. $\Theta = \Upsilon = 1$, then the welfare effects depend on the relative size of type-x agents to type-y agents in a country. Otherwise, the structure of internationalized production θ_k^j affects the welfare effects in a more complicated way as illustrated in the result 1 and 2.

4.2 Welfare Effects of Large Shocks

Corsetti and Pesenti (2001) find that the Home monetary policy which maximizes Home post-shock welfare is less expansionary than required to raise output to its efficient level. In this section, we reexamine whether this result is robust in our model.

Equation (5) does imply that as the size of monetary shocks increases the rising utility cost of foregone leisure tends to dominate the benefit from additional consumption. Therefore, the relation between money stock and welfare can take a shape of inverted U.

Suppose there is a stock of money $\overline{M}^h$ such that $\frac{\partial U^h}{\partial \overline{M}^h} = 0$, that is, $c_x^{1-\rho} = ax^2 V^h$. In addition, suppose that there is a money stock $\widetilde{M}^h$ such that at which the participation constraint (2) holds with equality, that is, $c_x^{1-\rho} = ax^2 \left(\theta_x^h + \theta_x^f\right)^{\frac{2\phi}{1-\phi}}$. Then, the condition to ensure that the Home monetary policy which maximizes Home post-shock welfare is less expansionary than required to raise output to its efficient level can be derived as

$$V^h > \left(\theta_x^h + \theta_x^f\right)^{\frac{2\phi}{1-\phi}}. \tag{7}$$

When condition (7) holds, the money stock $\overline{M}^h$ maximizes welfare but leaves the participation constraint held with inequality. Thus, the economy does not produce its output up to potential. In general, condition (7) may not hold. If $V^h < \left(\theta_x^h + \theta_x^f\right)^{\frac{2\phi}{1-\phi}}$ then efficient output level is attained while the sign of (5) is not zero. Since the equilibrium is solved given the feasible range of money stocks implied by the participation constraint, it is possible that the money stock which maximizes welfare is outside the range. In that case, the participation constraint is violated and it is not appropriate to use the solutions in Table 1 to evaluate welfare.

If $\theta_x^h = 1$ and $\theta_x^f = 0$ then condition (7) is equal to

$$1 + \rho \frac{1-\gamma}{\gamma} > 1,$$

which is always true and, therefore, is consistent with the result of Corsetti and Pesenti (2001).

In the presence of internationalized production, both countries' monetary policies affect the condition (7) through the ratio of M_{R0} to $\overline{M}_R$. In order to raise output to its efficient level, international coordination in monetary policies may play an important role.

5 Conclusion

Will a monetary shock be prosper-thy-neighbor or be beggar-thy-neighbor? The answer is important in implementing monetary policy and in coping with international dependence. Conventional inference is that depreciation in domestic currency will benefit oneself and hurt the trading partner. Recent development in the new open macroeconomics show that the policy implication is more complicated.

Many factors can crucially affect the welfare implication of monetary shocks. This paper focuses on internationalized production, arising from direct foreign investment by source country firms in operations in a host country, in determining the welfare effects. Complementary to the existing literature in which agents of the same country usually share the same welfare impact from a monetary shock, this paper emphasizes that internationalization production can result in differential impacts among agents of a country. In particular, due to internationalized production, a monetary shock benefits the workers employed by a home firm may, at the same time, hurts the workers hired by a foreign firm. Thus, whether a monetary shock is beneficial depends on the extent of internationalized production which also determines whether a welfare-maximization monetary shock is large enough to stimulate production to its potential. As the international resource mobility and multinational production become more prevailed, internationalized production shall play a more important role in determined policy effects.

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Appendix I

Let λ_k^j denote the Lagrange multiplier. The first order conditions of utility maximization are

$$\gamma \left(c_{k,t}^j\right)^{1-\rho} \left(x_{k,t}^j\right)^{-1} = \lambda_{k,t}^j p_{x,t}^j, \tag{8}$$

$$(1-\gamma) \left(c_{k,t}^j\right)^{1-\rho} \left(y_{k,t}^j\right)^{-1} = \lambda_{k,t}^j p_{y,t}^j, \tag{9}$$

$$\left(c_{k,t}^j\right)^{-\rho} = \lambda_{k,t}^j p_t^j, \tag{10}$$

$$\chi \left(m_{k,t}^j\right)^{-1} = \lambda_{k,t}^j - \beta \lambda_{k,t+1}^j, \tag{11}$$

$$\lambda_{k,t}^j = \beta(1+i_t^j)\lambda_{k,t+1}^j, \tag{12}$$

and

$$\left(l_{k,t}^j\right)^{\frac{1+\phi}{\phi}} = \Phi \lambda_{k,t}^j p_{k,t}^j k_t^{\frac{1}{\phi}}. \tag{13}$$

Condition (13) and equation (1) imply that $\lambda_{k,t}^h$ equals $E^{-1}\lambda_{k,t}^f$. Therefore, $c_{k,t}^h$ equals $c_{k,t}^f$ by equation (10), and i^h equals i^f by equation (12). Equations (8), (9) and (10) imply $p^j c_k^j = \gamma^{-1} p_x^j x_k^j = (1-\gamma)^{-1} p_y^j y_k^j$. The relationship of $c_{k,t}^h = c_{k,t}^f$ and the law of one price implies that x_k^h equals x_k^f and y_k^h equals y_k^f. Thus, we can define i, c_k, x_k, y_k, such that

$$i \equiv i^j, \ c_k \equiv c_k^j, \ x_k \equiv x_k^j, \text{ and } y_k \equiv y_k^j. \tag{14}$$

Equation (15) is derived by using Fisher's equation, $(1+r_t) = (1+i_t)p_t/p_{t+1}$, and (12). Equations (10) and (11) yield equations from (16) to (19), where $\delta = \beta^{-1}(1-\beta)$. Since initially neither country is a net debtor, the government constraint implies (20) and (21). Since $p^j c_k^j = \gamma^{-1} p_x^j x_k^j = (1-\gamma)^{-1} p_y^j y_k^j$, by summing up all individuals' consumptions, the resource constraints (3) leads to equations (22) and (23). Equations (10), (13) and the relationship of $\left(\theta_k^h + \theta_k^f\right)^{\frac{\phi}{\phi-1}} l_k = k$ yield another expression of the world output of good k, that is (24).

The structural form of the model is summarized as follows:

$$(c_k)^{-\rho} = \beta(1+r)\left(\overline{c}_k\right)^{-\rho}, \tag{15}$$

$$\frac{\overline{m}_k^h}{p^h} = \chi \frac{1+i}{i} \left(c_k\right)^{\rho}, \tag{16}$$

$$\frac{\overline{m}_k^h}{\overline{p}^h} = \chi \frac{1+\delta}{\delta} \left(\overline{c}_k\right)^{\rho}, \tag{17}$$

$$\frac{\overline{m}_k^h}{p^h} = \frac{E\overline{m}_k^f}{p^h}, \tag{18}$$

$$\frac{\overline{m}_k^h}{\overline{p}^h} = \frac{\overline{E}\overline{m}_k^f}{\overline{p}^h}, \tag{19}$$

$$\frac{\theta_k^j}{\theta_k^h + \theta_k^f} p_k^j k - d_k^j - p^j \theta_k^j c_k = \theta_k^j b_k^j, \tag{20}$$

$$\frac{\theta_k^j}{\theta_k^h + \theta_k^f} \overline{p}_k^j \overline{k} - \overline{d}_k^j - \overline{p}^j \theta_k^j \overline{c}_k = -\delta \theta_k^j \overline{b}_k^j, \tag{21}$$

$$k = \frac{\gamma_k p^j}{p_k^j} \left(\left(\theta_x^h + \theta_x^f \right) c_x + \left(\theta_y^h + \theta_y^f \right) c_y \right), \tag{22}$$

$$\overline{k} = \frac{\gamma_k \overline{p}^j}{\overline{p}_k^j} \left(\left(\theta_x^h + \theta_x^f \right) \overline{c}_x + \left(\theta_y^h + \theta_y^f \right) \overline{c}_y \right), \tag{23}$$

$$\overline{k} = \left(\theta_k^h + \theta_k^f \right)^{\frac{\phi+1}{\phi-1}} \left(\frac{\phi - 1}{a\phi} \right) \frac{\overline{p}_k^j}{\overline{p}^j} \left(\overline{c}_k \right)^{-\rho}, \tag{24}$$

$$b^h + E b^f = 0, \tag{25}$$

$$\overline{b}^h + \overline{E}\overline{b}^f = 0. \tag{26}$$

Appendix II

Before deriving the equilibrium, some relationships between long-run equilibrium and short-run equilibrium are proved as follows.

1 Prove $i = \delta$.

By equations (15), (16) and (17), we get

$$\frac{p^j}{\overline{p}^j} = \beta(1+r) \frac{(1+\delta)}{(1+i)} \frac{i}{\delta}.$$

Since $\beta = \frac{1}{1+\delta}$ and $\frac{p^j}{\overline{p}^j}(1+i) = (1+r)$, we have $i = \delta$.

2 Prove $E = \overline{E}$.

Equations (18) and (19) imply $E = \overline{E}$.

3 Prove $b^j = \overline{b}^j = 0$.

Aggregating the individuals' budget constraints in the first period after shock in a country j, we get

$$\frac{\theta_x^j}{\theta_x^h + \theta_x^f}\overline{p}_x^j \overline{x} + \frac{\theta_y^j}{\theta_y^h + \theta_y^f}\overline{p}_y^j \overline{y} - \overline{p}^j \theta_x^j \overline{c}_x - \overline{p}^j \theta_y^j \overline{c}_y = \overline{b}^j - (1+i)\, b^j.$$

Then, by equation (21), we get $\overline{b}^j - (1+i)\, b^j = -\delta \overline{b}^j$. Since $i = \delta$, we have $b^j = \overline{b}^j$.

Let $a_1^j = \theta_y^j \frac{\theta_x^h + \theta_x^f}{\theta_y^h + \theta_y^f} - \theta_x^j$ and $a_2^j = \theta_x^j \frac{\theta_y^h + \theta_y^f}{\theta_x^h + \theta_x^f} - \theta_y^j$. By (20) and (22), the short-run current account balance $\frac{b^j}{p^j c_x}$ is equal to $(1-\gamma)\, a_1^j + \gamma \frac{c_y}{c_x} a_2^j$. By (21) and (23), the long-run current account balance $\frac{-\delta \overline{b}^j}{\overline{p}^j \overline{c}_x}$ equals $(1-\gamma)\, a_1^j + \gamma \frac{\overline{c}_y}{\overline{c}_x} a_2^j$. Therefore, we get

$$\frac{b^j}{p^j c_x} - \left(\frac{-\delta \overline{b}^j}{\overline{p}^j \overline{c}_x} \right) = \frac{b^j}{p^j c_x} \left(1 + \delta \frac{p^j c_x}{\overline{p}^j \overline{c}_x} \right) = \gamma a_2^j \left(\frac{c_y}{c_x} - \frac{\overline{c}_y}{\overline{c}_x} \right).$$

Equation (15) implies $c_x/c_y = \overline{c}_x/\overline{c}_y$. Thus, $b^j = 0$. Therefore, it is easy to verify that $-\left(\frac{a_2^j}{a_1^j}\right) = -\left(\frac{a_2^{j'}}{a_1^{j'}}\right) = \Theta$.

4 Prove $c_x/c_y = \overline{c}_x/\overline{c}_y = \Upsilon\Theta$.

Note that $c_x/c_y = \overline{c}_x/\overline{c}_y = -\left(\frac{\gamma}{1-\gamma}\right)\frac{a_2}{a_1}$ directly comes from equation (15) and $(1-\gamma)\, a_1^j + \gamma \frac{c_y}{c_x} a_2^j = \frac{b^j}{p^j c_x} = 0$.

5 Prove $b_k^j = \overline{b}_k^j = 0$.

Similar arguments for showing $b^j = \overline{b}^j$ are applied to prove $b_k^j = \overline{b}_k^j$. Using equations (21) and $\overline{c}_x/\overline{c}_y = \Upsilon\Theta$, we can derive

$$-\frac{\delta}{\overline{p}\overline{c}_x}\left(\overline{b}_x^j - \overline{b}_y^j\right) = \left[a_2^j(\gamma - 1)\right]^{-1} \left[a_1^j\,(1+\Theta) + a_2^j\left(1 + \Theta^{-1}\right)\right] = 0.$$

Thus, $\overline{b}_x^j = \overline{b}_y^j$. Since $\overline{b}^j = \theta_x^j \overline{b}_x^j + \theta_y^j \overline{b}_y^j = 0$, we get $\overline{b}_x^j = \overline{b}_y^j = 0$.

6 Derivation of the long-run equilibrium.

Since (23) implies $\frac{\overline{p}_x^h}{\overline{p}_y^h} = \Upsilon \frac{\overline{y}}{\overline{x}}$ and (24) implies $\frac{\overline{x}}{\overline{y}} = \Theta^{\frac{1+\phi}{1-\phi}} \frac{\overline{p}_x^h}{\overline{p}_y^h} \left(\frac{\overline{c}_x}{\overline{c}_y}\right)^{-\rho}$, thus, by $\frac{\overline{c}_x}{\overline{c}_y} = \Upsilon\Theta$, we get $\frac{\overline{x}}{\overline{y}} = \Theta^{\frac{1}{2}\left(\frac{1+\phi}{1-\phi} - \rho\right)} \Upsilon^{\frac{1-\rho}{2}}$ and $\frac{\overline{p}_x^h}{\overline{p}_y^h} = \Theta^{\frac{-1}{2}\left(\frac{1+\phi}{1-\phi} - \rho\right)} \Upsilon^{\frac{1+\rho}{2}}$.

Equation (21) and $\overline{b}_k^j = 0$ imply that $\frac{\overline{p}_k^j \overline{k}}{\overline{p}^j} = \overline{c}_k \left(\theta_k^h + \theta_k^f\right)$. Since $\overline{p}^j = \frac{1}{\gamma_w} \left(\overline{p}_x^j\right)^{\gamma} \left(\overline{p}_y^j\right)^{1-\gamma}$, we have

$$\overline{c}_k \left(\theta_k^f + \theta_k^h\right) = \overline{k}\gamma_w \left(\frac{\overline{p}_k^j}{\overline{p}_{k'}^j}\right)^{\gamma_{k'}}. \tag{27}$$

According to equation (24), we can derive another relationship between $\overline{c}_k$ and $\overline{k}$, that is,

$$\overline{k} = \Phi\gamma_w \left(\theta_k^h + \theta_k^f\right)^{\frac{\phi+1}{\phi-1}} \left(\frac{\overline{p}_k^j}{\overline{p}_{k'}^j}\right)^{\gamma_{k'}} \overline{c}_k^{-\rho}. \tag{28}$$

By (27), (28), and $\frac{\overline{p}_x^j}{\overline{p}_y^j} = \Theta^{\frac{-1}{2}\left(\frac{1+\phi}{1-\phi}-\rho\right)} \Upsilon^{\frac{1+\rho}{2}}$ the solutions to $\overline{c}_x$, $\overline{c}_y$, $\overline{x}$ and $\overline{y}$ are derived.

The money market equilibrium is solved by using equation (19), $\frac{\overline{m}_k^h}{\overline{p}} = \chi\frac{1+\delta}{\delta} \left(\overline{c}_k\right)^{\rho}$. The exchange rate is solved by using the relation of $\left(\frac{\overline{M}^h}{\overline{p}^h}\right) / \left(\frac{\overline{M}^f}{\overline{p}^f}\right) = \overline{M}_R \overline{E}^{-1}$, where $\overline{M}^j = \theta_x^j \overline{m}_x^j + \theta_y^j \overline{m}_y^j$.

It can be shown that

$$\left(\frac{\overline{M}^h}{\overline{p}^h}\right) / \left(\frac{\overline{M}^f}{\overline{p}^f}\right) = \frac{\theta_x^h + \theta_y^h \left(\frac{\overline{c}_y}{\overline{c}_x}\right)^{\rho}}{\theta_x^f + \theta_y^f \left(\frac{\overline{c}_y}{\overline{c}_x}\right)^{\rho}} = \frac{\theta_x^h + \theta_y^h \left(\Upsilon\Theta\right)^{-\rho}}{\theta_x^f + \theta_y^f \left(\Upsilon\Theta\right)^{-\rho}}.$$

Thus, $\overline{E} = a_3 \overline{M}_R$, where $a_3 = \frac{\theta_x^f + \theta_y^f (\Upsilon\Theta)^{-\rho}}{\theta_x^h + \theta_y^h (\Upsilon\Theta)^{-\rho}}$.

Note that $\left(\frac{\overline{M}^h}{\overline{p}^h}\right)^{\gamma} \left(\frac{\overline{M}^f}{\overline{p}^f}\right)^{1-\gamma}$ equals $\overline{M}_w \overline{E}^{1-\gamma} \left(\overline{p}^h\right)^{-1}$. By equations (17) and (19), we get

$$\left(\frac{\overline{M}^h}{\overline{p}^h}\right)^{\gamma} \left(\frac{\overline{M}^f}{\overline{p}^f}\right)^{1-\gamma} = \chi\frac{1+\delta}{\delta} \left(\overline{c}_x\right)^{\rho} a_4^{1-\gamma} a_5^{\gamma},$$

where $a_4 = \left(\theta_x^f + \theta_y^f \left(\Upsilon\Theta\right)^{-\rho}\right)$ and $a_5 = \left(\theta_x^h + \theta_y^h \left(\Upsilon\Theta\right)^{-\rho}\right)$. Therefore, some algebra shows that

$$\overline{p}^h = \overline{M}^h a_3^{1-\gamma} \chi^{-1} \frac{\delta}{1+\delta} a_4^{\gamma-1} a_5^{-\gamma} \left(\overline{c}_x\right)^{-\rho}.$$

7 Derivation of the long-run equilibrium.

Since we know that

$$\left(\frac{\overline{M}^h}{p^h}\right)^{\gamma} \left(\frac{\overline{M}^f}{p^f}\right)^{1-\gamma} = \chi\frac{1+\delta}{\delta} a_4^{1-\gamma} a_5^{\gamma} c_x^{\rho} = \overline{M}_w \left(p_0^h\right)^{-1} E_0^{1-\gamma},$$

we obtain $c_k = \overline{M}_w^{\frac{1}{\rho}} M_{w0}^{\frac{-1}{\rho}} c_{k0} = \overline{M}_w^{\frac{1}{\rho}} M_{w0}^{\frac{-1}{\rho}} \overline{c}_k$. By equation (15), we get $1 + r = \frac{1}{\beta}\left(\frac{\overline{c}_x}{c_x}\right)^{\rho}$. Therefore, $1 + r = \beta^{-1} \overline{M}_w^{-1} M_{w0}$.

The short-run terms of trade is determined by

$$\frac{p^h_{x0}}{Ep^f_{y0}} = E^{-1}E_0\frac{p^f_{x0}}{p^f_{y0}} = \overline{M}_R^{-1}M_{R0}\frac{\overline{p}^j_x}{\overline{p}^j_y}.$$

Equation (20) implies that $x = \frac{(\theta^h+\theta^f)}{\gamma_w}\left(\frac{p^h_x}{p^h_y}\right)^{\gamma-1}c_x$. Since $\frac{p^h}{p^h_x} = E^{1-\gamma}\left(\frac{p^h_x}{p^f_y}\right)^{\gamma-1}$, $x = \frac{(\theta^h_x+\theta^f_x)}{\gamma_w}E^{1-\gamma}\left(\frac{p^h_x}{p^f_y}\right)^{\gamma-1}c_x$. The assumption of nominal rigidity results that $\frac{p^h_x}{p^f_y}$ equals $\frac{p^h_{x0}}{p^f_{y0}}$. The short-run terms of trade implies that $\frac{p^h_{x0}}{p^f_{y0}} = a_3M_{R0}\frac{\overline{p}^j_x}{\overline{p}^j_y}$. Thus, in the short-run equilibrium,

$$x = \overline{M}_R^{1-\gamma}M_{R0}^{\gamma-1}\frac{(\theta^h_x+\theta^f_x)}{\gamma_w}\left(\frac{\overline{p}^j_x}{\overline{p}^j_y}\right)^{\gamma-1}c_x.$$

This result and equation (22) yields that

$$y = \Upsilon^{-1}\overline{M}_R^{-1}M_{R0}\frac{\overline{p}^j_x}{\overline{p}^j_y}x.$$