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The Effectiveness of Asset Purchases in Small Open Economies

Eliezer Borenstein and Alex Ilek

Abstract

We examine the potential effectiveness of asset purchases (AP) in small open economies. To that end we extend the model of Gertler and Karadi (2011) to a small open economy, in which households and firms can borrow and lend in the global. financial market. Our results confirm a previous finding of the literature: In a small open economy, the response of the main variables to AP is weaker than in a closed economy. However, this weaker response does not necessarily imply a weaker benefit of AP: We show that even in a small open economy AP can improve welfare, and that the improvement could potentially be larger than in a closed economy. The reason is that conducting AP allows the economy to restore a more efficient financing structure, in the sense that it reduces intermediation costs paid to foreign lenders.

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Keywords: small-open economy, unconventional monetary policy, financial fric-tions, asset purchases, welfare. Bank of Israel. E-mail address: eliezer.borenstein@boi.org.il, alexei.ilek@boi.org.il;

אפקטיביות של רכישות נכסים במשק קטן ופתוח

אליעזר בורנשטיין ואלכס אילק

תמצית

אנו בוחנים את האפקטיביות הפוטנציאלית של רכישות נכסים במשק קטן ופתוח. לשם כך, אנו מרחיבים את המודל של Gertler and Karadi (2011) למשק קטן ופתוח שבו משקי הבית והפירמות יכולים ללוות ולהלוות בשוק ההון הבינלאומי. התוצאות שלנו מאששות ממצא קודם של הספרות: במשק קטן ופתוח, התגובה של המשתנים העיקריים לרכישות נכסים חלשה ביחס לזו שבמשק סגור. עם זאת, התגובה החלשה יותר אין בהכרח פירושה שהתועלת מרכישת נכסים במשקים קטנים ופתוחים נמוכה יותר: למעשה, אנו מראים כי התועלת במשקים קטנים ופתוחים עשויה להיות גדולה יותר, על אף התגובה החלשה של המשתנים העיקריים. מקור התועלת במשקים קטנים ופתוחים הוא בהשפעה שיש לרכישות הנכסים על מבנה המימון במשק: בכך שהבנק המרכזי רוכש נכסים הוא מסייע למשק, בתנאים מסוימים, לעבור למבנה מימון יעיל יותר במובן זה שהוא מקטין את הצורך בהסתמכות על תיווך פיננסי זר, ובכך חוסך למשק בעלויות התיווך הפיננסי.

1 Introduction

In the wake of the Global Financial Crisis, many central banks conducted an aggressive monetary easing policy, including reducing interest rates to historically low levels and conducting unconventional monetary policy in the form of large-scale asset purchases. Empirical and simulations-based studies found that asset purchases (henceforth, AP) conducted in the main economies (US, eurozone and Japan) reduced long-term yields and enhanced real activity (for example, Dell'Ariccia et al. (2018), Kozicki et al. (2011), Chen et al. (2012), Chung et al. (2012), and Chung et al. (2011)). On the theoretical side, Gertler and Karadi (2011) built a closed-economy model that provides a theoretical basis for the effectiveness of AP: When a financial friction inhibits the flow of funds in the economy, conducting an AP program effectively bypasses the friction and can thus improve welfare.

Only a few papers have examined the effectiveness of AP in small open economies (henceforth, SOE). The papers that have examined this issue concluded theoretically, through the use of models, that in SOE the impact of AP on financial variables (e.g. yields) and macroeconomic variables (e.g. inflation and output) should be weaker than in the large economies[1] (see Pietrzak (2016) and Kabaca (2016)). The limited ability of policymakers in SOE to influence domestic yields stems from the high dependence of the domestic interest rates on the global interest rates, which are exogenous (see de los Rios and Shamloo (2017), and Kulish and Rees (2011)).[2]

Two features of the existing literature seem to deserve a re-examination. First, the analysis of AP effectiveness in the literature focuses mainly on inflation, yields and out-

[1] We sometimes use the term "large economies" and sometimes the term "closed economies", which obviously have different meanings. In reality, the economies we refer to as "closed" are not closed in the sense that they cannot trade with the world, but rather they are closed in the sense that the dominant economic forces in those countries are domestic factors, as opposed to global factors.

[2] The empirical evidence on this issue seems scarce. Gambacorta et al. (2014) compare the macroeconomic effects of unconventional monetary policy in eight countries, some of which are SOE, and do not find major differences between the countries. Weale and Wieladek (2016) examined the macroeconomic effects of an AP shock in the UK, which can be considered an SOE, and found a smaller response than in the US.

put, and abstracts from welfare implications, which should be the ultimate goal of policy. Second, Pietrzak (2016) and Kabaca (2016), and in general the rest of the theoretical SOE literature as well, assume that households have access to foreign capital markets but firms do not (see for example Schmitt-Grohé and Uribe (2003), Adolfson et al. (2007), and Adolfson et al. (2008)). This assumption seems unrealistic, as in most countries firms have a significant share of foreign debt (see for example Anderson et al. (2003)). While in a frictionless model it does not matter which sector has access to the foreign capital market, we find that in the presence of a financial friction, this distinction does matter, as different openness structures entail different responses of the economy to shocks.

To address these two issues, we extend the Gertler and Karadi (2011) model to a SOE. The open economy is open to trade in goods and services with the world market and is also open financially to both households and firms. By assuming that trading in financial assets is potentially costly, we can compare a wide array of openness structures. For example, we consider the cases where access to foreign financial market exists only for households but not for firms and vice-versa. In order to assess the welfare effect of AP, we measure welfare directly from the household's utility function (in line with Faia and Monacelli (2007), and Gertler and Karadi (2011)).

Our main finding is that, in general, the response of most variables (yields, output, inflation, etc.) to asset purchases is weaker than in a closed economy. This result corroborates the conclusions of the aforementioned literature. However, importantly, this weaker response does not necessarily imply a weaker benefit of AP. The reason for the welfare improvement can be summarized for the case of a fully open economy as follows: AP allow firms to obtain funding from domestic households (via the central bank), instead of having to rely on foreign lenders. Whenever the cost of domestic finance is lower than the cost of foreign finance, AP will result in a "financial switch", in which firms increase borrowing from domestic households and reduce the amount borrowed abroad. Since domestic financing is cheaper, this will result in a decrease in the amount of resources that the economy

has to spend on intermediating funds, and hence in an increase in welfare. Another point that our analysis highlights, is that in open economies, changes in spreads might be uninformative regarding the magnitude of the ongoing financial crisis or regarding the degree of success of the AP policy. Thus, it may instead be more useful for policymakers to directly monitor changes in the net worth of financial intermediaries and the flows of foreign assets and liabilities of domestic agents.

The paper is organized as follows. Section 2 presents the model. Section 3 describes the calibration of the parameters in the model. Section 4 analyzes how the economy reacts to a crisis under various forms of financial openness. Section 5 investigates the welfare implications of AP. Section 6 concludes.

2 The model

The model for a SOE consists of two blocks, and its structure is presented in Figure 1. The first block contains the domestic economy: households, banks, intermediate goods producers, capital production firms, retailers, exporting and importing firms, central bank, and government. The second block contains the global economy ("world"), which has a parsimonious specification. Now we will describe the model in detail.

2.1 Households

The household's utility kernel is:

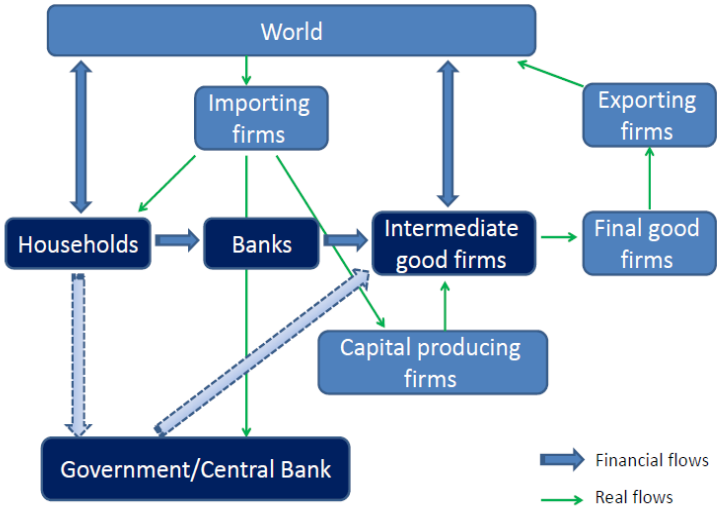
$$u_t(C_t, L_t) = \log(C_t - hC_{t-1}) - \chi \frac{L_t^{1+\omega}}{1+\omega}, \tag{1}$$

where C_t denotes consumption and L_t denotes labor effort. The household's budget constraint is:

$$C_t + B_t + rer_t B_t^* + \Phi(B_t^*) + T_t = W_t L_t + R_{t-1} B_{t-1} + R_{t-1}^* rer_t B_{t-1}^* + \Sigma_t \tag{2}$$

where $rer_t = \frac{\xi_t P_t^*}{P_t}$ is the real exchange rate, ξ_t is the nominal exchange rate (the price of world currency in terms of the domestic currency), P_t is the CPI in the domestic economy,

Figure 1: **The Model Structure**



P_t^* is the CPI abroad, B_t is the amount of inflation-indexed domestic bonds paying (gross) real interest rate R_t (government bonds and bank deposits are perfect substitutes), B_t^* is the amount of inflation-indexed foreign bonds paying (gross) real interest rate R_t^*; $\Phi(B_t^*)$ is the portfolio adjustment cost associated with holding foreign bonds, W_t is the real wage, T_t is the (real) lump-sum taxes, and Σ_t is real dividend income. Households seek to maximize discounted expected utility $E_t\sum_{i=0}^{\infty}\beta^i u_{t+i}$ subject to the budget constraint in Eq. (2). The first order conditions (henceforth F.O.C.) of the households are summarized below.

The F.O.C. with respect to domestic bonds B :

$$1 = E_t(sdf_{t,t+1}R_t) \tag{3}$$

where $sdf_{t,t+1} = \beta\frac{\Lambda_{t+1}}{\Lambda_t}$is a stochastic discount factor of the domestic households. Λ_t is given by:

$$\Lambda_t = \frac{1}{C_t - hC_{t-1}} - h\beta E_t\frac{1}{C_{t+1} - hC_t}$$

The F.O.C. with respect to foreign bonds B^*:

$$\Phi'(B_t^*) = E_t\left[sdf_{t,t+1}R_t^* rer_{t+1}\right] - rer_t \tag{4}$$

Combining Eq. (4) with Eq. (3) yields a UIP condition in terms of real exchange rate. We follow Schmitt-Grohé and Uribe (2003) and Uribe and Yue (2006) by assuming portfolio adjustment costs associated with holding foreign bonds:

$$\Phi(B_t^*) = \frac{\varphi_{B^*}}{2}\left(B_t^* - B^*\right)^2 \tag{5}$$

where B^* is the steady state value of foreign bonds (like here, wherever we want to denote a steady-state value for a variable, we omit the time subindex t).

The F.O.C. with respect to labor L:

$$\chi L_t^{\omega} = \Lambda_t W_t \tag{6}$$

The household's consumption basket consists of domestically-produced consumption goods $\left(C_t^H\right)$ and imported consumption goods $\left(C_t^F\right)$:

$$C_t = \left[(1-o_C)^{\frac{1}{\zeta_C}}\left(C_t^H\right)^{\frac{\zeta_C-1}{\zeta_C}} + o_C^{\frac{1}{\zeta_C}}\left(C_t^F\right)^{\frac{\zeta_C-1}{\zeta_C}}\right]^{\frac{\zeta_C}{\zeta_C-1}} \tag{7}$$

where o_C is a weight of imported goods in the consumption basket and ζ_C is the elasticity of substitution between domestic and imported consumption goods.

The demand for domestically-produced consumption goods and for imported consumption goods is presented by the two following conditions:

$$C_t^H = (1-o_C)\left(p_t^H\right)^{-\zeta_C} C_t \tag{8}$$

$$C_t^F = o_C\left(rer_t\right)^{-\zeta_C} C_t \tag{9}$$

where $p_t^H = \frac{P_t^H}{P_t}$ is a relative domestic price, $p_t^F = \frac{P_t^F}{P_t} = rer_t$ is a relative foreign price (in terms of domestic currency), which is a real exchange rate under assumption of purchasing power parity, $P_t^F = \xi_t P_t^*$ (P_t^H and P_t^F are prices of domestically-produced goods and imported goods, respectively).

2.2 Banks

The banking sector in our setting is the same as in Gertler and Karadi (2011). The following is a summarization of the main equations.

The balance sheet of bank j at the end of period t is (in real terms):

$$Q_t^s S_{jt}^P = B_{jt} + N_{jt} \tag{10}$$

where S_{jt}^P denotes the number of claims (stocks) purchased by bank j and Q_t^s denotes the (real) price of each claim, B_{jt} denotes the total deposits in this bank and N_{jt} denotes its net worth. The objective of the banker j is to maximize the expected terminal wealth, $V_{j,t}$:

$$V_{j,t} \equiv \max E_t \sum_{i=0}^{\infty} (1-\theta)\, \theta^i sdf_{t,t+i+1} N_{j,t+i+1} \tag{11}$$

where θ denotes the probability that a banker would keep operating, and $1-\theta$ is the complementary probability—that the banker exits the market and transfers his retained capital to the household. The law of motion of bank j's net worth is given by:

$$N_{jt+1} = (R_{t+1}^S - R_t) Q_t^s S_{jt}^P + R_t N_{jt} \tag{12}$$

where R_{t+1}^S is the ex-ante yield on the claims realized at period $t+1$ and R_t is the real risk-free interest rate known in period t. As long as the discounted risk-adjusted premium in any period, $E_t\left[sdf_{t,t+1+i}\left\{((R_{t+1+i}^S - R_{t+i})\right\}\right]$, is positive, the bank will want to expand its assets by borrowing from households. To motivate a limit on its ability to do so, Gertler and Karadi (2011) introduce a moral hazard/costly enforcement problem. At the beginning of each period the banker can divert a fraction λ of its funds and transfer it to his family. In such a case the depositors will force the banker into bankruptcy and recover the rest, $1-\lambda$ of the assets. Thus, the depositors will be willing to supply deposits to the bank as long as the value of the bank is larger than the gain from diverting a fraction of assets, that is:

$$V_{j,t} \geqslant \lambda Q_t^s S_{jt}^P \tag{13}$$

The value function in Eq. 11 can be represented as:

$$V_{j,t} \equiv \nu_t Q_t^s S_{jt}^P + \eta_t N_{jt} \tag{14}$$

where $\nu_t = E_t \left[sdf_{t,t+1} \left\{ (1-\theta)(R_{t+1}^S - R_t) + \theta \chi_{t,t+1} \nu_{t+1} \right\} \right]$, $\chi_{t,t+1} = \frac{Q_{t+1}^s S_{jt+1}^P}{Q_t^s S_{jt}^P}$,

$\eta_t = E_t \left\{ (1-\theta) + \theta sdf_{t,t+1} \zeta_{t,t+1} \eta_{t+1} \right\}$, and $\zeta_{t,t+1} = \frac{N_{t+1}}{N_t}$.

Assuming that Eq. (13) is binding, its combination with Eq. (14) yields the required leverage ratio for bank j, $\phi_t = \frac{Q_t^s S_{jt}^P}{N_{jt}} = \frac{\eta_t}{\lambda - \nu_t}$. Since all banks are symmetric, the aggregation over all banks leads to the following condition:

$$\phi_t \equiv \frac{\eta_t}{\lambda - \nu_t} = \frac{Q_t^s S_t^P}{N_t} \tag{15}$$

Under the constraint in Eq. (15) we can rewrite Eq. (12) as (taking one period backward): $N_t = \left[(R_t^S - R_{t-1})\phi_{t-1} + R_{t-1} \right] N_{t-1}$,where R_t^S is a realized rate at period t. The aggregate net worth is the sum of the net worth of the new bankers and of the existing bankers: $N_t^T = N_t^n + N_t^e$, where the net worth of the existing bankers is: $N_t^e = \theta N_{t-1} \left\{ R_t^S - R_{t-1})\phi_{t-1} + R_{t-1} \right\}$.

The new bankers receive start-up funds from the households. As in Gertler and Karadi (2011), the amount of the funds is a fraction $\frac{\varpi}{1-\theta}$ of the value of the exiting bankers, so that in the aggregate, $N_t^n = \varpi Q_t^s S_{t-1}^P$. Summing up N_t^n and N_t^e, we derive the aggregate net-worth:

$$N_t = \theta N_{t-1} \left\{ R_t^S - R_{t-1})\phi_{t-1} + R_{t-1} \right\} + \varpi Q_t^s S_{t-1}^P \tag{16}$$

2.3 Intermediate good firms

There is a continuum of firms in the economy, each firm indexed by $j \in [0,1]$. Each firm j produces intermediate good $Y_t(j)$ using labor and capital. Its production function is:

$$Y_t(j) = A_t(\varepsilon_t^k U_t K_{t-1}(j))^\alpha (L_t(j))^{1-\alpha} \tag{17}$$

where ε_t^k is a shock to quality of capital, A_t is a technological shock, and U_t is the utilization rate of capital. The capital depreciation is a function of utilization rate[3]: $\delta(U_t) = \delta + k_1(U_t -$

[3]The specification of the utilization rate function is similar to Gertler and Karadi (2011).

$1) + 0.5k_2(U_t - 1)^2$, where $U_{ss} = 1$. Therefore, $\delta(U_{ss} = 1) = \delta$ and $\delta'(U_t) = k_1 + k_2(U_t - 1)$. Each firm finances new capital acquisition by issuing stocks (claims) to the domestic banks. We extend Gertler and Karadi (2011) by allowing firms to also finance capital acquisition through foreign loans at interest rate R_t^{*D}, subject to adjustment costs:

$$\Phi(D_t^*) = \frac{\varphi_{D^*}}{2}\left(D_t^* - D^*\right)^2 \tag{18}$$

We assume that the interest rate required on foreign loans is higher than the interest rate paid on foreign bonds, that is $R_t^{*D} > R_t^*$. As we will see in Sections 5.1 and 5.2, this assumption is critical for the effectiveness of asset purchases in the SOE.

The balance sheet of each firm j is:

$$Q_t^s S_t(j) + rer_t D_t^*(j) = Q_t^k K_t(j) \tag{19}$$

where Q_t^s and Q_t^k are real prices of stocks and capital, respectively, and $rer_t D_t^*$ is the real value of loans from abroad.

The firm's profit in real terms is (since all firms are identical we omit index j):

$$\begin{aligned}\Pi_t \;=\; & \frac{P_t^m}{P_t} Y_t + Q_t^k(1 - \delta(U_{t-1}))\varepsilon_t^k K_{t-1} - W_t L_t - R_t^S Q_{t-1}^s S_{t-1} \\ & - R_{t-1}^{*D} rer_t D_{t-1}^* - \Phi(D_{t-1}^*)\end{aligned} \tag{20}$$

Each firm seeks to maximize its expected profits $E_t \sum_{i=0}^{\infty} sdf_{t,t+i}\Pi_{t+i}$ and decides about optimal labor, capital, capital utilization, and amount of loans borrowed from abroad. The first term is income from sales (the price of intermediate good P_t^m is the same across all firms), the second term is income from reselling the capital; the third term is a wage bill. The next two terms are dividends on issued stocks (to the domestic banks) and repayment of foreign loans, respectively. The last term is the cost associated with raising loans from abroad (we assume that in steady state $D^* = 0$).The F.O.C. are summarized below.

The F.O.C. with respect to labor:

$$\frac{P_t^m}{P_t}(1 - \alpha)\frac{Y_t}{L_t} = W_t \tag{21}$$

Eq. (21) equalizes real wage to the marginal product of capital.

The F.O.C. with respect to capital:

$$E_t\left[sdf_{t,t+1}\left(\frac{\alpha\frac{P^m_{t+1}}{P_{t+1}}\frac{Y_{t+1}}{K_t}+Q^k_{t+1}(1-\delta)\varepsilon^k_{t+1}}{Q^k_t}-R^S_{t+1}\right)\right]=0 \tag{22}$$

Eq. (22) equalizes the expected return on capital (first expression in the brackets) to the expected return on stocks (marginal cost of finance, the second expression in brackets). The F.O.C. with respect to the amount of foreign loans:

$$E_t\left[sdf_{t,t+1}(R^S_{t+1}rer_t-R^{*D}_t rer_{t+1})\right]=\Phi'(D^*_t) \tag{23}$$

Eq. (23) is the UIP condition for firms, which is analogous to the UIP condition of the households shown in Eq. (4). Eq. (23) complements the optimality condition in Eq. (22), because it equalizes the cost of finance in the domestic economy (stocks) to the cost of finance from abroad (foreign loans). That is, the real exchange rate and cost of foreign borrowing are adjusted to make firms indifferent between domestic finance and foreign finance.

Finally, the F.O.C. with respect to capital utilization is:

$$\frac{\alpha\frac{P^m_t}{P_t}Y_t}{U_t}=E_t\left(sdf_{t,t+1}Q^k_{t+1}\delta'(U_t)\varepsilon^k_{t+1}K_t\right) \tag{24}$$

Eq. (24) equalizes the marginal benefit of utilization (increase in output) to the marginal cost of the utilization (lower income from reselling the "over-depreciated" capital in the next period).

2.4 Capital production firms

Producers of capital goods sell capital to the intermediate goods producers, purchase depreciated capital from them, and create new capital. The investment aggregate is determined

by domestically produced investment goods and imported investment goods [4]:

$$I_t = \left[(1-o_C)^{\frac{1}{\eta_C}} \left(I_t^H\right)^{\frac{\eta_C-1}{\eta_C}} + o_C^{\frac{1}{\eta_C}} \left(I_t^F\right)^{\frac{\eta_C-1}{\eta_C}}\right]^{\frac{\eta_C}{\eta_C-1}}$$

The demand for domestic and imported investment goods is given by the two following equations:

$$I_t^H = (1-o_C)\cdot I_t \cdot \left(p_t^H\right)^{-\eta_c}$$

$$I_t^F = o_C \cdot I_t \cdot (rer_t)^{-\eta_C}$$

The profit (in real terms of CPI) of each capital production firm in period t is:

$$\Pi_t^I = Q_t^k K_t - Q_t^k(1-\delta(U_{t-1}))\varepsilon_t^k K_{t-1} - I_t - \Gamma(\frac{I_t}{I_{t-1}})I_t$$

where $\Gamma(\frac{I_t}{I_{t-1}})$ is the adjustment costs of creating new capital, $\Gamma(\frac{I_t}{I_{t-1}}) = \frac{\gamma_I}{2}(\frac{I_t}{I_{t-1}}-1)^2$.[5]

The evolution of capital is:

$$K_t = (1-\delta(U_{t-1}))\varepsilon_t^k K_{t-1} + I_t \tag{25}$$

The firm chooses the optimal I_t to optimize its expected profits $E_t\sum_{i=0}^{\infty} sdf_{t,t+i}\Pi_{t+i}^I$.The optimality condition implies the relationship between the investment and the price of capital:

$$Q_t^k = 1 + \frac{\gamma_I}{2}(\frac{I_t}{I_{t-1}}-1)^2 + \gamma_I(\frac{I_t}{I_{t-1}}-1)\frac{I_t}{I_{t-1}} - \gamma_I E_t\left(sdf_{t,t+1}(\frac{I_{t+1}}{I_t}-1)\frac{I_{t+1}^2}{I_t^2}\right)$$

2.5 Retailers (final good firms)

Retailers repackage intermediate output. It takes one unit of intermediate output to make a unit of retail output. Final domestic good Y_t^H is a composite of a continuum of mass

[4] The specification here relies on the simplifying assumption that the share of imported investment goods in total investment is the same as a share of imported consumption goods in total private consumption, namely $o_I = o_C$. The equality assumption also holds for the elasticity of substitution between domestic and foreign investment goods $\eta_I = \eta_C$. This implies that the price of investment goods is the same as the price of consumption goods, namely $P_t^I = P_t = \left[(1-o_C)\cdot\left(P_t^H\right)^{(1-\eta_C)} + o_C\cdot\left(P_t^F\right)^{(1-\eta_C)}\right]^{\frac{1}{1-\eta_C}}$

[5] This adjustment cost function is taken from Gertler and Karadi (2011).

unity of differentiated retail outputs:

$$Y_t^H = \left[\int_0^1 \left(Y_{ft}\right)^{\frac{\eta_H - 1}{\eta_H}} dj \right]^{\frac{\eta_H}{\eta_H - 1}} \tag{26}$$

where Y_{ft} is a good of retailer f and η_H is the elasticity of substitution between domestically produced differentiated goods. The demand for differentiated retail good f is given by:

$$Y_{ft} = \left(\frac{P_{ft}^H}{P_t^H} \right)^{-\eta_H} Y_t^H$$

where the price of domestic composite good P_t^H is given by:

$$P_t^H = \left[\int_0^1 \left(P_{ft}^H\right)^{1-\eta_H} dj \right]^{\frac{1}{1-\eta_H}} \tag{27}$$

The differentiated retail firms face a Calvo price rigidity. $1 - \theta_H$ is the probability that the price could be changed at period t. A firm which cannot change the price at period t is left with its price from the previous period indexed to past inflation (the degree of indexation to past inflation is denoted as $\gamma_H \in [0, 1]$). Since all firms that are allowed to change their price are identical, they choose the same price, which we denote by $\widetilde{P}_t^H$. The firms's objective is to choose an optimal $\widetilde{P}_t^H$to maximize the expected profits:

$$\max E_t \left[\sum_{j=0}^{\infty} \theta_H^j sdf_{t,t+j} \frac{\Pi_{t+j}}{P_{t+j}} \right]$$

where the firm's profit (in period $t + j$) is $\Pi_{t+j} = P_{f,t+j}^H Y_{ft+j} - P_{t+j}^m Y_{ft+j}$. $P_{f,t+j}^H = \widetilde{P}_t^H (\frac{P_{t+j-1}^H}{P_{t-1}^H})^{\gamma_H}$ is the price (in period $t + j$) of a firm that set its price $\widetilde{P}_t^H$at time t but it is subject to Calvo rigidity j periods after that. Combining he F.O.C. and the law of large numbers, we get that the evolution of the domestic price index is given by:

$$P_t^H = \left[\theta_H \left((\pi_{t-1}^H)^{\gamma_H} \ P_{t-1}^H \right)^{1-\eta_H} + (1 - \theta_H) \left(\widetilde{P}_t^H \right)^{1-\eta_H} \right]^{\frac{1}{1-\eta_H}} \tag{28}$$

2.6 Exporting and importing firms

There is a complete competitive market of exporting firms in the domestic economy, which buy the composite good Y_t^H at price P_t^H in the domestic market and sell it abroad at price $\frac{P_t^H}{\xi_t}$,where ξ_t is the nominal exchange rate. We assume that the domestic composite good exported abroad is used there for consumption by foreign households and is not a complete substitute for the composite good produced abroad. This assumption is critical to guarantee finite demand, neither zero nor infinite, by the foreign households for composite good produced in the domestic economy. Their demand is (the export of the SOE):

$$EXP_t = \left(\frac{\frac{P_t^H}{\xi_t}}{P_t^*} \right)^{-\zeta_C^*} Y_t^* \tag{29}$$

where ζ_C^* is the elasticity of substitution between goods imported from the SOE and goods produced abroad. The demand depends on the relative price $\frac{\frac{P_t^H}{\xi_t}}{P_t^*} = \frac{p_t^H}{rer_t}$ and on the foreign aggregate output Y_t^*.[6]

There is also an importing firm that buys the composite goods C_t^F, I_t^F and G_t^F abroad at price P_t^* and sells them in the domestic market at price P_t^F, where[7]:

$$P_t^F = \xi_t P_t^*$$

2.7 Net foreign asset position and trade balance

The trade balance in terms of foreign currency is:

$$TB_t^{\$} = \frac{P_t^H}{\xi_t} EXP_t - P_t^* IMP_t$$

where EXP_t is an amount of exports and IMP_t is an amount of imports, where $IMP_t = C_t^F + I_t^F + G_t^F$.

[6] A similar specification of demand function for export is commonly used in models for SOE (see for example, Kollmann (2001) and Smets and Wouters (2002)).

[7] We assume purchasing power parity. The assumption concerning determination of export and import prices guarantees zero profits for exporting and importing firms.

The trade balance (in real terms of domestic CPI) is:

$$TB_t = p_t^H EXP_t - rer_t IMP_t \tag{30}$$

The net foreign asset position of the economy is:

$$\frac{NFA_t}{P_t} \equiv rer_t(B_t^* - D_t^*) = rer_t(R_{t-1}^* B_{t-1}^* - R_{t-1}^{*D} D_{t-1}^*) + TB_t \tag{31}$$

The net foreign asset position of the economy is defined as the value of total foreign assets the economy holds net of the value of total liabilities to abroad. In our model (see (Eq. 31)), this is captured by the difference between foreign bonds held by the domestic households (B_t^*) and foreign loans to domestic firms (D_t^*). Each period, the net foreign asset position is determined by its value from the previous period plus an interest rate, plus the value of the trade balance in the current period (see Eq. (30)).

2.8 Government and Central Bank

The central bank acts according to a standard Taylor rule:

$$r_t^{CB} = r^{CB} + \vartheta_1 \pi_t + \vartheta_2 \tilde{y}_t^H \tag{32}$$

where r^{CB} is the steady-state level of the nominal interest rate and $\tilde{y}_t^H$ is the output gap, namely the deviation of actual output from its potential that would prevail under flexible prices. The relation between the nominal and real interest rates is given by the Fisher relation $1 + r_t^{CB} = E_t[R_t(1 + \pi_{t+1})]$.

We assume that government consumption is exogenous following a simple rule:

$$\log G_t = \log G + \varepsilon_t^G \tag{33}$$

where ε_t^G is a shock to government consumption.

Like consumption and investment, government consumption is also composed of domestically produced goods and imported goods[8]:

$$G_t = \left[(1-o_C)^{\frac{1}{\zeta_C}} \left(G_t^H\right)^{\frac{\zeta_C-1}{\zeta_C}} + o_C^{\frac{1}{\zeta_C}} \left(G_t^F\right)^{\frac{\zeta_C-1}{\zeta_C}} \right]^{\frac{\zeta_C}{\zeta_C-1}}$$

The demand for G_t^H and G_t^F is given by the two following equations:

$$G_t^H = (1-o_C)\left(p_t^H\right)^{-\zeta_C} G_t$$

$$G_t^F = o_C \left(rer_t\right)^{-\zeta_C} G_t$$

In addition to standard fiscal policy, we assume that in periods of crisis the government conducts an unconventional policy (see Section 4 for details). In particular, the government seeks to replace constrained private finance to the intermediate firms by purchasing assets from them of amount S_t^G (at required interest rate R_{t+1}^S), such that the total amount of claims S_t is, $S_t = S_t^G + S_t^p$. The asset purchases are financed by newly issued bonds B_t^G to households (at interest rate R). The proportion of assets held by the government as a share of total assets is denoted as Ψ_t,that is $S_t^G = \Psi_t S_t$. The government's consolidated budget constraint is:

$$G_t + \xi \Psi_t Q_t^s S_t = T_t + (R_t^S - R_{t-1})\Psi_{t-1} Q_{t-1}^s S_{t-1} \tag{34}$$

where $(R_t^S - R_{t-1})\Psi_{t-1} Q_{t-1}^s S_{t-1}$ is the profits from the AP and $\xi B_t^G = \xi \Psi_t Q_t^s S_t$ are efficiency costs that we assume away.

Finally, after combining all sectors of the economy, we obtain the resource constraint:

$$C_t + G_t + \xi \Psi_t Q_t^s S_t + I_t + \Gamma(\frac{I_t}{I_{t-1}})I_t + \frac{P_t^H}{P_t} EXP_t - rer_t IMP_t + \Phi(B_t^*) + \Phi(D_t^*) = p_t^H Y_t^H \tag{35}$$

[8] We make the same simplifying assumption concerning G_t as we made concerning I_t. That is, we assume that the share of imported government consumption goods (o_G) in total G_t is the same as the share of imported consumption goods in total private consumption, namely $o_G = o_C$. The equality holds also for the elasticity of substitution between domestic and foreign government consumption, $\eta_G = \eta_C$ which is the same as for consumption goods. These assumptions imply that the price of government consumption goods is equal to the consumption price, namely CPI:$P_t^G = P_t = \left[(1-o_C)\left(P_t^H\right)^{(1-\eta_C)} + o_C \left(P_t^F\right)^{(1-\eta_C)} \right]^{\frac{1}{1-\eta_C}}$.

2.9 The world economy

As our focus is the analysis of a domestically generated crisis, we assume a very simple structure of the world economy in which all the foreign variables are assumed to be fixed. Thus the world economy is summarized by the following four variables: π^*(foreign inflation), $\log Y^*$(foreign output), R^*(the interest rate for lenders abroad), and $Spread^*$ (the spread between the interest rate for borrowers and lenders abroad). The following defines the interest rate for borrowers abroad: $R_t^{*D} = R_t^* + spread_t^*$.

3 Calibration

Table 1 summarizes the calibration of the structural parameters for our model. The calibration is based on Gertler and Karadi (2011). The parameters that are not shared by both models, that is, the parameters that are relevant only for the open economy, were calibrated based on small open economy models in the literature. Imported consumption as a share of total consumption (o_C) was set to 0.3, similar to Adolfson et al. (2007). The elasticity of substitution between foreign-produced and exported domestic goods (ζ_C^*) was set to 6 due to our simplifying assumption that foreign and domestic agents have symmetric preferences with respect to their demand for imports.

Table 1 - Parameters

Households		
Discount rate	β	0.99
Habit formation parameter in consumption	h	0.815
Inverse Frisch elasticity of labor supply	ω	0.276
Relative utility weight of labor	χ	3.409
Steady state share of foreign consumption in total consumption	o_C	0.30
Elasticity of substitution between domestic and imported goods	ζ_C	6.0
Degree of financial openness of domestic households to abroad	φ_{B^*}	Varying
Financial Intermediaries		
Fraction of capital that can be diverted by bankers	λ	0.381
Proportional transfer to the entering bankers	ϖ	0.002
Survival rate of the bankers	θ	0.972
Steady state spread between interest rate for borrowers and lenders	$spread^*$	0.0025
Intermediate good firms		
Capital share in the production function	α	0.33
Steady state capital utilization rate	U	1
Steady state depreciation rate	δ	0.025
First parameter in the utilization function	k_1	0.04
Second parameter in the utilization function	k_2	0.27
Degree of financial openness of domestic firms to abroad	φ_{D^*}	Varying
Capital Producing Firms		
Inverse elasticity of net investment to the price of capital	γ_I	1.728
Retail firms		
El. of substitution between differentiated domestically produced goods	η_H	4.167
Probability of keeping prices fixed	θ_H	0.779
Measure of price indexation	γ_H	0.241
Government and central bank		
Inflation coefficient in the Taylor rule	ϑ_1	1.50
Output gap coefficient in the Taylor rule	ϑ_2	0.50/4
Steady state share of government expenditures in GDP	$\frac{G}{Y}$	0.20
Steady state proportion of government purchases	Ψ	0
Efficiency cost parameter of government purchases	ξ	0
Exporting firms		
El. of substitution between foreign produced and exported domestic goods	ζ_C^*	6.0

4 Crisis experiment

In this section we examine the economy's evolution in a crisis under different forms of financial openness. The degree of financial openness for households and firms is determined by parameters φ_{B^*} and φ_{D^*} in Eq. (5) and Eq. (18), respectively. In the model we define four forms of openness as follows:

1. Fully open: $\varphi_{B^*} = \varphi_{D^*} = 0$ ("OO"). Here we assume that financial activity with abroad for both sectors does not entail any costs. That is, the economy faces an elastic supply of foreign bonds (at interest rate R_t^*) and foreign loans (R_t^{*D}), respectively.

2. Fully closed: $\varphi_{B^*} = \varphi_{D^*} = 10^6$ ("CC"). In this case, the costs of engaging in financial activity with abroad for both sectors are enormous. This assumption simply eliminates any incentive to trade financially with the world and, the economy is financially closed to abroad.

3. Open to households only: $\varphi_{B^*} = 0, \varphi_{D^*} = 10^6$ ("OC"). Here access to the global financial market is free for households (they face an elastic supply of foreign bonds at interest rate R_t^*), whereas firms face enormous costs when borrowing from abroad, meaning that this channel of finance is closed for them.

4. Open to firms only: $\varphi_{B^*} = 10^6, \varphi_{D^*} = 0$ ("CO").This case is opposite to (3), so that households do not save using foreign bonds whereas firms can borrow from abroad at interest rate R^{*D}.

These four different openness structures could be thought of as limiting cases, where a sector is either completely open or completely closed. It is plausible that the reality, for every country, lies somewhere on this range. That is, in most countries, both sectors (households and firms) probably have some ability to access foreign markets.

4.1 Response of the economy to a crisis under various forms of financial openness

This section describes the impact of the financial crisis on the economy, according to its openness type: either fully open or fully closed ("OO" and "CC"). Appendix A describes the two remaining forms of openness ("OC" versus "CO").

Starting from the steady state, we hit the economy with a large negative shock to the quality of capital (ε_t^k).[9] This shock originates in the production side of the economy (see Eq. (17), (25)), and has a financial consequence in that it deteriorates the financial strength of banks, which lowers their ability to provide finance to firms. For both economies we assume that the initial level of the spread is equal, that is, they were both equally financially constrained prior to the shock.

Figure 2 shows the evolution of the main variables under the two economies. We start by describing the results in the "CC" economy (as in Gertler and Karadi (2011)). The shock directly reduces the effective amount of capital, and lowers its price. As a result, banks incur losses, and their net worth decreases. Given the reduction in their net worth, banks must reduce their credit, which causes investment to fall, and the price of capital to decline even further, which exacerbates the negative effect on banks' net worth. The lower net worth of banks increases the friction in the economy, and is reflected by the opening of a financial spread between the expected return on capital, which goes up, and the risk-free rate, which goes down. As a result of the shock, output declines for a prolonged period of time. The reduction in output is partly caused by a supply factor - the lower level of effective capital, and partly by a demand factor - reduced demand for investment and for consumption (which is the result of the decline in households' income). The decline in demand is dominant, as can be seen from the decline in inflation.

Turning to the "OO" economy, the response of the main variables - output, consumption, inflation, etc. - is generally weaker than in the closed economy. This is because firms are

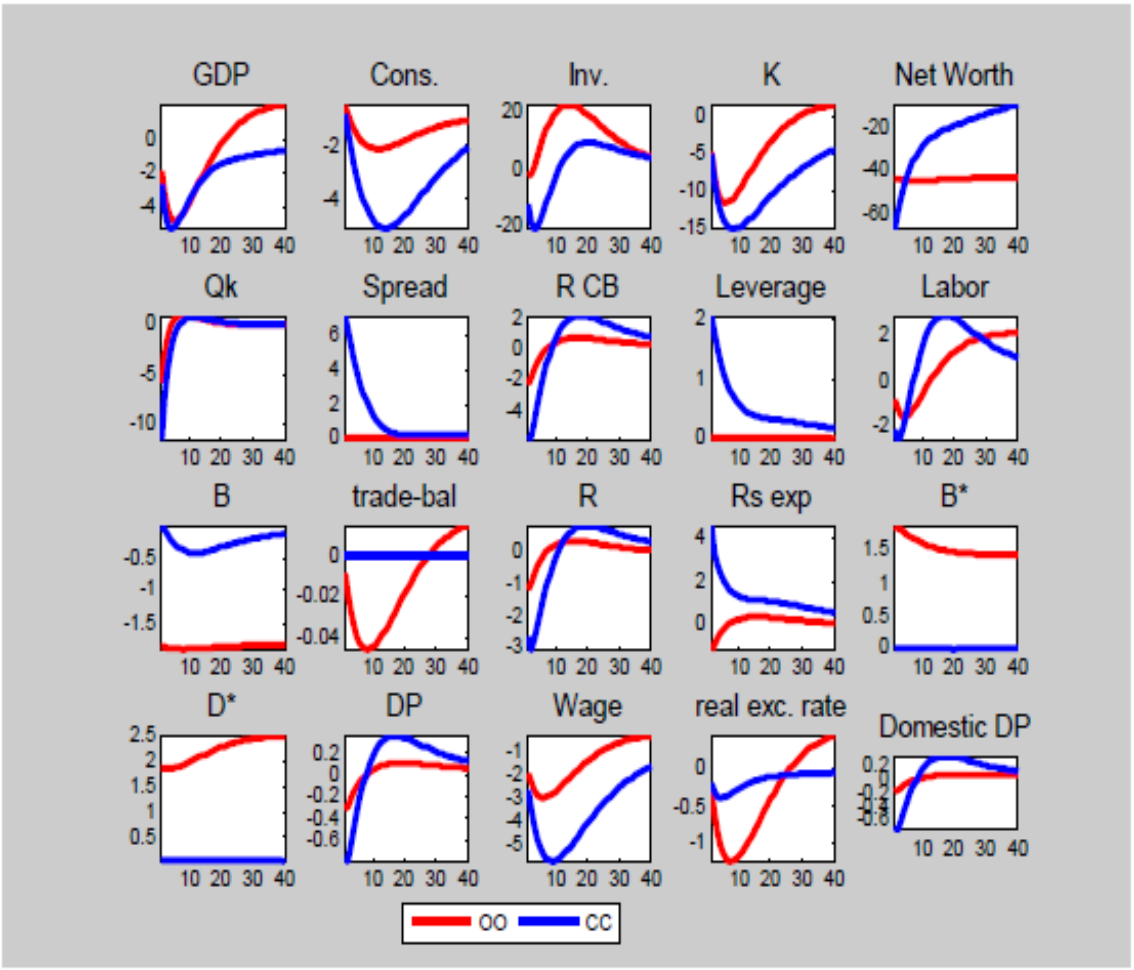
[9] We specify an AR(1) process for the shock, with a coefficient of 0.66.

not constrained by the lower banking credit, as they borrow abroad in order to obtain the necessary funds to acquire the capital they need (D^*). This contributes to a higher level of investment than in a closed economy, and thus to a higher level of capital, which supports a higher level of output, leading to higher income for households.

Two additional points are worth highlighting. First, in response to the decline in banks' net worth, households choose to withdraw some of their deposits. In the closed economy, these resources can only be used for consumption, which means that households save less than they otherwise would have chosen. In contrast, the open economy also contains the option of lending abroad (by purchasing foreign bonds), which they can easily do, as can be seen in the increase of B^*.

Second, in the open economy, the spread between the expected return on the risky asset and the risk-free rate does not change at all in response to the shock, which is in stark contrast to the closed economy. This reflects the fact that in the open economy, the shock does not affect the degree of financial friction - households are not constrained in their savings' decisions and firms are not constrained in their borrowing decisions. This means that while in the closed economy, the spread is a good indicator of the severity of a financial crisis, the same is not necessarily true in an open economy: A totally open economy has no informational content regarding the severity of the crisis.

Figure 2: **The IRF of Main Variables to a Negative Shock to the Quality of Capital, "OO" & "CC"**



Notation: *GDP* –gross domestic product; *Cons.*–private consumption; *Inv.*–investment; *K* –capital; *Net Worth* –net worth of banks; *Qk* –price of capital; *Spread* –spread between interest rate for borrowers and lenders; *R CB* –nominal CB interest rate; *Leverage* –leverage rate of banks; *Labor* –labor effort of households; *B* –amount of domestic deposits; *trade – balance* –trade balance; *R* –interest rate for lenders; *Rs exp* –interest rate for borrowers; *B** –amount of foreign bonds; *D** –amount of foreign loans; *DP* – CPI inflation; *Wage* –real wage; *real exc.rate* –real exchange rate; *Domestic DP* –domestic inflation.

5 The effectiveness of asset purchases

Facing a crisis as the one described above, the CB may choose to purchase assets. We measure the effectiveness of AP in terms of improvement in the value function (V_t) of the representative household:

$$V_t = u_t(C_t, L_t) + \beta E_t V_{t+1} \tag{36}$$

where $u_t(C_t, L_t)$ is shown in Eq. (1).

We solve the value function in Eq. (36), as well as other variables in the model, by a second order approximation around the deterministic steady state,[10] following Faia and Monacelli (2007) and Gertler and Karadi (2011). The solution of the value function can be decomposed into three components:

$$V = \bar{V} + \frac{1}{2}\Delta + IRF_1^V(\epsilon_t^\Psi) \tag{37}$$

where $\bar{V}$ is the deterministic steady state of the value function, $\frac{1}{2}\Delta$ is a correction term that reflects the effect of the shocks' volatility on the stochastic steady state, and $IRF_1^V(\epsilon_t^\Psi)$ is an impulse response of the value function (in the first period). To measure the welfare effect of AP, we compute the $IRF_1^V(\epsilon_t^\Psi)$ term and treat the $\frac{1}{2}\Delta$ as constant. In other words, we treat the use of AP as a one time event, which does not affect the economy's response to possible future shocks.[11]

To evaluate the effectiveness of the AP, we should compare the endogenous effects of a financial crisis with and without AP. However, in order to make a "fair" comparison that focuses on the effectiveness of AP per a given intervention scale, we impose an identical evolution of the amount of assets purchased Ψ_t for each type of economy. Formally, we

[10] We solve the model by the second order in Dynare (Adjemian et al. (2011). We use pruning in Dynare to avoid explosive solutions. With a second order approximation Dynare uses the pruning algorithm of Kim et al. (2008).

[11] A similar approach was taken by Gertler and Karadi (2011), who neglect the correction term and focus on the short-term welfare implications of AP.

impose an identical, exogenous, path of purchased assets:

$$\Psi_t = \rho\Psi_{t-1} + \varepsilon_t^{\Psi} \tag{38}$$

where we assume that in the first period the government purchases 10% of firms' assets ($\varepsilon_t^{\Psi} = 10\%$) and then the stock of purchased assets gradually dies out toward zero ($\rho^{\Psi} = 0.99$, $\Psi = 0$ in steady state). We report the improvement in the value function in terms of the equivalent annual increase in private consumption. Table 2 shows the welfare gain as a result of the exogenous AP shown in Eq. (38) under various forms of financial openness. The table shows that, in general, openness does not reduce the effectiveness of the AP with regard to improving welfare. Interestingly, in a fully open economy the welfare contribution of AP is far from being zero. In fact, in our calibration it is even larger than in the closed economy. Under the two other forms of openness, AP is also welfare improving, though somewhat less than in the closed economy. These results are explained in sections 5.1 and 5.2 .

Table 2 - The contribution of AP to welfare (in terms of annual consumption) under various forms of financial openness

Type of openness	Contribution of AP to C (%)
Fully open	3.25%
Fully closed	1.49%
Open to Households only	1.32%
Open to Firms only	0.89%

5.1 The source of the welfare gain induced by asset purchases

To understand the source of the welfare gain under the different openness types, we analyze the effect that implementing AP has in terms of its net benefit to the economy (i.e. the benefit that it yields minus the cost that it entails, from the perspective of the whole economy). To be precise, starting from the steady state of the economy, we employ an AP program that is the size of one unit of the economy's good. That is, the CB borrows one

unit of the good and lends it to the intermediate good firms. We refer to the resulting cost and benefit as a marginal cost and a marginal benefit. We start with the closed economy:

Case 1 - Fully closed

Marginal cost: By borrowing one unit from households, AP reduce consumption by one unit, thus resulting in a decrease in utility of $U'(C)$, the marginal utility of consumption.

Marginal benefit: Firms get additional finance from the CB which enables them to purchase one additional unit of capital (since in steady state the prices of consumption and of capital are equal). This increases output in the next period by the marginal product of capital (net of depreciation), which could be used to increase consumption. Thus, the AP's net benefit for the economy in terms of current utility is: $U'(C)(-1+\beta \cdot MPK) = U'(C)\frac{MPK-R}{R}$ (where $MPK = \alpha\frac{P^m}{P}\frac{Y}{K}+1-\delta$ and $\beta = \frac{1}{R}$). Notice that the interest rate that the CB pays for borrowing from households is irrelevant from the economy's perspective as it is offset by the interest rate income of households.

Case 2 - Fully open

Marginal cost: By borrowing one unit from households, AP reduce households' foreign bonds holdings by one unit. Thus, they forgo an interest rate income of R^*.[12]

Marginal benefit: Firms get a unit of the good from the CB, which they use to replace foreign borrowing.[13]They therefore save the interest rate payment on the foreign loans in the next period, R^{*D}, which could be used to increase consumption by that amount. Thus, the AP's net (current) benefit for the economy is: $\beta U'(C)\left(-R^* + R^{*D}\right) = U'(C)\frac{R^{*D}-R^*}{R^*}$.

The next two cases are essentially a combination of cases (1) and (2):

Case 3 - Open to Households only

[12] At the margin, that is, for an infinitely small unit of the good, households are indifferent between giving up on a unit of consumption and forgoing the foreign interest rate on lending that unit. But for any larger amount, they will choose to forgo the foreign interest rate, since the marginal utility of consumption will increase above the foreign interest rate, which is constant.

[13] Similar to the previous footnote, at the margin firms are indifferent between using the additional unit to replace foreign loans and using it to acquire new capital. But for any larger amount, replacing foreign loans would be strictly preferred, since the marginal product of capital would decrease below the foreign interest rate, which is constant.

Marginal cost: As in case 2.

Marginal benefit: As in case 1.

Case 4 - Open to Firms only

Marginal cost: As in case 1.

Marginal benefit: As in case 2.

Table 3 - AP's marginal net benefit to welfare under various forms of financial openness

Financial structure of the economy	Net (marginal) benefit from AP
Fully closed	$U'(C)\frac{MPK-R}{R}$
Fully open	$U'(C)\frac{R^{*D}-R^*}{R^*}$
Open to households only	$U'(C)\frac{MPK-R^*}{R^*}$
Open to firms only	$U'(C)\frac{R^{*D}-R}{R}$

Table 3 summarizes the discussion above and demonstrates that in all economy types, the existence of a positive spread entails a welfare benefit of AP.[14] Intuitively, the spread measures the cost that the economy pays for not being able to transfer funds from a low utility use to a high utility use. The higher the cost is, the more scope there is for a welfare-improving intervention in the form of AP.[15]

5.2 The economy's response to asset purchases

This section examines the economy's reaction to AP. Figure 3 shows the evolution of the main variables in "OO" and "CC" economies in response to an exogenous AP shock as shown in Eq. (38). The other two openness levels, "OC" and "CO", are examined in Appendix A. We start by describing the response under "CC". As a result of the AP, firms are able to get financing from the CB to acquire new capital, so investment increases.

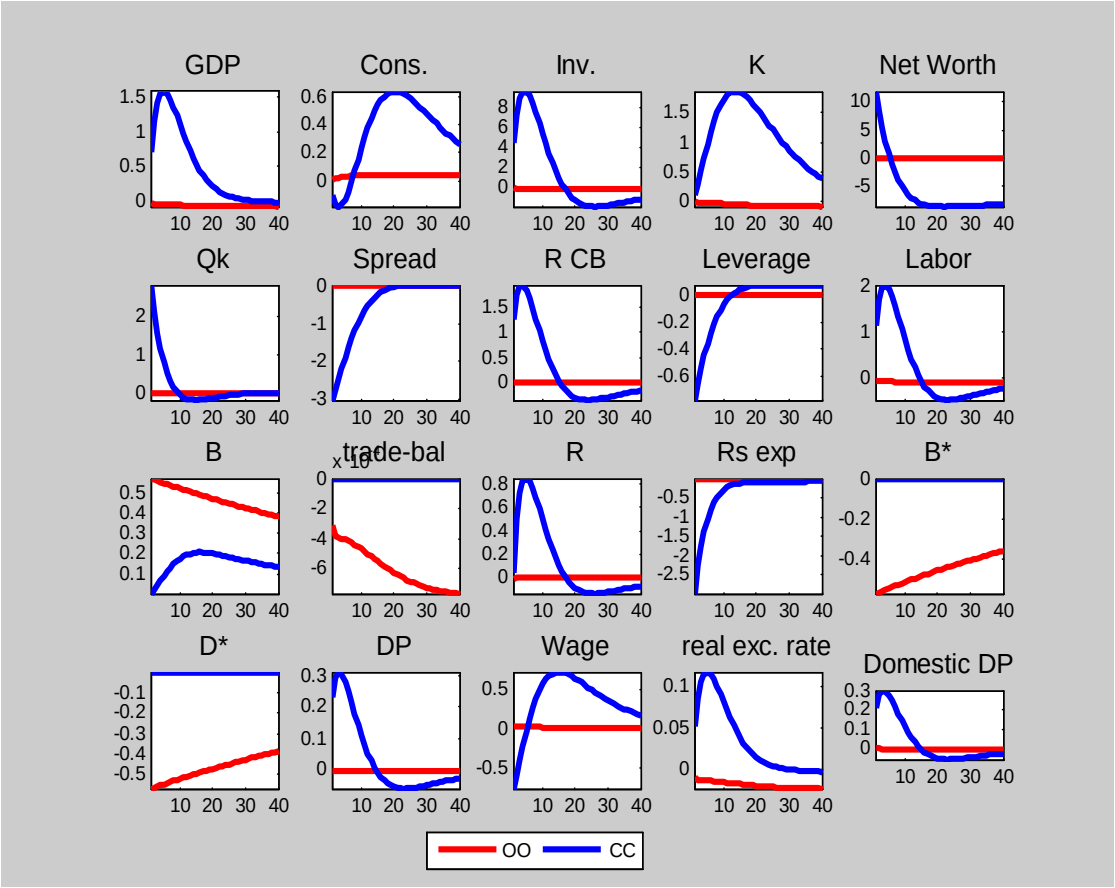
[14] We assumed AP are costless. If they do have cost, it should be substracted from the net benefit that we presented here.

[15] In our calibration the steady state spread is calibrated to be equal for all four economies, but this does not mean that the welfare benefit of AP should be the same, as Table 2 shows, since the results here were based on analyzing a marginal intervention.

The rise in investment, which raises aggregate demand, leads to an increase of both output and inflation. The increased investment also generates an increase in the price of capital, thereby improving the banks' financial condition (net worth) and enabling them to acquire more deposits and to increase lending to firms. The increased price of capital is reflected in a lower expected return on capital and thus in a lower spread.

The results under "OO" are completely different. When domestic firms get the new finance from the CB, instead of using it to increase the level of capital, they choose to decrease their level of foreign debt (D^*). Thus, AP do not affect the price of capital, the expected return on capital, or the spread. AP also affects domestic households: While they lend more domestically, they reduce their savings in foreign bonds (B^*) by the same amount. Thus, the main effect of AP in the completely open economy is a change in the asset-liability structure: a reduction in firms' foreign debt accompanied by a reduction in households' foreign bonds holdings. Since the interest rate that firms pay on their foreign debt is higher than the rate that households earn on their foreign savings, this change results in less resources that the economy has to pay to foreign entities, and thus generates a positive wealth effect, which is reflected in a very small, but very long-lasting, increase in consumption and decrease in labor. The fact the amount saved affects consumption and labor so persistently (effectively permanently), derives from the ability to completely smooth consumption intertemporally via the foreign economy. Readers of Schmitt-Grohé and Uribe (2003) might suspect that our results may be the result of a poor approximation of a nonstationary system around a wrong steady state. Thus, in appendix B we analyze the welfare effect of AP when we move gradually from a completely open economy to a closed one. Our results seem to imply that the welfare benefit does not arise due to an approximation problem.

Figure 3: **The Effect of AP on the Economy: "OO" & "CC"**



Notation: *GDP* –gross domestic product; *Cons.*–private consumption; *Inv.*–investment; *K* –capital; *Net Worth* –net worth of banks; *Qk* –price of capital; *Spread* –spread between interest rate for borrowers and lenders; *R CB* –nominal CB interest rate; *Leverage* –leverage rate of banks; *Labor* –labor effort of households; *B* –amount of domestic deposits; *trade – balance* –trade balance; *R* –interest rate for lenders; *Rs exp* –interest rate for borrowers; B^* –amount of foreign bonds; D^* –amount of foreign loans; *DP* – CPI inflation; *Wage* –real wage; *real exc.rate* –real exchange rate; *Domestic DP* –domestic inflation.

6 Conclusions

This paper analyzes the effectiveness of conducting asset purchases in a SOE. We found that, in general, the openness of an economy weakens the effect of AP on most macroeconomic variables (e.g output and inflation). This corroborates previous findings in the literature. However, importantly, the welfare analysis we conducted showed that the weaker reaction of the macroeconomic variables does not necessarily imply a lower welfare gain from conducting asset purchases. In fact, in our calibration, the welfare gain was higher than in the closed economy. The source of the welfare gain induced by AP is the resources that are saved to the domestic economy by reducing the amount of foreign intermediation. Thus, as long as the costs associated with AP are small enough, they can be an effective tool for central banks in SOE as well.

Finally, another point which the analysis highlighted is that in open economies changes in spreads might be uninformative regarding the depth of the ongoing financial crisis or regarding the degree of success of AP policy. Thus, it may instead be more useful for policymakers to directly monitor changes in the net worth of financial intermediaries and flows of foreign assets and liabilities of domestic agents.

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Appendices

Appendix A: The response of semi-open economies to a crisis and the effectiveness of AP

In Section 4.1 we examined the responses of the fully open and the fully closed economies to a financial crisis, and in Section 5.2 we evaluated the effectiveness of AP in those economies. In this Appendix we perform the same analysis for semi-open economies, that is, an economy that is open only to households ("OC") and an economy that is open only to firms ("CO").

In the absence of financial frictions, the type of financial openness does not matter: it is irrelevant whether funds to firms are transferred from domestic households or from abroad. In the presence of financial frictions this is no longer the case. Figure 4 demonstrates that there are noticeable differences in the reactions of the variables in both economies to a negative quality-of-capital shock. Specifically, although the dynamics of the spreads in both economies are very similar, their components develop quite differently: while in the CO economy it is the reduction of the risk-free rate that causes the spread to increase, in the OC economy the risk-free rate stays relatively stable, but the expected return to capital increases strongly. This might imply that economies that are relatively closed on the households side, are more prone to get stuck at the zero lower bound, in comparison to economies that are relatively more open on firms side. For completeness, Figure 5 presents the response of the two economy types to an AP shock. Here as well, the differences between the responses are noticeable.

Figure 4: **The IRF of Main Variables to a Negative Shock to the Quality of Capital, "OC" & "CO"**

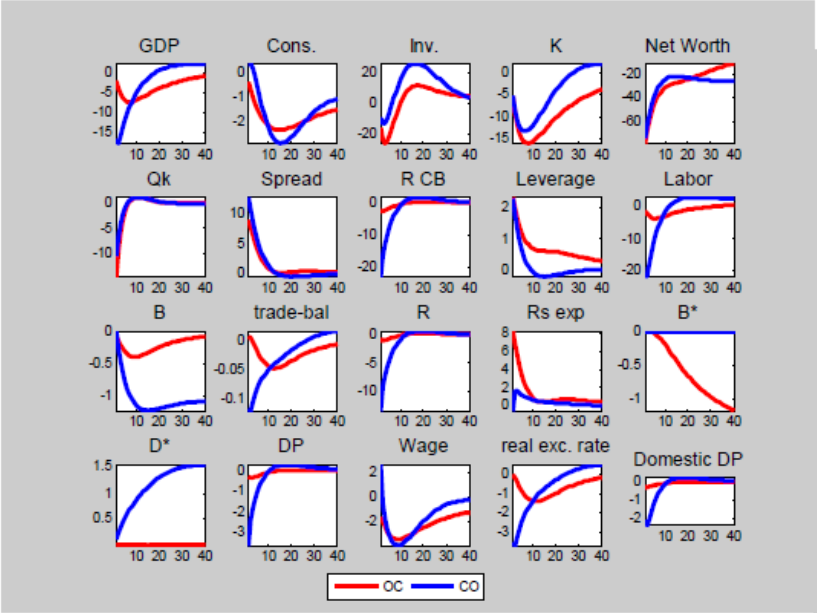
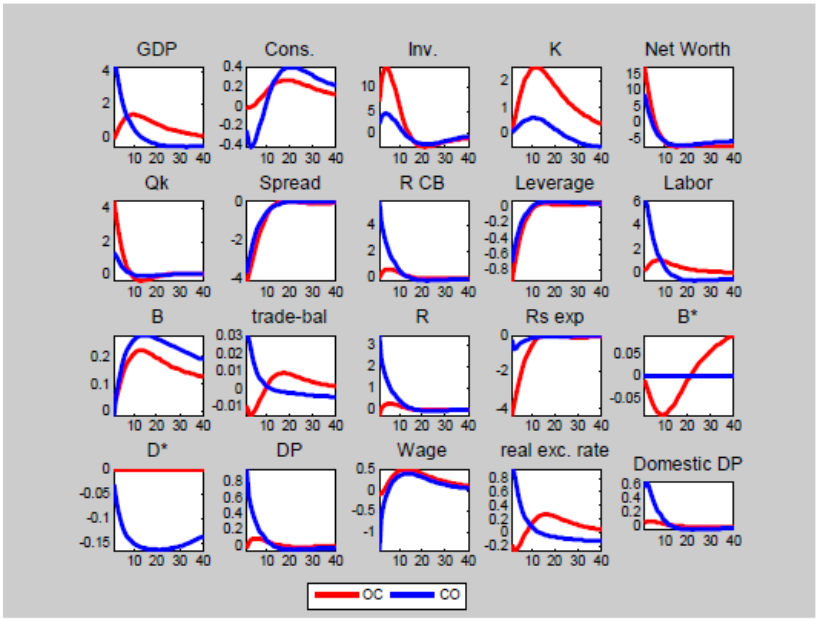


Figure 5: **The Effect of Exogenous AP on Main Variables in "OC" & "CO"**



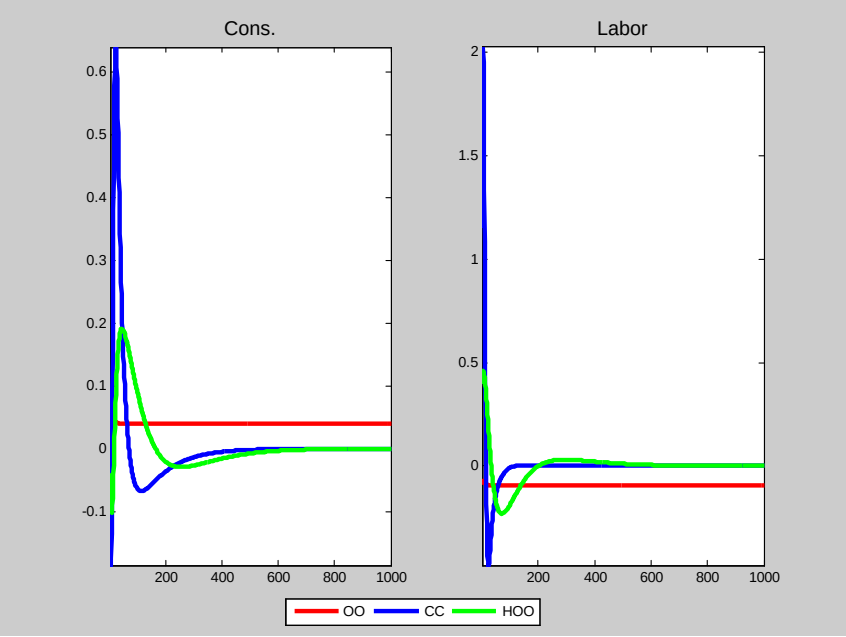
Appendix B: Asset purchases and welfare - the role of persistence

This section examines whether the existence of a welfare benefit in a completely open economy (both absolutely and relative to the closed economy) stems from a problem in the approximation of our model. Schmitt-Grohé and Uribe (2003) showed that a fully open economy exhibits nonstationary behavior, which is a problem if one is interested in using an approximation around a given steady state. To see whether a nonstationarity problem is what drives our results, we first start by looking at the response of consumption and labor to an AP shock over a very long time span (1000 periods). Figure 6 shows that while in the closed economy consumption and labor eventually return to their steady state level, in the open economy they stay at what seems to be a permanently different level, that is, they exhibit a nonstationary behavior. To these two cases, we add another, "HOO", that represents a "nearly open economy". Formally, we assume $\varphi_{B^*} = \varphi_{D^*} = 7.4 \times 10^{-4}$, which is the value used by Schmitt-Grohé and Uribe (2003) (for the households) in their small open economy model. What figure 6 shows is that with this small cost, the model exhibits a stationary behavior.[16]

Next, Figures 7 and 8 show how the welfare effect of AP depends on the degree of financial openness, that is, under various values of φ_{B^*} and φ_{D^*}. In Figure 7 we set $\varphi_{B^*} = \varphi_{D^*}$, and in Figure 8 we relax this assumption and consider asymmetric openness of both sectors ($\varphi_{B^*} \neq \varphi_{D^*}$). What can be seen from Figures 7 and 8 is that the more financially open the economy is, the bigger the contribution of the AP is to welfare. The value function is monotonic with respect to financial openness, where the lowest gain is obtained when the economy is fully closed ("CC") and the highest gain is obtained when the economy is fully open ("OO"). For example, if we look at the value that Schmitt-Grohé and Uribe (2003) used to describe a small open economy, we have seen in Figure 6 that the model is stationary, and we see in Figures 7 and 8 that the welfare effect is positive even

[16] In fact, as long as $\varphi_{B^*}, \varphi_{D^*} > 0$ the model is stationary because all roots are less than one.

Figure 6: **Role of AP Persistence**



in this case. It is even still slightly higher that in the closed economy. Furthermore, there is no evidence for discontinuity of the value function at the point $\varphi_{B^*} = \varphi_{D^*} = 0$. Thus, it seems that the welfare gain from AP in the "OO" economy is not achieved due to a poor approximation of the nonstationary model.

Figure 7: **Welfare Gain From AP as a Function of Financial Openness (Equal Openness to Firms and to Households)**

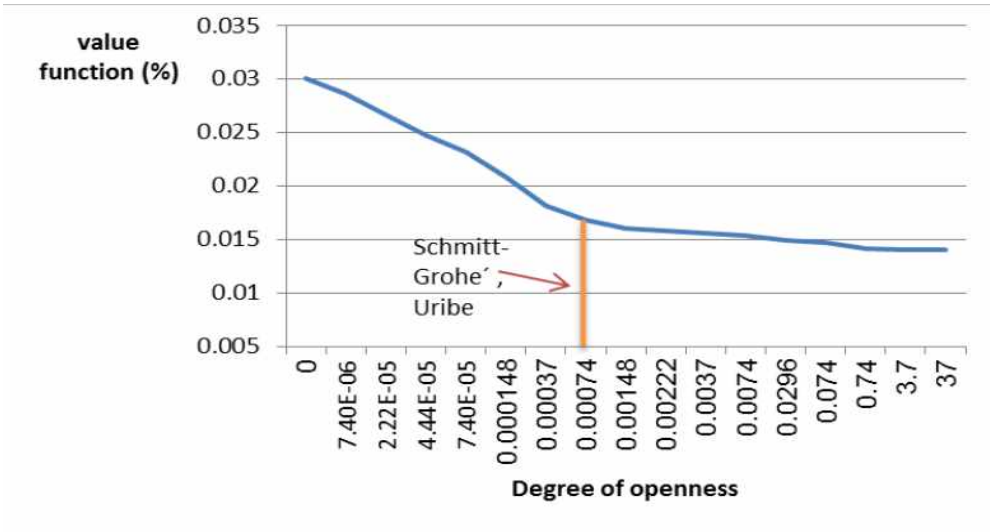


Figure 8: **Welfare Gain From AP as a Function of Financial Openness.(Different Openness to Firms and to Households)**