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Monetary Policy Transmission in a Small Open Economy under Financial and Trade Restrictions

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JEL Codes: E52, E58, G01, G28.

Monetary policy transmission in a small open economy under financial and trade restrictions*

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13 January 2025

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1 Introduction

In this paper, I address the question how restrictions on international borrowing and imports transform the effect of macroeconomic shocks on imports and the stance of monetary policy. For this purpose, I build and calibrate a standard small open economy model where the imported good serves as a production factor. The not so standard features of my model are the quadratic costs of external borrowing and imports.

I use the model to re-confirm that, in the absence of the above-mentioned restrictions, an adverse shock in the terms of trade, which results in a contraction of export revenues, has a zero effect on inflation. The economy adjusts to the shock via a nominal and real depreciation, i.e. a rise in the real price of imports is compensated by a decrease of real wages. As a result, the marginal cost of production remain unchanged and no inflation pressures arise. In these circumstances, monetary policy of a central bank targeting inflation remains neutral.

The restrictions on financial and trade transaction with the rest of the world raise the price of imports in the current period relative to other periods: the restriction on international borrowing – via an increase in the interest rate on external borrowing, which is raised to finance imports, the restriction on imports – via its direct effect on the domestic price of the imported good. All this motivates firms to substitute the imported good by labor to the extent that production technology makes it possible. Imperfect subsitutability between the imported input and labor does not allow to eliminate the inflationary effect of a rise in the price of imports. As a result, a macroeconomic shock in the terms of trade, being neutral with respect to inflation in the absence of the restrictions on external borrowing and imports, becomes inflationary in their presence. In its turn, this leads to monetary policy becoming tighter.

The rest of the paper is structured as follows. Section 2 discusses the place of this study in the related literature. Section 3 describes the theoretical model and explains how its parameters are calibrated. Section 4 contains a description of a model experiment and a discussion of findings. Section 5 concludes.

2 Related literature

This study is related to two strands of literature. First, this is the research analyzing the effect of trade and financial restrictions on the economy. Itskhoki and Mukhin [2022] undertake a theoretical analysis of the effect that international sanctions of various sorts have on the exchange rate. Lorenzoni and Werning [2022] offers a minimalist model explaining ruble behavior during the period of the enactment of sanctions at the beginning of 2022. Eichengreen et al. [2023] run an empirical investigation of the effect of sanctions on exchange rate dynamics from the historical perspective. Dreger et al. [2016] study the effect of sanctions and changes in the international price of oil on the ruble exchange rate in 2014–2015 Lymar et al. [2022] study a long-run effect of sanctions on a structural transformation of the economy of a primary commodity exporter.

The second strand of literature is monetary policy in economies that specialize in the exporting of natural resources and that target inflation. Growth in the international prices of primary commodities leads to an improvement in the terms of trade for these economies and to a real appreciation of their exchange rates. This suppresses inflation and triggers monetary policy easing. Accordingly, the endogenous response of monetary policy amplifies the effect of the terms-of-trade shock, which makes the business cycle more volatile. Examples of research in this direction include Bejarano et al. [2016], Bergholt et al. [2019], Charnavoki and Dolado [2014], Shousha [2016].

In contrast to the above-mentioned papers, our study focuses on the transformation of the character of monetary policy in a small open economy that exports primary commodities and that is subject to international trade and financial restrictions.

3 Model

This sections consists of two subsection. In the Subsection 3.1, an unrestricted baseline two-period New Keynesian model of a small open economy is developed. In Subsection 3.2, the baseline model is modified by adding restrictions on trade in financial assets and goods with the rest of the world.

3.1 Model without restrictions

I consider a two-period small open economy with a representative household that produces two goods – an exportable good and a nontradable final consumption good. The exportable good is exported to the rest of the world in full in exchange for an imported intermediate good. The final good is produced using the imported good and labor provided by households and is entirely consumed domestically. The first period ($t = 1$) is the short run, during which the prices of the final good is partially rigid. The second period ($t = 2$) is the long run, during which the prices of the final good are completely flexible. There is no uncertainty in the second period. The only source of disturbances in the home economy is unexpected changes in export revenues.

3.1.1 Preferences

The preferences are described by a two-period utility function

$$\frac{c_1^{1-\sigma}}{1-\sigma} - \frac{h_1^{1+\phi}}{1+\phi} + \beta \left(\frac{c_2^{1-\sigma}}{1-\sigma} - \frac{h_2^{1+\phi}}{1+\phi} \right),$$

where c_t is consumption in period $t = 1, 2$; h_t is hours worked in period $t = 1, 2$; $\sigma > 0$ is the coefficient of relative risk aversion; $\phi > 0$ is the inverse of the Frisch elasticity of labor supply; and $0 < \beta < 1$ is subjective time discount factor.

The composite consumption good c_t is a Dixit–Stiglitz aggregator over a unit continuum of differentiated consumption goods $c_t(j)$

$$c_t = \left(\int_0^1 c_t(j)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}}, \ t \in \{1, 2\}, \tag{1}$$

where $j \in [0; 1]$ is the index of the differentiated consumption goods; $\epsilon > 1$ is the cross elasticity of substitution between different varieties of the consumption good.

3.1.2 Technology

Production of the final good involves two stages. On the first stage, a homogeneous intermediate good is produced by a perfectly competitive industry with labor h_t and the homogeneous imported input m_t

$$y_t = \left(\alpha^{\frac{1}{\theta}} m_t^{\frac{\theta-1}{\theta}} + (1-\alpha)^{\frac{1}{\theta}} h_t^{\frac{\theta-1}{\theta}}\right)^{\frac{\theta}{\theta-1}},$$

where $\theta > 0$ is the cross-elasticity of substitution between labor and the imported input in intermediate goods production; $\alpha \in (0.5; 1]$ characterizes the relative weight of the imported good in the production of the intermediate good. On the second stage, the intermediate good serves as the only input to produce differentiated consumption goods by a unit continuum of monopolistically competitive firms ("retailers") using a linear technology

$$c_t(j) = y_t(j), \quad j \in [0, 1],$$

where $y_t(j)$ is the amount of the intermediate input involved in the production of a differentiated good j in the quantity of $c_t(j)$.

3.1.3 Price setting

Labor market is perfectly competitive with flexible nominal wage, which is determined in equilibrium. The price of the imported good expressed in the units of foreign currency is determined on the international market and is therefore exogenously given for the small open economy under consideration. Without loss of generality, the price of imports is set equal to one. Assuming the the law of one price holds, the domestic nominal price of the imported good equals the nominal exchange rate, which is defined as the quantity of home currency units per one foreign currency unit. Hence, under freely floating exchange rate, the domestic price of the imported good is flexible – similarly to nominal wage. The price of the intermediate good, which is determined in a perfectly competitive market equilibrium, is also flexible in both periods.

The prices of differentiated consumption goods in the long run – in period $t = 2$ – are flexible. In $t = 1$, i.e. in the short run, fraction ξ of differentiated goods producers sell their product at the price that was set in the previous period at the level of $P_1^{fix}(j)$, whereas fraction $1 - \xi$ of differentiated goods producers choose the price optimally at the level of $P_1^{flex}(j)$. Provided that different varieties of the differentiated good enter the Dixit–Stiglitz aggregator for final consumption (1) with equal weights and that that all final goods producers have exactly the same linear production technology, one can conclude that, in a symmetric equilibrium, all producers within each of the two groups offer the same price: $P_1^{fix}(j) = P_1^{fix}$ and $P_1^{flex}(j) = P_1^{flex}$.

3.1.4 External sector

The home economy produces the homogeneous exportable good in the amount that is exogenously given. The exportable good is sold to the rest of the world in full at an exogenously given international price. Export revenues in period t expressed in the units of foreign currency equals x_t. Exogenous changes in x_t can occur due to changes in the volume of production as well as due to changes in the international prices of the exportable good. The external budget constraints (the balance-of-payment relationships) for $t = 1$ and $t = 2$ are

$$m_1 + \frac{b_2}{1 + i^*} = x_1, \quad (2)$$

$$m_2 = x_2 + b_2, \quad (3)$$

where m_t is imports; b_t is net foreign assets; x_t is export revenues; i^* is the exogenously given international interest rate. The only asset traded internationally is one-period risk-free zero-coupon bonds denomanated in foreign currency. Equation (2) states that export revenues is spent on the purchase of imports and net foreign asset accumulation. Here I implicitly assume that the stock of net foreign assets of the home economy as of the beginning of period $t = 1$ is zero: $b_1 = 0$. This assumption is without loss of generality: in the case the amount of bonds maturing in $t = 1$ – b_1 – is different from zero, one can always re-define x_1 by adding b_1 to it. Equation (3) implies that as of the end of period $t = 2$ the amount of net foreign assets is zero: $b_3/(1 + i^*) = 0$. The horizon of net foreign asset accumulation is limited by the span of the existence of the economy.

3.1.5 Monetary policy

Given that in the second period, i.e. in the long run, all nominal prices are flexible there is no output–inflation trade-off in that period. This trade-off exists in the short run however, i.e. in the first period, when final goods prices are partially rigid. For this reason, in the long run, the central bank can engineer inflation at the target, which is assumed to be zero, without real output loss:

$$\pi_2 = 0,$$

where π_2 is the rate of inflation between $t = 1$ and $t = 2$.

In period $t = 1$, the central bank uses the nominal interest rate i_1 as monetary policy instrument. I assume that monetary policy is implemented in accordance with the rule

$$1 + i_1 = \frac{1}{\beta}(1 + \pi_1)^{\gamma_\pi},$$

where $\gamma_\pi > 0$.

3.2 Model with restrictions

The baseline model described in Subsection 3.1 is further modified by adding two restrictions – the restrictions on the accumulation of net foreign assets in the first period, $b_2/(1 + i^*)$, and an upper limit on the quantity of the imported good. It is assumed that one of the two or both restrictions are imposed only in the first period but not in the second one since otherwise it might be impossible to satisfy the intertemporal budget constraint. Suppose, for instance, that the restriction on imports is introduced both in the first and the second periods. If the home economy's net exports are positive in the first period then the country purchases foreign bonds in the amount equal to the value of net exports, and these bonds are due in the second period. Debt repayment by the rest of the world can be implemented only via the trade deficit of the home economy in the second period, i.e. the value of its imports should exceed the value of its exports by the amount of maturing foreign bonds in its portfolio. Given that the value of exports x_2 in the second period is an exogenous parameter it is possible that the res of the world will not be able to repay its debt to the home economy in the second period in full because of the restriction on imports in place in this period.

3.2.1 Restriction on financial transactions with the rest of the world

The restriction on external borrowing is modeled using a quadratic cost function similar to that in Bianchi and Lorenzoni [2022]:

$$\Phi\left(\frac{b_2}{1+i^*}\right) = \frac{\kappa}{2}\left(\frac{b_2}{1+i^*}\right)^2,$$

where parameter $\kappa > 0$ characterizes the severity of the restriction.

In Bianchi and Lorenzoni [2022], the cost function is asymmetric. In addition to interest expenses, a small open economy bears extra costs when borrowing from abroad. When purchasing foreign bonds, it does not face any costs but receives interest income at the international interest rate. In my model the cost function is symmetric: both purchases of foreign bonds and borrowings from abroad are associated with portfolio adjustment costs. The quadratic cost function implies that the *marginal* cost related to financial transactions with the rest of the world grow linearly with the absolute size of the foreign bond portfolio. The extreme case of $\kappa = 0$ corresponds to free trade in financial assets with the rest of the world, as in Subsection 3.1, whereas $\kappa = \infty$ – to the absence of trade in assets altogether, i.e. financial autarky.

3.2.2 Restriction on imports

The restriction on imports in period $t = 1$ is also modeled using a quadratic loss function:

$$\Psi(m_1) = \frac{\chi}{2}m_1^2,$$

where $\chi > 0$ characterizes the severity of the restriction. The extreme case $\chi = 0$ corresponds to free trade in goods with the rest of the world, as in subsection 3.1, $\chi = \infty$

– to autarky, i.e. a complete lack of trade in goods with the rest of the world.

It is worth noting that, under financial autarky ($\kappa = \infty$), trade links with the rest of the world can exist but, in this case, the trade will be balanced in each period – with zero trade balance. However, in the absence of trade in goods with the rest of the world ($\chi = \infty$), i.e. with closed current account, the financial account will also be closed ($b_2 = 0$).

3.2.3 Law of one price

The restriction on imports gives rise to a deviation of the domestic price of the imported good from its international price:

$$p_1^m = e_1(1 + \chi m_1),$$

where $p_1^m = P_1^m / P_1$ is the real domestic price of the imported good; $e_1 = \mathcal{E}_1 / P_1$ is real exchange rate; $\mathcal{E}_1$ – is nominal exchange rate; P_1^m is the nominal domestic price of the imported good; P_1 is nominal price level in the home economy. In the absence of the restriction on imports ($\chi = 0$) the domestic price of the imported good equals $P_1^m = \mathcal{E}_1$ in nominal terms or $p_1^m = e_1$ in real terms. The restriction on imports in the form of non-price costs Ψ invalidates the law of one price for the imported good so that its domestic price in the home economy exceeds the international price by the value of the marginal non-price cost of imports χm_1.

3.2.4 Interest rate parity

The restriction on external financial transactions and the restriction on imports break the uncovered interest parity (UIP) relationship. The no-arbitrage condition is now takes the form

$$\frac{e_1}{e_2} \frac{1 + i_1}{1 + i^*} \left(1 + \frac{\kappa b_2}{1 + i^*} \right) = 1 \tag{4}$$

If there is no restriction on financial transactions with the rest of the world then $\kappa = 0$ and equation (4) turns to the standard UIP equation:

$$1 + i_1 = (1 + i^*)\frac{e_2}{e_1} = (1 + i^*)\frac{\mathcal{E}_2}{\mathcal{E}_1},$$

where the last equality is accounts for the fact that $\pi_2 = 0$ and therefore $e_2/e_1 = \mathcal{E}_2/\mathcal{E}_1$.

In the presence of the financial restriction, the effective interest rate on financial transactions faced by the agents in the home economy is

$$\frac{1 + i^*}{1 + \kappa b_2/(1 + i^*)}$$

and differs from the international rate. The effective rate is above the international one if the home economy is a debtor with respect to the rest of the world ($b_2 < 0$) and above the international one if the home economy is a creditor with respect to the rest of the world ($b_2 > 0$). The difference between the effective rate and the international rate equals the marginal non-interest cost of financial transactions with the rest of the world, $\kappa b_2/(1+i^*)$.

3.2.5 Balance of payments

The equation of the balance of payments in the presence of both restrictions in period $t = 1$ is

$$m_1 + \frac{b_2}{1 + i^*} + \Phi\left(\frac{b_2}{1 + i^*}\right) + \Psi(m_1) = x_1 \tag{5}$$

$$m_2 = x_2 + b_2 \tag{6}$$

Equation (6) coincides with equation (3) of the balance of payments in the absence of the financial restriction and the restriction on imports. The balance-of-payments equation (5) for the first period differs from the similar/analogous equation (2) for the case with no restrictions by the value of additional costs on the expenditure side, which are caused by the two restrictions and which disappear in the absence of these restrictions.

3.2.6 Equilibrium

The definition of the equilibrium is standard. Given trajectories of prices and exogenous variables and also given the monetary policy rule of the central bank, the agents of each type – households and firms in different sectors – solve their optimization problems under the condition that budget constraints and the restrictions on external financial and trade transactions. The solution of these optimization problems is demand or supply functions for goods and production factors. Equilibrium prices of goods and production factors are settled down so that all markets for goods and production factors are cleared, i.e. there is no excess/insufficient demand or supply on either market.

The list of all variables that appear in the model along with their description can be found in Appendix A.1. The system of non-linear algebraic equations that determines equilibrium allocations and prices can be found in Appendix A.2.

3.2.7 Calibration

The parameters of the model are calibrated as shown in Appendix A.3.

The main part of the parameters are calibrated in standard way. The time discount coefficient β is set equal to 0.95, which, on annual frequency, corresponds to the long-run real interest rate of 5%. The international interest rate i^* is also set equal to 5%. The coefficient of the relative risk aversion σ is often calibrated in the interval from 1 to 2. For this study, I choose the value of $\sigma = 1$, which corresponds to the logarithmic dependence of the utility function on consumption. The cross-elasticity of substitution between the imported good and labor in the production of the domestic intermediate good θ is set equal to 0.8, which implies a fair degree of complementarity between these two inputs in the production of the home intermediate good. The cross-elasticity of substitution between different varieties of the final good in preferences ϵ is set equl to 6, which corresponds to the size of the monopolistic price markup over marginal cost equal to 20%. The share of the imported good in the production of the home intermediate good, which is captured by parameter α, is set equal to 0.3, which corresponds to the percentage imports share of 30%. The parameter of the inverse Frisch elasticity of labor supply ϕ is set equal to 1. The fraction of sellers with rigid prices in the short run ξ equals 0.5. The coefficient that characterizes the response of the monetary policy instrument to inflation γ_π in the monetary policy rule equals 1.5.

The calibration of non-standard parameters, namely κ in the financial restriction and χ in the restriction on imports, warrants careful discussion. In the absence of both restrictions ($\kappa = \chi = 0$) the equilibrium values of net foreign assets and imports in the first period are $b_2 = -0.26$ and $m_1 = 1.25$, respectively. In the presence of the costs of external financial transactions, their share in this volume of transactions is

$$\frac{1}{2}\frac{\kappa|b_2|}{1+i^*} \approx 0.12\kappa.$$

I consider the range of κ values from 0 to 2, where the upper limit corresponds to the costs of external financial transactions equal to 0.24, or 24%. Similarly, I set an upper limit for the share of the costs of imports in the volume of imports in the first period

$$\frac{1}{2}\chi m_1 \approx 0.6\chi$$

at the level of 0.24, or 24%. Accordingly, I consider the range of values of parameter χ between 0 and 0.4.

4 Model experiment

In this section we describe a numerical experiment based on our model and report its findings.

4.1 Objective and design of the experiment

The experiment is organized as follows. Initially, the economy rests in a steady state with the values of export revenues in the first and second periods equal to $x_1 = x_2 = 1.5$. In period $t = 1$, a macroeconomic shock arrives: export revenues unexpectedly contract from $x_1 = 1.5$ to $x_1 = 1$. The objective of the experiment is to answer the question how the response of various macroeconomic variables to the shock depends on the severity of the financial restriction κ and the restriction on imports χ.

The experiment consists of two parts. First, I analyze the sensitivity of impulse responses with respect to the severity of financial restriction given the severity of the restriction on imports. The value of χ is subsequently fixed at 0, 0.2, and 0.4, whereas the value of κ varies in the range from 0 to 2 separately for each value of chi, where 0 corresponds to the absence of the financial restriction. For each combination of the values of κ, χ, the model is solved numerically, and its solution is plotted as a dot on a graph, separate for each of 20 endogenous variables, where the value of κ is on the horizontal axis and the equilibrium value of the respective variable – on the vertical axis. Figures 1–5 summarize the results of the first part of the experiment.

Second, I analyze the sensitivity of the solution with respect to the severity of the restriction on imports following a similar procedure. In this case, I consequently fix the value of κ at 0, 1, and 2, and for each value of κ I vary the value of χ in the range from 0 to 0.4 where 0 corresponds to the absence of the restriction on imports. Figures 6–10 summarize the results of the second part of the experiment.

4.2 Sensitivity of equilibrium responses to the severity of the financial restriction κ

I start by considering Figures 1–5 that show the impulse responses of 20 endogenous variables to a negative shock in export revenues x_1 from 1.5 to 1. The values of parameter κ are on the horizontal axis in the range from 0 to 2. On each impulse response graph, three curves are depicted – dotted for $\chi = 0$, dashed for $\chi = 0.2$, and solid for $\chi = 0.4$.

In the steady state with equal values of export revenues in the first and second periods, the volume of production, hours worked, and consumption will be the same in each period. If net foreign assets are zero as of the beginning of the first period, which is scenario assumption, then the value of imports in each period will be exactly equal to the value of export revenues so that there is no need either to purchase foreign bonds or to borrow from abroad so that $b_2 = 0$.

The contraction of export revenues in the first period implies that there are fewer resources for the production of the final good since the home economy can afford to import less than before the shock in the first and the second periods in total. However, the motive to smooth consumption between the first and the second periods still remains.

I first analyze the frictionless case $\kappa = \chi = 0$, which corresponds to the intersection of the dotted line with the vertical axis. In the absence of the trade and financial frictions the small open economy is able to smooth the time profile of consumption at the level of 1.61 with the help of external borrowing. In this case, the home economy receives the same volume of imports equal to 1.245 in both periods and and employs the same amount of hours worked equal to 0.7975 in the production, which allows it to produce the same quantity of the intermediate good equal to 1.61. Real wages and real exhcnge rate are the same on both periods and are equal to 1.283 and 0.255, respectively. The real prices of "flexible" and "fixed" sellers do not change and remain at the level of 1. The reason is that the real marginal costs remain unchanged compared with the before-shock level. The latter is caused by the fact that the increase in the real price of the imported good, which is the real exchange rate, is compensated by a decline of the real wage. The real exchange rate increases because the imported good becomes relatively scarcer in both periods. the real wage declines because labor becomes relatively more abundant in each of the two periods. The unchanged prices of "flexible" and "fixed" sellers in the first period imply that final goods' prices remain unchanged relative to the previous period so that inflation in the first period equals zero. Zero inflation triggers zero response of the interest rate, which remains equal to the international rate of 5%.The value of the interest rate at the neutral level $1/\beta - 1 = r^*$, on the one hand, and the equality of final consumption volumes in the first and the second periods, on the other hand, are consistent with the Euler equation. The equality of the domestic and the international interest rates, on the one hand, and exchange rate invariability between the first and the second periods, on the other hand, are consistent with the frictionless version of the uncovered interest parity. In the absence of trade frictions, the domestic price of the imported good p_1^m equals its international price, which coincides with the exchange rate

e_1 and equals 0.255.

Now assume that there are no trade costs in the first period whereas the financial costs, which are characterized by parameter κ, rise from 0 to 2. The increase in κ results in a rise in the effective interest rate

$$\frac{1+i^*}{1+\kappa b_2/(1+i^*)},$$

at which the small open economy can borrow from the rest of the world. This, in its turn, raises the intertemporal price of the imported good in the first period relative to the second period: the imported good becomes relatively scarcer in the first period and relatively more abundant in the second period. Since in the absence of the trade costs, the domestic and international prices of the imported good coincide and equal e_1, the growth of the relative scarcity of the imported good in the first period, as described above, is expectedly is accompanied by an exchange rate depreciation in the first period and an appreciation in the second period as κ goes up. The graphs of the impulse responses for the use of imports in Figure 2 demonstrate that, as the financial restriction becomes tighter, the use of the imported good in production declines in the first period and rises in the second period. Labor appears to be simultaneously a complement and a substitute with regard to the imported good in production. The graphs of the impulse responses for hours worked in the first period (Figure 1) indicate that, as the financial restriction in the first period tightens, which raises the intertemporal price of the imported good in the first period, the more expensive imported good is substituted by labor, which results in an increase of hours worked in the first period. In the second period, hours worked also grow as the financial restriction becomes tighter. This is dues to the fact that, in the second period, the imported good is more available than in the first period. The increase in the use of the imported good in production in the second period raises the marginal product of labor, which leads to an increase in labor demand by firms producing the intermediate good, and as a consequence, the real wage rises (Figure 3, the upper right graph). The real wage in the first period is influenced by two effects working in the opposite directions. On the one hand, a decline in the use of the imported good decreases the marginal product of labor along with labor demand by firms. On the other hand, a rise in the intertemporal price of the imported good in the first period creates incentives for firms to substitute the imported good for labor, which leads to an increase in labor demand and wage growth. As shown in Figure 3 (the upper left graph), in the absence of trade costs, the first effect dominates, and as a result, the real wage in the first period declines as κ goes up. The decline in the real wage in the first period proves to be insufficient to offset/compensate the real exchange rate depreciation and the resulting rise in the price of the imported good involved in production. The outcome is an increase in the real marginal cost (Figure 4, the upper left graph) and the price of "flexible" firms (Figure 4, the lower left graph), which yields positive inflation (Figure 5, the upper right graph). In accordance with the monetary policy rule, the interest rate rises (Figure 5, the lower left graph). Higher values of parameter κ the effective interest rate on borrowing and thus create an incentive for the small open economy to borrow less from the rest of the world (Figure 5, the upper left graph). Nevertheless, the positive contribution of the cost of borrowing overweighs the contribution of the expected appreciation of the home currency in the version of the interest rate parity condition with frictions:

$$1 + i_1 = (1 + i^*)\frac{e_2}{e_1}\left(1 + \frac{\kappa b_2}{1 + i^*}\right)^{-1}$$

A higher, compared to its pre-shock level, value of the interest rate i_1, on the one hand, and a greater volume of consumption in the second period compared to that in the first period, on the other hand, are consistent with the Euler equation.

I now turn to the analysis of the economy's response to the shock in the presence of the restriction on imports $\chi = 0.2$ and $\chi = 0.4$. The respective impulse responses are depicted by the dashed and solid lines on the graphs shown in Figures 1–5.

The presence of trade costs results in the domestic price of the imported good p_1^m in the first period now exceeding its international price e_1. The two prices are connected via the relationship

$$p_1^m = (1 + \chi m_1)e_1,$$

and the difference between the domestic price and the international prices is greater as the volume of imports in the first period m_1 goes up. Obviously, the presence of trade costs implies that, given the trajectory of export revenues x_1, x_2, the discounted value of imports $m_1 + m_2/(1 + i^*)$ that the small open economy can afford shrinks. This inevitably leads to a decrease in the time profile of consumption c_1, c_2. In the scenario being analyzed, I assume no trade costs in the second period. This implies that, as χ goes up, the domestic price of the imported good in the first period rises compared to the that in the second period. This reinforces the motive for the substitution of more expensive imports in the first period for less expensive imports in the second period, which emerges because of the restriction on external financial transactions. This is clearly seen on Figure 2 (the upper graphs) where the value of imports in the first period contracts as χ goes up for all values of κ, whereas the value of imports in the second period grows. In the first period, the imported good is substituted by labor in production (Figure 1, the lower left graph). In the second period, hours worked also grow as χ goes up, which is caused by higher demand for labor under greater availability of imports. The increase in the use of labor in production in the first period does not allow to compensate the contraction of imports, and that is why the volume of intermediate good production declines as χ goes up. In its turn, this makes the trajectory of consumption steeper: consumption contracts in the first period and rises in the second period (Figure 1, the upper graphs).

Remarkably, the dependence of the real wage in the first period on the tightness of the financial restriction κ differs depending on the tightness of the trade restriction (Figure 3, the upper left graph). In the absence of trade costs, the real wage declines as κ goes up (the dotted line), whereas in their it grows in their presence (the dashed and solid lines). This can be explained by the fact that, in the first case when the rise in the price of imports is caused only by the increase in its intertemporal price (i.e. the interest rate on external borrowing), the effect of the diminishing marginal product of labor dominates, which results in a decline of wages. In the second case, an additional factor behind the rise in the price of imports arises – the trade costs, which makes firms substitute imports for labor in production more aggressively, and higher demand for labor leads to results in higher wages as κ goes up.

The presence of trade costs in the first period affects the real exchange rate response: as χ goes up, the home currency appreciates in real terms for each value of κ (Figure 3, the lower left graph). The reason is that higher trade costs lead to a contraction of the demand for imports, and hence, to a reduction in foreign borrowing in the first period. Given the value of export revenues x_1, which creates the supply of foreign currency, the reduction in the demand for foreign currency induced by the contraction in the demand for imports and for external borrowing results in a nominal appreciation. Furthermore, the growth of the domestic price of imports p_1^m as χ goes up for each value of κ (Figure 5, the lower right graph) will translate in higher marginal costs (Figure 4, the upper left graph) and inflation (Figure 5, the higher right graph). The price growth in the first period will further reinforce the real appreciation caused by the nominal appreciation, as χ goes up for each value of κ. The real appreciation is accompanied herewith by a rise rather than by a reduction of the domestic price of the imported good (Figure 5, the lower right graph).

The presence of the trade costs in addition to the financial costs will result in a more pronounced growth of the marginal cost of production and, as a consequence, to higher inflation (Figure 10, the upper right graph). In the case when cost parameters κ and χ take on their maximum values from the ranges under consideration, namely 2 and 0.4 respectively, inflation caused by the macroeconomic shock equals about 6%. In the absence of trade and financial costs though inflation remains zero. Higher inflation in the presence of the trade and financial restrictions requires a more aggressive reaction of monetary policy, and that is why the interest rate response becomes stronger as the value of parameters κ and/or χ go up (Figure 5, the lower left graph).

4.3 The sensitivity of equilibrium responses to the tightness of the restriction on imports χ

Figures 6–10 show the responses of endogenous variables to the macroeconomic shock depending on the value of the trade cost parameter χ in the range from 0 to 0.4 for three different values of the financial restriction tightness parameter κ – 0, 1, and 2. This can be treated as an alternative view on the reaction of the small open economy to the shock with regard to what was discussed in the previous subsection and what is shown in Figures 1–5.

For each value of parameter κ a tightening of the trade restriction makes imports in the first period more expensive compared to that in the second period. This creates incentives for the small open economy to reduce the use of imports in production in the first period (Figure 7, the upper left graph) and substitute it for labor (6, the lower left graph). Because of imperfect technological substitutability between labor and imports and also a rise in the interest rate in response to inflation pressures, the volume of production (Figure 7, the lower left graph) and consumption (Figure 6, the upper left graph) in the first period decline. The growth of employment in the first period, as χ goes up, is accompanied by a decrease in the real wage (Figure 8, the upper left graph) due to the fact that labor becomes less productive as the use of the imported good in production declines. The real exchange rate appreciates (Figure 8, the lower left graph) as χ goes up, first, because of a contraction of the demand for foreign currency on the back of the reduction of the demand for imports (Figure 7, the upper left graph) and for external borrowing (Figure 10, the upper left graph) given the unchanged supply (x_1) and, second, because of inflation (Figure 10, the upper right graph), induced by the rise in the domestic price of the imported good (Figure 10, the lower right graph) and, as a consequence, the marginal cost of production (Figure 9, the upper left graph). The reduction of the use of imports in the first period results in greater use of imports in production in the second period, which is accompanied by the growth of output, employment, consumption, and the real wage as well as by a real appreciation in the second period as χ goes up. Inflation growth (Figure 10, the upper right graph) in the first period as χ goes up triggers a more aggressive response of monetary policy (Figure 10, the lower left graph).

5 Conclusion

In the presence of restrictions on foreign borrowing and imports, an adverse shock resulting in the contraction of export revenues makes imported goods more expensive (e.g. a shock in the terms of trade). In the case of financial costs, this occurs because the economy has to pay higher interest rate on foreign borrowing that is raised to finance imports, whereas in the case of trade costs – because of the direct effect of the trade costs on the growth of the domestic price of the imported good. The rise in the price of imports via one or both channels creates incentives for firms to reduce the use of imports in production and also to substitute the imported input for labor to the extent that the production technology makes it possible. The rise in the price of imports puts an upward pressure of the firms' marginal cost and, as a consequence, leads to inflation, which is higher if the financial and trade restrictions are tighter. Given the monetary policy rule, higher inflation triggers a more aggressive response of monetary policy. Remarkably, in the absence of the trade and financial restrictions, the effect of the shock on inflation is zero and the monetary policy stance remains neutral. Accordingly, in the presence of the restrictions on external financial transactions and imports, macroeconomic shocks that are neutral with respect to inflation in the absence of the restrictions become inflationary, which makes monetary policy tighter.

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A Appendix

A.1 Model variables

Notation	Variable
c_t	Real consumption
h_t	Hours worked
m_t	The volume of the imported good
y_2	The production volume of the intermediate good
w_t	The real wage
e_t	The real exchange rate
mc_t	The real marginal cost
p_1^{flex}	The real price of sellers with flexible prices
p_1^{fix}	The real price of sellers with rigid prices
b_2	The nominal value of net foreign assets in the households' portfolio as of the end of $t = 1$
π_1	The rate of inflation between $t = 1$ and $t = 1$
i_1	The interest rate set by the central bank at $t = 1$
p_1^m	The equilibrium domestic price of the imported good ($p_1^m = e_1$ in the absence of trade frictions)

A.2 Model equations

The Euler equation for home bonds:

$$c_1^{-\sigma} = \beta(1 + i_1)c_2^{-\sigma} \tag{7}$$

Note: long-term inflation target $\pi_2 = 0$
the Euler equation for foreign bonds:

$$c_1^{-\sigma} = \beta \frac{1 + i^*}{1 + \kappa b_2/(1 + i^*)} \frac{e_2}{e_1} c_2^{-\sigma} \tag{8}$$

where $e_t \equiv \mathcal{E}_t/P_t$ is the real exchange rate.
Labor supply:

$$w_1 c_1^{-\sigma} = h_1^{\phi} \tag{9}$$

$$w_2 c_2^{-\sigma} = h_2^{\phi} \tag{10}$$

where w_t is real wage.
Demand for the imported good by firms producing the intermediate good:

$$m_1 = \alpha y_1 \left(\frac{p_1^m}{mc_1} \right)^{-\theta} \tag{11}$$

$$m_2 = \alpha y_2 \left(\frac{e_2}{mc_2} \right)^{-\theta} \tag{12}$$

Labor demand by firms producing the intermediate good:

$$h_1 = (1 - \alpha) y_1 \left(\frac{w_1}{mc_1} \right)^{-\theta} \tag{13}$$

$$h_2 = (1 - \alpha) y_2 \left(\frac{w_2}{mc_2} \right)^{-\theta} \tag{14}$$

The real marginal cost of firms producing differentiated final goods:

$$mc_1 = \left(\alpha \left(p_1^m \right)^{1-\theta} + (1 - \alpha) w_1^{1-\theta} \right)^{\frac{1}{1-\theta}} \tag{15}$$

$$mc_2 = \left(\alpha e_2^{1-\theta} + (1 - \alpha) w_2^{1-\theta} \right)^{\frac{1}{1-\theta}} \tag{16}$$

The equilibrium domestic price of the imported good:

$$p_1^m = (1 + \chi m_1) e_1 \tag{17}$$

The real price of differentiated final goods producers with flexible prices in $t = 1$:

$$p_1^{flex} = \frac{\epsilon}{\epsilon - 1} mc_1 \tag{18}$$

The price level in $t = 1$:

$$(1 - \xi) \left(p_1^{flex} \right)^{1-\epsilon} + \xi \left(p_1^{fix} \right)^{1-\epsilon} = 1 \tag{19}$$

where p_1^{fix} is the real price of producers with rigid prices in $t = 1$

The real price of differentiated final goods in $t = 2$:

$$1 = \frac{\epsilon}{\epsilon - 1} mc_2 \tag{20}$$

International budget constraints:

$$m_1 + \frac{b_2}{1+i^*} + \frac{\kappa}{2}\left(\frac{b_2}{1+i^*}\right)^2 + \frac{\chi}{2} m_1^2 = x_1 \tag{21}$$

$$m_2 = x_2 + b_2 \tag{22}$$

The rate of inflation between $t = 0$ and $t = 1$:

$$1 + \pi_1 = \frac{P_1}{\bar{P}_1} = \frac{1}{p_1^{fix}} \tag{23}$$

the demand for the intermediate good:

$$y_1 = c_1 \left((1-\xi) \left(p_1^{flex}\right)^{-\epsilon} + \xi \left(p_1^{fix}\right)^{-\epsilon} \right) \tag{24}$$

$$y_2 = c_2 \tag{25}$$

Monetary policy rate:

$$1 + i_1 = \frac{1}{\beta}(1+\pi_1)^{\gamma_\pi} \tag{26}$$

The system of 20 equations (7)–(26) is solved for 20 unknowns: c_1, c_2, h_1, h_2, m_1, m_2, y_1, y_2, w_1, w_2, e_1, e_2, mc_1, mc_2, p_1^{flex}, p_1^{fix}, π_1, i_1, p_1^m, b_2, given exogenous x_1 and x_2. The solution is found by (global) numerical methods using function `fsolve` in MATLAB.

A.3 Model parameter calibration

Parameter	Symbol	Value
Time discount coefficient	β	0.95
The coefficient of relative risk aversion	σ	1
The cross-elasticity of substitution between differentiated goods	ϵ	6
The inverse of the Frisch elasticity of labor supply	ϕ	1
The share of imports in production	α	0.3
The cross-elasticity of substitution between the imported good and labor in production	θ	0.8
The fraction of sellers with rigid prices in $t = 1$	ξ	0.5
Export revenues in $t = 1$	x_1	1, 1.5
Export revenues in $t = 2$	x_2	1.5
The international interest rate	i^*	$1/\beta - 1$
The elasticity of monetary policy response to inflation	γ_π	1.5
The tightness of the restriction on foreign borrowing	κ	$[0; 2]$
The tightness of the restriction on imports	χ	$[0; 0.4]$

B Figures

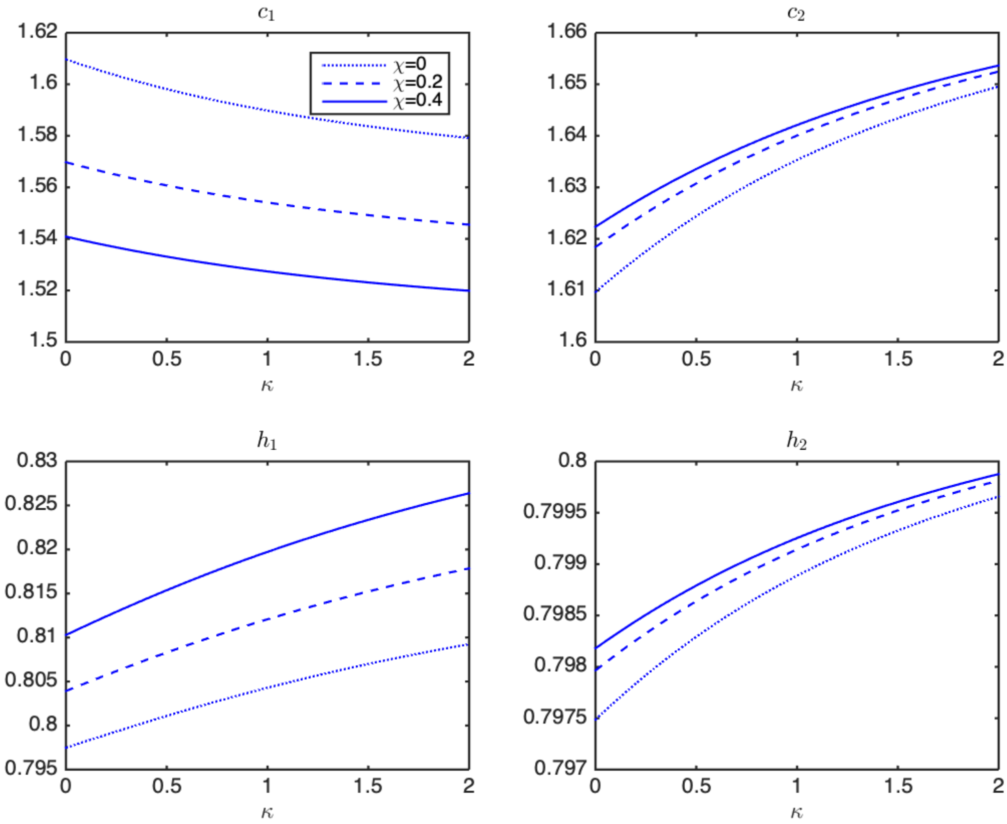

Figure 1: Equilibrium c_1, c_2, h_1, and h_2 given $x_1 = 1$ and $\chi \in \{0, 0.2, 0.4\}$ depending on κ.

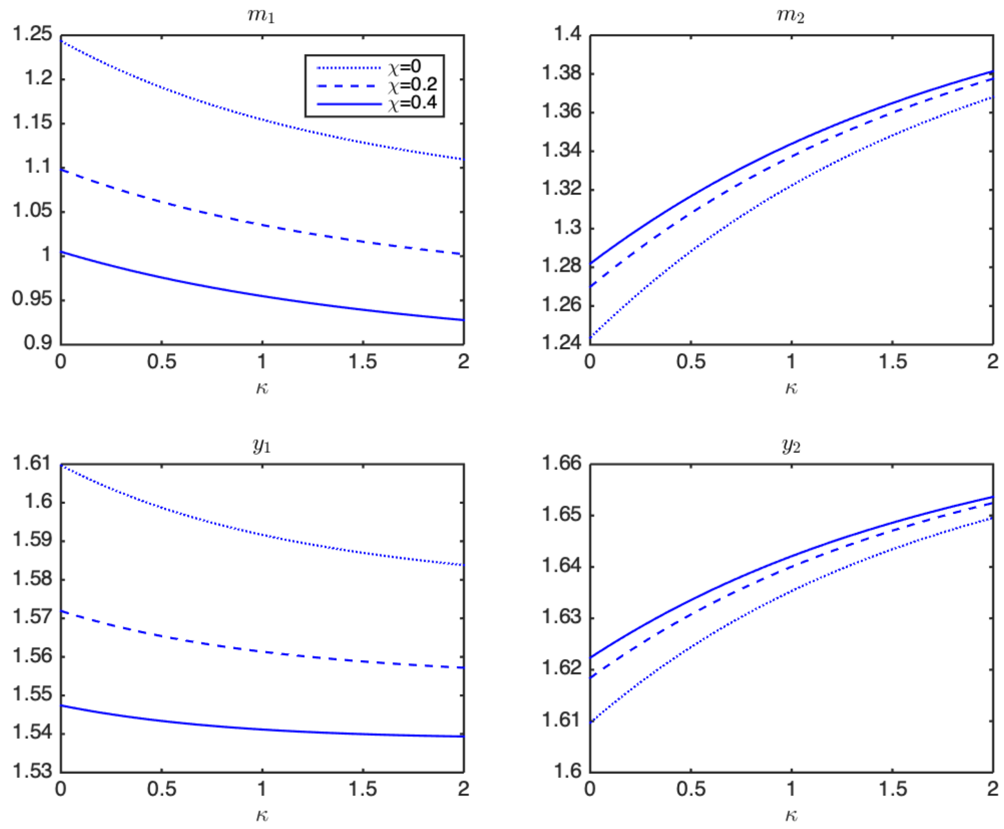

Figure 2: Equilibrium m_1, m_2, y_1, and y_2 given $x_1 = 1$ and $\chi \in \{0, 0.2, 0.4\}$ depending on κ.

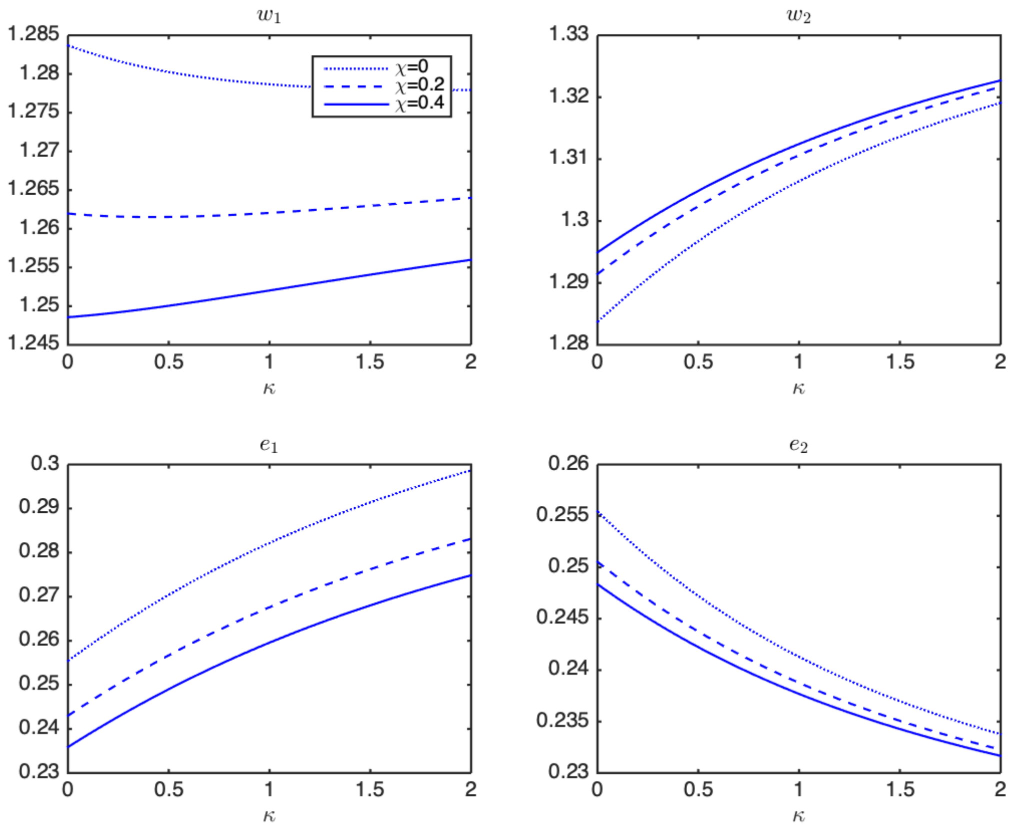

Figure 3: Equilibrium w_1, w_2, e_1, and e_2 given $x_1 = 1$ and $\chi \in \{0, 0.2, 0.4\}$ depending on κ.

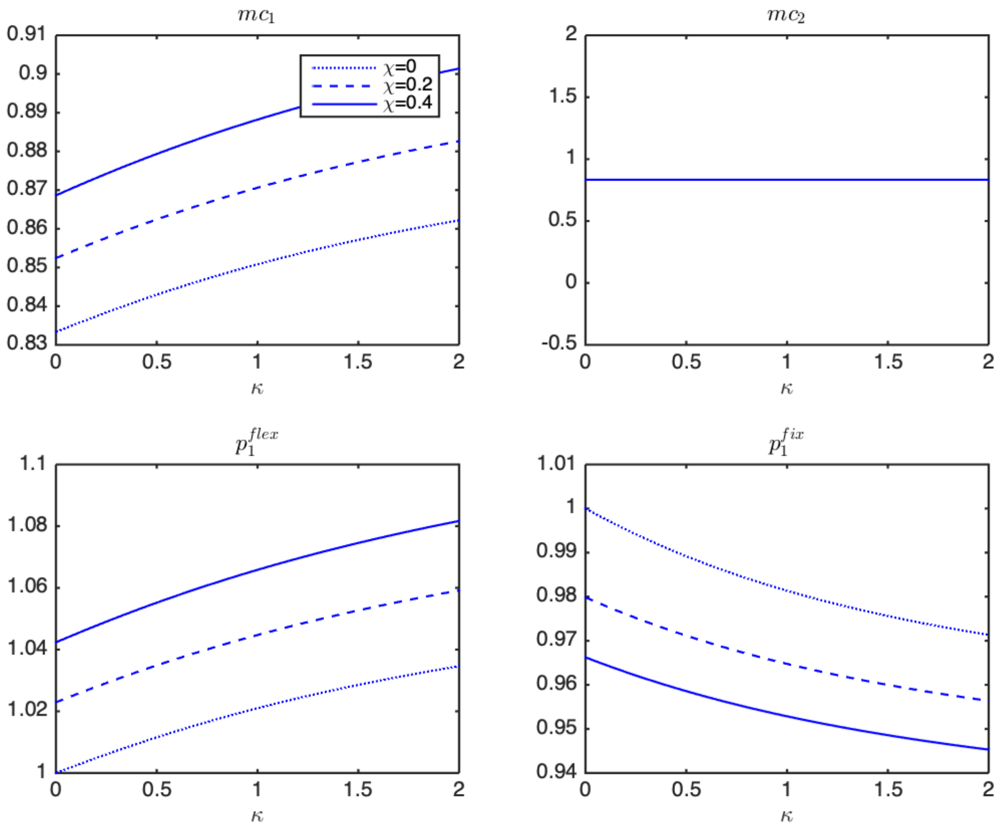

Figure 4: Equilibrium mc_1, mc_2, p_1^{flex}, and p_1^{fix} given $x_1 = 1$ and $\chi \in \{0, 0.2, 0.4\}$ depending on κ.

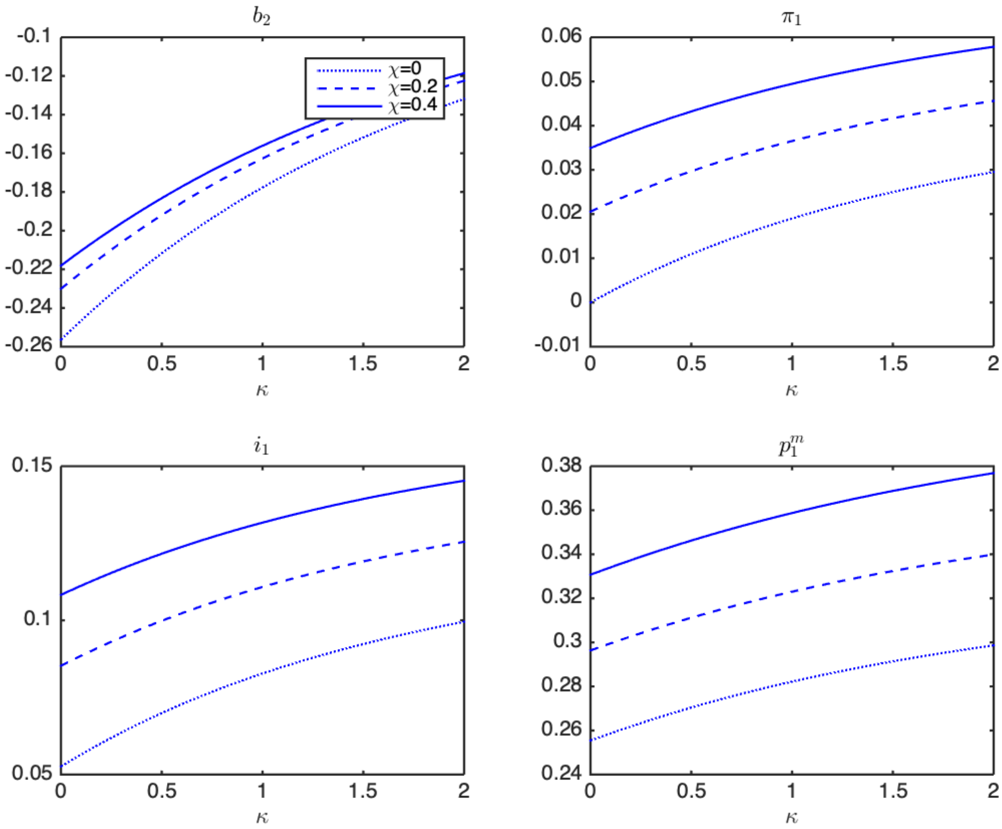

Figure 5: Equilibrium b_2, π_1, i_1, and p_1^m given $x_1 = 1$ and $\chi \in \{0, 0.2, 0.4\}$ depending on κ.

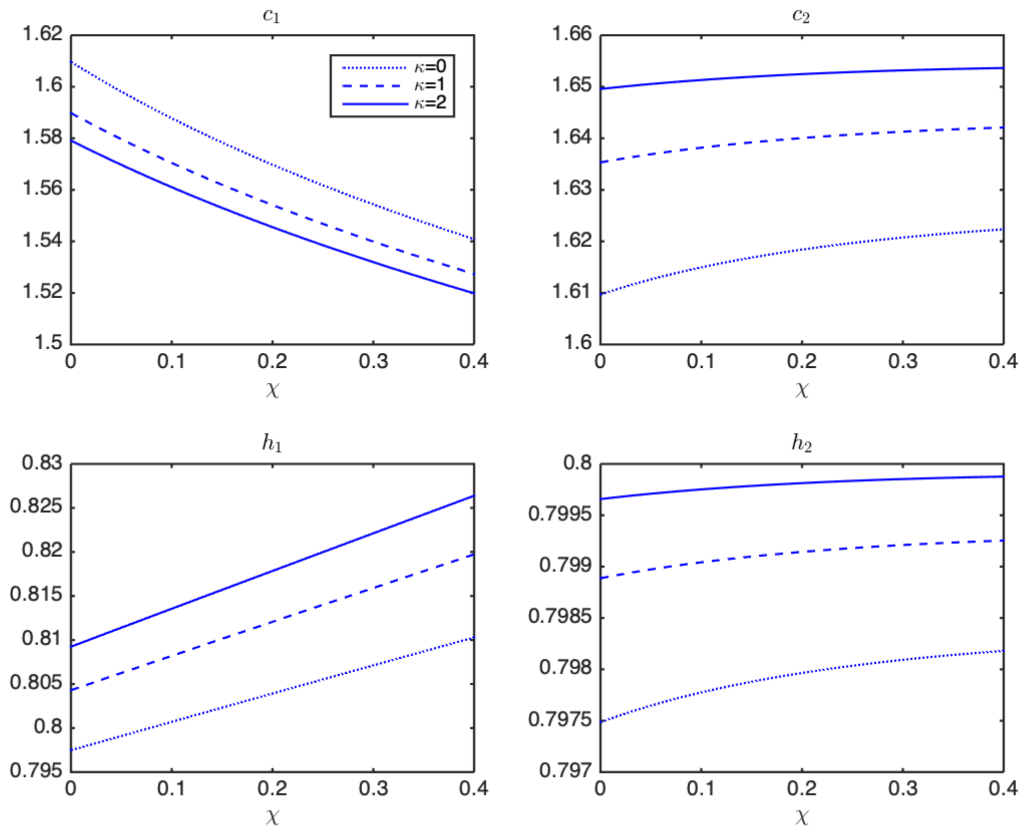

Figure 6: Equilibrium c_1, c_2, h_1, and h_2 given $x_1 = 1$ and $\kappa \in \{0, 1, 2\}$ depending on χ.

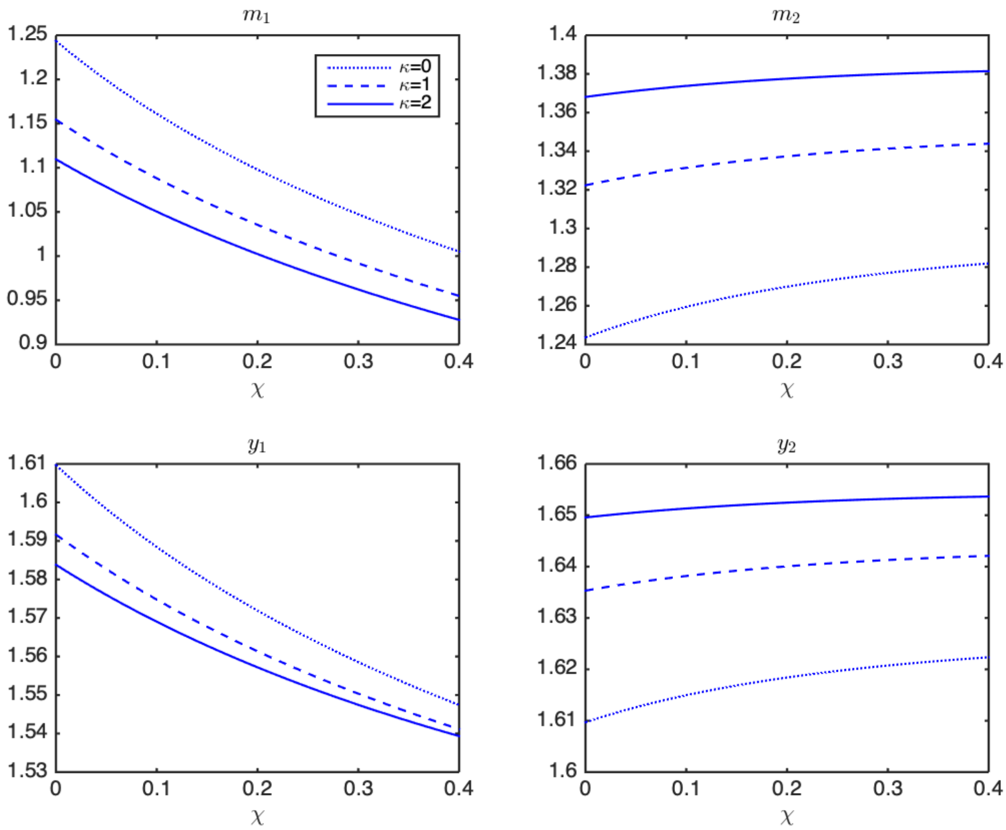

Figure 7: Equilibrium m_1, m_2, y_1, and y_2 given $x_1 = 1$ and $\kappa \in \{0, 1, 2\}$ depending on χ.

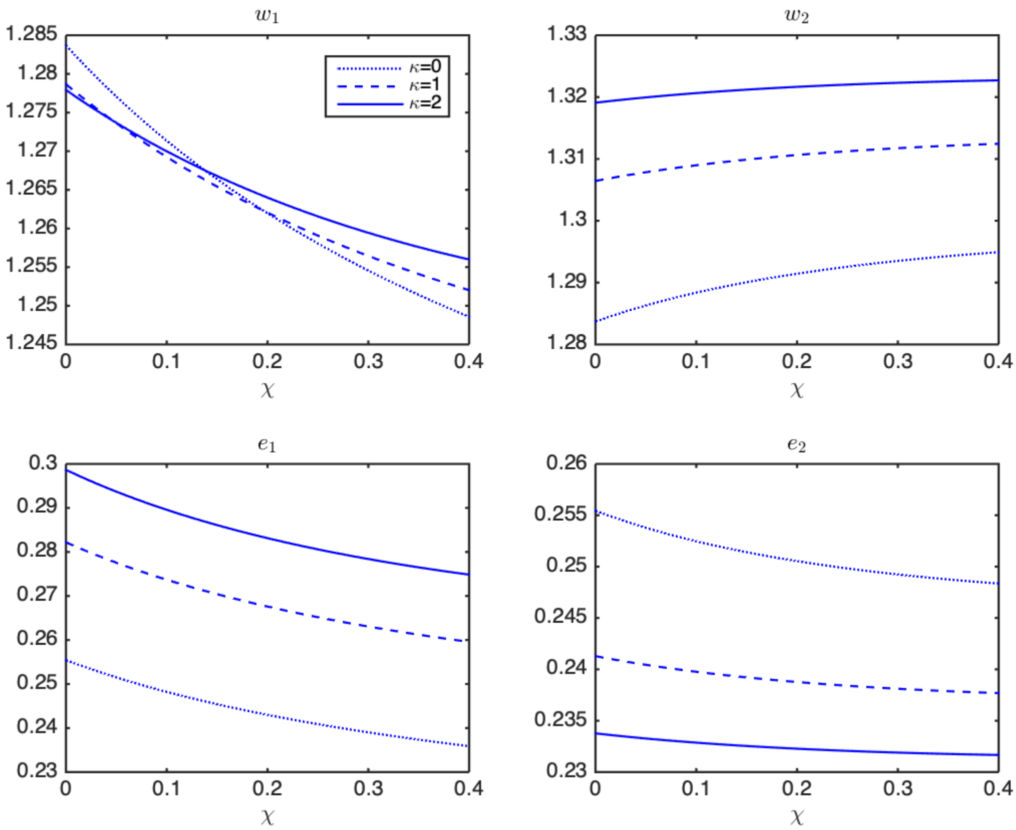

Figure 8: Equilibrium w_1, w_2, e_1, and e_2 given $x_1 = 1$ and $\kappa \in \{0, 1, 2\}$ depending on χ.

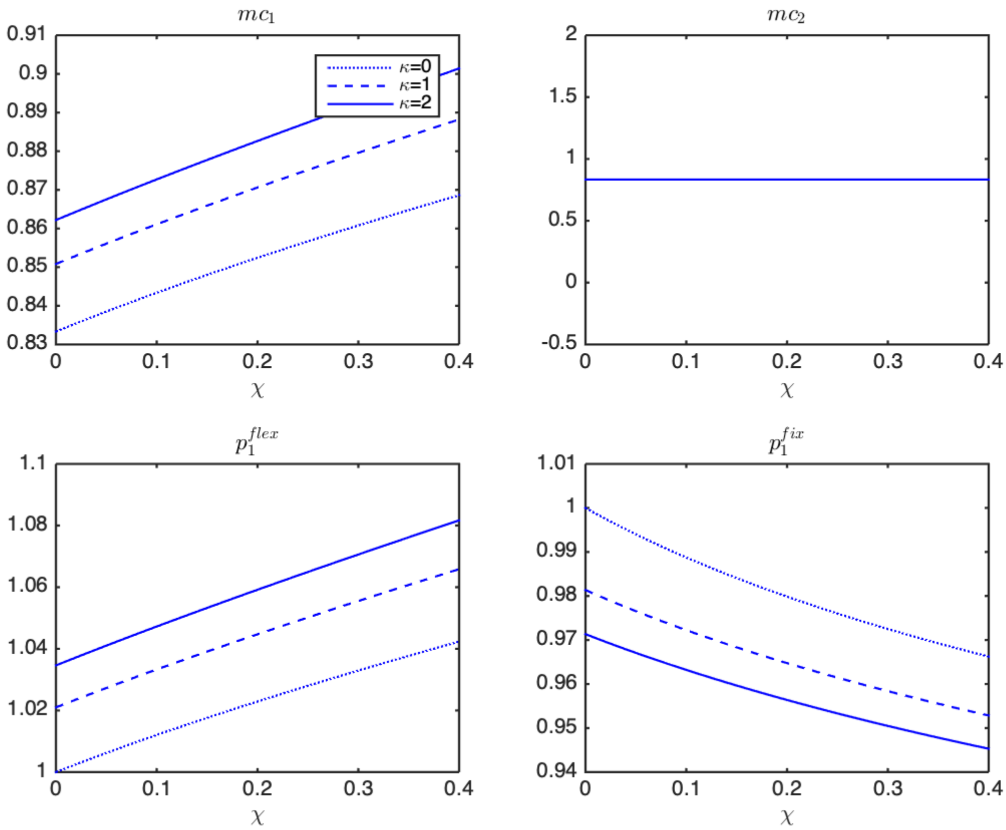

Figure 9: Equilibrium mc_1, mc_2, p_1^{flex}, and p_1^{fix} given $x_1 = 1$ and $\kappa \in \{0, 1, 2\}$ depending on χ.

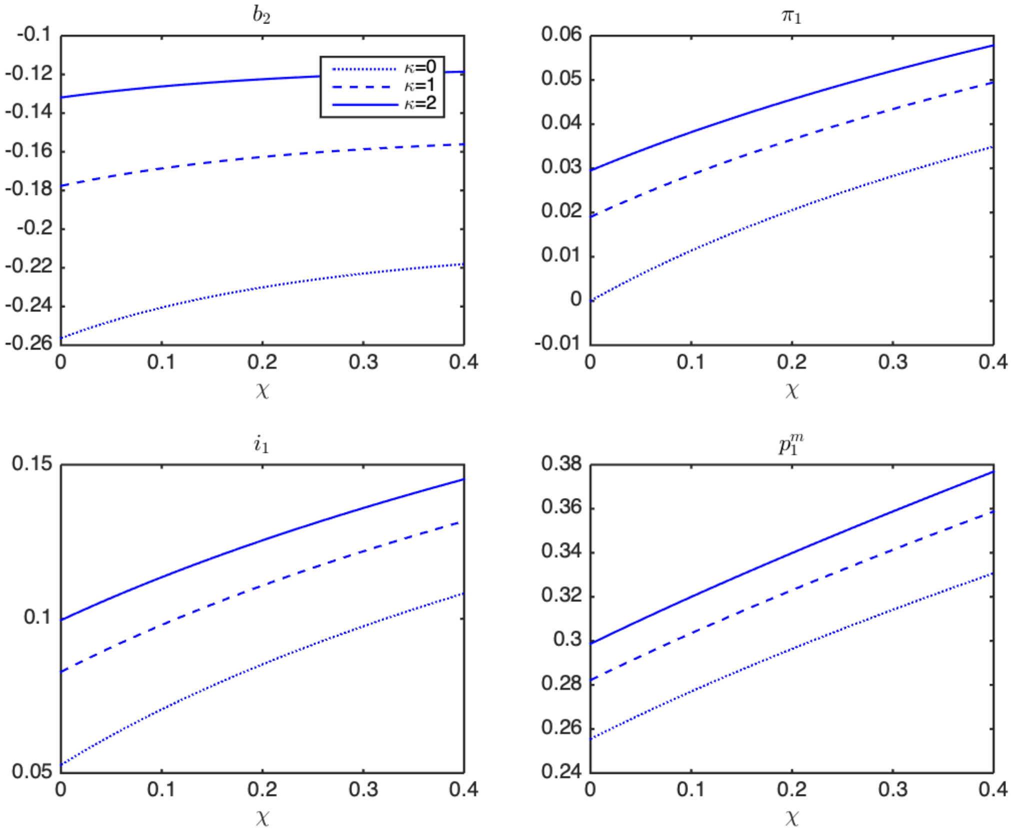

Figure 10: Equilibrium b_2, π_1, i_1 and p_1^m given $x_1 = 1$ and $\kappa \in \{0, 1, 2\}$ depending on χ.