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Global implications of national unconventional policies

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ABSTRACT

Financial integration in the markets for banks' assets and liabilities makes balance sheet constraints highly correlated across countries, resulting in a high degree of financial and macroeconomic interdependence. Likewise, under financial integration unconventional policies aimed at stabilizing domestic financial and credit conditions could entail large international spillovers. Therefore, stabilization by one country will also benefit other countries, reducing incentives to implement credit policies in a classic free-riding problem, especially when these policies entail domestic costs. We show that this outcome can emerge in an open economy model featuring financial intermediaries that face endogenously determined balance sheet constraints.

1. Introduction

The recent financial crisis has witnessed governments and monetary authorities around the world engaging in a number of unprecedented and unconventional policy interventions. Central banks in particular acted aggressively, deploying traditional tools, for instance lowering interest rates, but also introducing extraordinary measures geared toward redressing malfunctioning financial markets and cushioning national economies from recessionary consequences. These measures included various kinds of credit facilities to ease conditions in financial and credit markets. In some cases, central banks acted directly as intermediaries in dysfunctional markets. For instance, the Federal Reserve and the Bank of England conducted sizable purchases of private and government assets, totalling close to 18 and 12% of GDP, respectively, which resulted in a dramatic expansion of the size of their balance sheets (see e.g. Kozicki et al., 1996). The Bank of Japan and the European Central Bank implemented more modest programs of asset purchases. The ECB however enhanced bank credit by greatly expanding its provision of liquidity to the banking sector, far beyond standard short-term maturities, especially after the second half of 2011. By March 2012, the nominal size of the Eurosystem balance sheet was similar to that of the Federal Reserve System, reaching around 3 trillion euros (vis-à-vis around 2.9 trillion dollars).

Given the unusual size and scope of these unconventional policies, a fast growing literature has been invaluable in providing an early assessment of their effectiveness, and of their underpinnings in theoretical models (see e.g. Gertler and Kiyotaki, 2010 and references therein, and Del Negro et al., 2010). However, most positive and especially normative analyses of unconventional policy measures have been framed in terms of closed economies, thus neglecting a key aspect of the financial and economic crisis that triggered them: its global reach.[1] At the center of the crisis and its universally widespread repercussions were arguably highly leveraged financial intermediaries: Unable to raise short-term funds to finance their global asset portfolios, they were instrumental in the amplification and propagation of the widespread collapse in asset prices and increase in credit spreads (see e.g. Milesi-Ferretti and Tille, 2011; Shin, 2012). Recent work by

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[1] The international financial market effects of the US Large-Scale Asset Purchases have been recently documented by Neely (2010). In addition, major central banks established swap lines in foreign currency (see e.g. Goldberg et al., 2010).

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e.g. Mendoza and Quadrini (2010), Perri and Quadrini (2011) and Dedola and Lombardo (2012), has shown that in line with the experience of the Great Recession, the combination of financial frictions with international financial integration results in very strong cross-border spillovers especially of financial shocks.[2]

In this paper we study the international dimension of unconventional policies in open economies featuring financial frictions. Specifically, we are interested in the implications for international policy coordination, of factors that account for a higher degree of financial and macroeconomic interdependence, such as financial integration. If a country specific shock has global repercussions, then spillovers from national policy responses could also be large. In this case, it is legitimate to ask whether national responses, such as unconventional policies, should better be coordinated across countries. To this aim, we consider financial frictions in the form of balance sheet constraints on financial intermediaries à la Gertler and Karadi (2011, henceforth GK). Financial intermediaries raise short term funds domestically and abroad, and allocate them to domestic and foreign assets, subject to time varying endogenous balance sheet constraints. When the markets for banks' assets (e.g. loans to firms) and liabilities (e.g. short-term deposits) are integrated across countries, credit spreads become highly correlated (Dedola and Lombardo, 2012). A shock that brings about a tightening of the balance sheet constraint in one country generates endogenously a tightening of the balance sheet constraint in the other country too, resulting in a global contraction of credit. By the same token, a national policy that aims at mitigating the consequences of such an adverse shock, for instance by trying to relax the balance sheet constraint faced by domestic financial intermediaries through purchases of domestic assets, will inevitably benefit foreign intermediaries too. This positive spillover has the potential to generate a free-riding behavior, especially when the unconventional policy measures entail domestic costs, with the risk of a globally suboptimal under-reaction.

We first document the international propagation of country-specific shocks. We confirm previous results in the literature that with a high degree of financial integration, country specific shocks with a financial origin result in a much greater degree of macroeconomic synchronization across countries than real shocks, such as shocks to the quality of capital studied e.g. by GK. We then turn to the study of a set of unconventional policies similar to those analyzed by GK and Gertler et al. (2011, henceforth GKQ).[3] Credit policy is modeled as direct purchases of private assets, assumed to be a linear feedback rule in prevailing credit spreads. We study both cooperative and noncooperative policies. Under cooperation, credit policy is set to jointly maximize the equally weighted sum of Home and Foreign households' lifetime utility. Noncooperative (Nash) policies are the result of each government maximizing the domestic agent's lifetime utility while taking as given the rule followed by the other country.

Our key finding is that lack of cooperation in general will result in suboptimal credit policies. Due to the positive policy spillovers, stabilization by one country will also benefit the other one, reducing its incentive to intervene (at a cost) in a classic free-riding problem. Undertaking this class of credit policies against both capital quality and financial shocks under Nash could be welfare reducing from the perspective of an individual country, particularly if these policies are costly. Such a finding could be accounted for by standard second-best reasoning. In our economy there is a wedge between the pricing of capital by the financially constrained intermediaries and the pricing that would emerge in a frictionless world, resulting in a lower capital stock. Ideally the policymaker would like to completely eliminating this wedge and increase the capital stock. Nevertheless, the credit policy only affects the capital stock through the average and the volatility of the credit spread, rather than directly through the inefficient wedge. A reduction in mean and variance of the spread leads to a fall of private intermediation and thus of credit supply by the financial sector. Under moderate amounts of credit policy interventions, the result is a drop in overall capital accumulation, in spite of the fall in the average credit spread. As the size of asset purchases by the government rises, the average capital stock also increases, resulting in higher welfare. Therefore, for empirically reasonable costs of intervention, lack of international cooperation always leads to not responding to shocks. However, the resulting welfare gains from cooperation are generally not very large, in line with standard results in the literature for other business cycle shocks (see e.g. Obstfeld and Rogoff, 2002).

The structure of the paper is as follows. The next section presents a two-country version of the GK model of financial frictions, under flexible prices. Section 3 documents some properties of the model in terms of the international propagation of real and financial shocks. Section 4 reports on the credit policy experiments, while the last section concludes.

2. An open-economy version of Gertler and Karadi (2011)

In this section we describe our two-country model economy with financial frictions. The core framework is a standard open-economy model such as Backus et al. (1995), to which we add financial intermediation of fund transfers between households and nonfinancial firms. Intermediation is constrained by an agency problem which limits the ability to raise funds from households. We will focus on the implications of different assumptions about international capital markets for the international transmission of country-specific shocks to the quality of capital and to the financial sector. Absent financial frictions the first shock only causes a small output fall, while the second is obviously inconsequential. Conversely,

[2] See also Devereux and Yetman (2010), Coeurdacier et al. (2010), and Ueda (2012). The extensive literature on financial frictions in open economy includes Gertler et al. (2007) and Faia (2007).

[3] We assume flexible prices similarly to GKQ, thus abstracting from explicit interactions with conventional monetary policy — see Goodfriend (2011).

when financial intermediaries face binding constraints to their activity, both shocks induce a tightening of credit supply and bring about a domestic recession. As we show, when intermediaries operate in integrated deposit and loan markets, both country-specific shocks spillover abroad, causing a global slump. It is against the background of these inefficiencies that there is a potential role of coordinated government interventions in the credit markets. We now proceed to outline the basic ingredients of the model.

2.1. The baseline model

Before introducing financial frictions, we present the basic environment, which is not too different from standard IRBC models with intermediate homogenous goods and investment adjustment costs, such as Backus et al. (1992). The world economy comprises two entirely symmetric countries producing a homogeneous good, and populated by a continuum of infinitely lived households. Therefore, we abstract from the role of international relative prices. A key difference from Backus et al. (1995), is that we consider incomplete market environments, with financial frictions. In addition to households, there are three types of firms in the model: goods, capital producers, and banks.

Preferences: Focusing on the Home country (we will denote with an asterisk '*' the variables in the other, Foreign country), households preferences are quite standard:

$$E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t}\left[\frac{(C_\tau - hC_{\tau-1})^{1-\sigma}}{1-\sigma} - \chi\frac{L_\tau^{1+\varphi}}{1+\varphi}\right], \tag{1}$$

where E_t is the expectation operator conditional on date t information and β, σ, h, φ, χ are all positive parameters, with $0<\beta<1$, $0<h<1$. Preferences feature consumption habit formation to enhance consumption dynamics, but retain separability in consumption and labor.

Technology and production: In each country there are a continuum of perfectly competitive firms of unity mass. Each firm produces a homogeneous output using an identical constant returns to scale production function with capital and local labor as inputs. While labor is immobile across countries, we will explore how different degrees of capital markets integration affect the transmission of country specific shocks and the design of cooperative and unilateral unconventional policies.

Output Y_t is a Cobb–Douglas function of capital and labor hours L_t as follows:

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha} \quad 0<\alpha<1, \tag{2}$$

where A_t is TFP, which is potentially stochastic following a (country-specific) stationary Markov process.

Let S_t be the aggregate capital stock at the end of period t that could be used for production in period $t+1$. This capital stock "in process" at t for $t+1$ is the sum of current investment I_t and the stock of undepreciated capital, $(1-\delta)K_t$:

$$S_t = (1-\delta)K_t + I_t. \tag{3}$$

Capital in process for period $t+1$ is transformed into capital for production after the realization of a country-specific multiplicative shock to capital quality, ξ_{t+1}

$$K_{t+1} = \xi_{t+1} S_t. \tag{4}$$

The random variable ξ_{t+1} could be thought of as capturing some form of economic obsolescence, as opposed to physical depreciation (Appendix B in Gertler et al., 2011 working paper version provides microfoundations). Following the finance literature (e.g. Merton, 1973), Gertler and Karadi (2011) consider the capital quality shock as a simple way to introduce an exogenous source of asset price dynamics. Because of investment adjustment costs, the market price of capital will be endogenous and will respond to the random variable ξ_{t+1}.

2.2. Households

Following GK, the household sector is modeled in a way that allows to introduce a substantive role for financial intermediation while keeping the tractability of the representative agent approach. Households consume, supply labor and save. They save by lending funds to financial intermediaries (domestically and possibly abroad), and to the government. In particular, there is a representative household with a continuum of members of measure unity. Within the household there are two types of members: $1-f$ "workers" and f "bankers", who pool consumption risk perfectly. Workers supply labor and bring the wage they earn back to the household every period. Each banker manages a financial intermediary (dubbed a "bank") and returns nonnegative profits back to the household subject to its flow of fund constraint. The household thus owns the banks managed by its bankers. It is convenient to assume that households supply funds to domestic (and depending on the degree of international financial integration also foreign) banks other than the ones they own. Banks can raise funds from households other than their own only by offering noncontingent riskless short term debt ("deposits" D_t). This assumption is important as banks will face constraints in obtaining this kind of external funds. In addition, households may acquire short-term (riskless) government debt (B_t). Both bank deposits and government debt are one period real riskless bonds and thus are perfect substitute, hence paying the same gross real return R_t from t to $t+1$. Furthermore, without loss of generality, we may assume that only domestic residents hold their own government bonds.

Clearly, when there is an integrated bank deposit market so that the risk free rate is the same across countries, households can absorb more government debt by reducing their holdings of equivalent domestic and foreign deposits.

The representative household in the Home country chooses consumption, labor supply, riskless debt $(C_t; L_t; D_t + B_t)$ to maximize expected discounted utility subject to the budget constraint

$$C_t + D_t + B_t = (1+\tau_t)w_t L_t + \Pi_t + R_{t-1}(D_{t-1} + B_{t-1}) - T_t. \tag{5}$$

Here w_t is the real wage rate, T_t is lump sum taxes, Π_t is net profit distributions from ownership of both banks and capital producing firms, and τ_t is a tax/subsidy on labor (depending on whether it is negative or positive). Let u_{C_t} and u_{L_t} denote the marginal utility of consumption and labor, respectively, and $\Lambda_{t;t+1}$ the household's stochastic discount factor. Then the quite standard household's first order conditions for labor supply and consumption/saving are given by

$$w_t(1+\tau_t) = \frac{u_{L_t}}{u_{C_t}}$$

$$E_t(\beta \Lambda_{t;t+1})R_t = 1$$

$$\Lambda_{t;t+1} = \frac{u_{C_{t+1}}}{u_{C_t}}.$$

We want to rule out the possibility that over time bankers do not accumulate enough internal funds that they do not need to borrow to finance their investments. In this case, the financial constraint they face will not be binding anymore. In order to limit bankers' ability to save to overcome financial constraints, GK assume they face a finite horizon. GK assume that with i.i.d. probability $1-\theta$ a bank shuts down next period. This probability is thus independent of the length of tenure as a banker. Despite the fact that the expected survival time $1/1-\theta$ may be quite long, the finite expected horizon induces payouts while the financial constraints are still binding. While every period $(1-\theta)f$ bankers exit and become workers, a similar number of workers randomly become bankers, keeping the fraction of each type constant. Bankers who exit pay out accumulated retained earnings to their respective households. On the other hand, each new banker receives from the household "start up" funds necessary to be able to operate and raise deposits from the other households. As anticipated earlier, Π_t includes net funds transferred to the household, namely dividends paid by exiting bankers minus the funds transferred to new bankers (aside from profits of capital producers).

2.3. Nonfinancial firms

Here we describe the program of the two types of nonfinancial firms: goods producers and capital producers.

Goods producers: Firms producing goods for consumption and investment operate a Cobb–Douglas production function (discussed earlier) with capital and labor inputs, under perfect competition. Conditional on their choice of capital, goods producers choose labor inputs to satisfy

$$W_t = (1-\alpha)\frac{Y_t}{L_t}. \tag{6}$$

At the end of period t, a goods producer acquires capital S_t for use in production in the subsequent period in the amount $\psi_{t+1}S_t$. After production, the firm has the option of selling the (depreciated) capital stock on the open market. There are no adjustment costs at the firm level, thus the capital choice problem is static. It follows that we may express *gross* profits per unit of capital (Z_t) as its marginal product:

$$Z_t = \alpha\frac{Y_t}{K_t}. \tag{7}$$

Goods producers finance capital purchases each period by obtaining funds from intermediaries against perfectly state-contingent securities. They face no frictions in obtaining these funds. Banks are efficient at evaluating and monitoring goods producers and also at enforcing contractual obligations with these borrowers. On the other hand, goods producers can commit to pay all the future gross profits to the creditor bank. That is why they rely exclusively on banks to obtain funds. The producer then uses the funds to buy new capital goods from capital goods producers. Each unit of the security issued by the latter is a state-contingent claim to the future returns from one unit of investment (which is best thought of as equity or perfectly state-contingent debt). Through perfect competition, the price of new capital goods is equal to Q_t, the price of the state-contingent securities, and goods producers earn zero net profits. This frictionless funding contrasts with the process of intermediaries in raising funds from households as they face funding constraints. These constraints, in turn, affect the supply of funds available to nonfinancial firms and hence the required rate of return on capital these firms must pay.

Capital producers: Competitive capital producers use final output as input in their activity. They build new capital, subject to adjustment costs, which is sold to goods producers at the price Q_t, as described above. In particular we assume the following functional form for the investment adjustment costs:

$$f_\imath(\cdot)\equiv\begin{cases}\dfrac{\eta_i}{2}\left(\dfrac{I_t}{\delta K_t}-1\right)^2\dfrac{\delta K_t}{I_t} & \text{if } \imath=0,\\ \dfrac{\eta_i}{2}\left(\dfrac{I_t}{I_{t-1}}-1\right)^2 & \text{if } \imath=1.\end{cases}$$

This specification allows us to encompass two widely used functional forms in the business cycle literature: for $\imath=0$, adjustment costs are proportional to the (aggregate) past capital stock, as e.g. in Chari et al. (2002); for $\imath=1$ adjustment costs depend on the growth rate of investment as e.g. in Christiano et al. (2005).

Households are assumed to own capital producers. The objective of a capital producer is to choose I_t to maximize discounted profits:

$$\max E_t\sum_{\tau=t}^{\infty}\beta^{\tau-t}\Lambda_{t;\tau}\{Q_\tau I_\tau-[1+f_\imath(\cdot)]I_\tau\}.$$

The price of capital goods is thus equal to the marginal cost of investment goods production:

$$Q_t=\left[1+f_\imath(\cdot)+\frac{\partial f_\imath(\cdot)}{\partial I_t}I_t+E_t\beta\Lambda_{t;t+1}\frac{\partial f_\imath(\cdot)}{\partial I_t}I_{t+1}\right].$$

Note that all capital producers choose the same net investment rate. Because of the flow adjustment costs, capital producers may earn profits outside of the steady state. As explained above, these profits are redistributed lump sum to households.

2.4. Financial intermediaries

Financial intermediaries lend funds obtained from domestic (and possibly foreign) households to domestic (and possibly foreign) goods producers. In doing so they engage in maturity and liquidity transformation, holding long-term, risky assets whose valuation is subject to market fluctuations, against short-term, risk-free liabilities redeemable at face value. They also act as specialists in channeling funds from savers to investors. Thus, financial intermediaries in this model are meant to capture in a stylized way investment banks as well as commercial banks.

In addition to obtaining deposits from households, banks raise funds also internally. The bank has its own net worth—accumulated from retained earnings. The bank then uses all its available funds to make loans to goods producers. As noted above, banks finance goods producers by purchasing state-contingent securities as there are no frictions in dealings between intermediaries and firms. The total value of loans for a bank is equal to the price Q_t times the number of state-contingent claims s_t^h ($Q_t^*s_t^f$ for loans abroad) on the future returns of a unit of capital at the end of period t in process for $t+1$.

Ignoring at this stage any supply of funds from the government, for an individual bank the value of loans funded within a given period (i.e. $Q_ts_t^h+Q_t^*s_t^f$ when banks can lend to both domestic and foreign firms) must equal the sum of bank net worth (N_t), and deposits raised from households (D_t). The intermediary balance sheet is then given by

$$\mathcal{W}_t\equiv Q_ts_t^h+Q_t^*s_t^f=N_t+D_t. \tag{8}$$

We assume it is prohibitively costly for incumbent bankers to issue equities to bring in new ones with sufficient wealth. Thus, bank's net worth N_t is the gross payoff from loans extended in the previous period, net of interest payments to depositors. Let $R_{k,t}(R_{k,t}^*)$ denote the gross rate of return on a unit of the bank's domestic (foreign) loans from $\mathbf{t-1}$ to $\mathbf{t}$:

$$R_{k,t}=\xi_t\frac{[Z_t+(1-\delta)Q_t]}{Q_{t-1}},$$

$$R_{k,t}^*=\xi_t^*\frac{[Z_t^*+(1-\delta)Q_t^*]}{Q_{t-1}^*}.$$

In general returns on loans are country specific, as they depend on the price of capital and on the payoffs, including the quality shocks ξ_t and ξ_t^*. Then we can express net worth as the difference between earnings on assets and interest payments on deposit liabilities:

$$\begin{aligned}N_t&=[Q_{t-1}s_{t-1}^hR_{k,t}+Q_{t-1}^*s_{t-1}^fR_{k,t}^*-R_{t-1}D_{t-1}]\\&=\left[(R_{k,t}-R_{t-1})-\frac{Q_{t-1}^*s_{t-1}^f}{\mathcal{W}_{t-1}}(R_{k,t}-R_{k,t}^*)\right]\mathcal{W}_{t-1}+R_{t-1}N_{t-1}.\end{aligned}$$

Any growth in net worth above the deposit rate R_{t-1} depends on the spread over it that the intermediary earns on domestic and foreign assets, as well as the total value of assets $\mathcal{W}_{t-1}$. Recalling that $\beta\Lambda_{t,t+1}$ is the (household) discount factor, due to the assumption of risk pooling within each family, for the intermediary to be profitable to operate in any period it must be that the following hold:

$$E_t\beta\Lambda_{t,t+1}(R_{k,t+1}-R_t)\geq 0$$
$$E_t\beta\Lambda_{t,t+1}(R^*_{k,t+1}-R_t)\geq 0.$$

The bank will not fund assets with a (discounted) rate of return below the borrowing cost. With frictionless capital markets, the above relations holds with equality and the risk-adjusted spreads are always zero. With financial frictions, however, the spread may be (inefficiently) positive due to limits on the intermediary ability to borrow.

Given a bank facing financing constraints and thus positive spreads, it is in its interest to invest all its funds and thus retain all earnings until the time it exits. Upon exit, the banker pays out accumulated retained earnings as dividends. Accordingly, the objective of the bank at the end of period t is the expected present value of the future terminal dividends,

$$\begin{aligned} V_t &= \max E_t\sum_{i=0}^{\infty}(1-\theta)\theta^i\beta^{i+1}\Lambda_{t,t+1+i}(N_{t+i+1}) \\ &= \max E_t\sum_{i=0}^{\infty}(1-\theta)\theta^i\beta^{i+1}\Lambda_{t,t+1+i}[(R_{k,t+1+i}-R_{t+i})\mathcal{W}_{t+i} \\ &\quad -Q^*_{t+i}s^f_{t+i}(R_{k,t+1+i}-R^*_{k,t+1+i})+R_{t+i}N_{t+i}], \end{aligned} \tag{9}$$

where θ is the probability of surviving into the next period.

To the extent that the (discounted) spread is positive, the intermediary will want to borrow additional funds from households to expand its assets indefinitely. To motivate an endogenous constraint on the bank's ability to obtain funds, following GK we introduce the following simple agency/moral hazard problem. After a banker obtains funds, he or she may transfer a fraction of assets to his or her family (e.g. by paying out large bonuses or dividends). It is the recognition of this possibility that has (other) households limit the funds they lend to banks. Specifically, at the end of each period a (potentially stochastic) fraction λ_t of available funds can be diverted by the banker. If a banker diverts assets, it is forced into bankruptcy and is shut down. The creditors may re-claim the fraction $(1-\lambda_t)\mathcal{W}_t$ of assets. However, it is too costly to recover the remaining fraction of assets $\lambda_t\mathcal{W}_t$.

Specifically, in order for lenders to be willing to supply funds the following incentive-compatibility constraint must be satisfied for each bank

$$V_t\geq\lambda_t\mathcal{W}_t.$$

The right hand side is the gain from absconding with a fraction λ_t of bank assets, which we assume is the same for domestic and foreign assets (see below for a discussion). The left hand side is what the banker would lose by having to shut down operations as a consequence. The banker's decision over whether to divert funds must be made at the end of the period t but before the realization of aggregate uncertainty in the following period. Here the idea is that if the banker is going to divert funds, it takes time to position assets and this must be done between the periods (e.g. during the night).

Define recursively the objective of the bank as follows:

$$V_t=\max\beta E_t\{\Lambda_{t,t+1}[(1-\theta)N_{t+1}+\theta V_{t+1}]\},$$

and conjecture the following linear solution in total assets and net worth:

$$V_t=\nu_t\mathcal{W}_t+\eta_t N_t;$$

the incentive constraint thus becomes

$$\nu_t\mathcal{W}_t+\eta_t N_t\geq\lambda_t\mathcal{W}_t.$$

Letting ϕ_t be the maximum ratio of bank total intermediated assets to bank net worth, which we will refer to as the banking/financial sector leverage, it must be that $W_t=\phi_t N_t$. Inserting the latter expression in the guess for V_t in the bank maximization problem we can derive the following expressions defining ν_t and η_t

$$E_t[\Omega_{t+1}(R_{k,t+1}-R_t)]=\nu_t>0,$$
$$E_t(\Omega_{t+1})R_t=\eta_t>1,$$

where

$$\Omega_{t+1}=\beta\Lambda_{t,t+1}[1+\theta(\eta_{t+1}+\nu_{t+1}\phi_{t+1}-1)],$$

can be interpreted as the banker effective discount factor, which differs from the household one $(\beta\Lambda_{t,t+1})$ because of financial frictions.[4] Finally, assuming that constraint binds we have that:

$$\mathcal{W}_t=\frac{\eta_t}{\lambda_t-\nu_t}N_t=\phi_t N_t. \tag{10}$$

This expression is a key equilibrium feature of the banking sector: it indicates that when the borrowing constraint binds, the total quantity of private assets that a bank can intermediate is limited by its net worth. The relation is

[4] In the frictionless economy $\eta_t=1$ and $\nu_t=0$.

intuitive: holding net worth constant, a surge in bank's assets by raising more deposits will reduce profits and the franchise value of the bank, and increase the incentives to divert funds. For positive levels of net worth, the constraint binds only if $\lambda_t > \nu_t > 0$. When this occurs, the leverage ratio is obviously decreasing in λ_t, the fraction of funds banks are able to divert, other things equal. Conversely, leverage is increasing in two factors which raise the charter value of the bank: η_t, the marginal saving in borrowing costs from an extra dollar of net worth; ν_t, namely the discounted excess return on bank (domestic and potentially foreign) assets. Because both these factors raise the bank's charter value, they reduce the incentives to divert funds, making depositors more willing to lend funds. Moreover, in a stochastic environment ν_t and thus equilibrium leverage is also a function of risk. To the extent that the ex-post return on domestic (and possibly foreign) assets comove negatively with the bank discount factor Ω_{t+1}, the more volatile the credit spread $(R_{k,t+1}-R_t)$, the lower ν_t and thus ϕ_t. As argued by GKQ, other things equal increased volatility would reduce the charter value of the bank and thus its ability to borrow.

The incentive constraint does not bind if ν_t increases above λ_t, as the value from intermediation exceeds the gains from absconding with funds. In the equilibria we study the incentive constraint will always bind in a neighborhood of the nonstochastic steady state.

We can derive the aggregate evolution of net worth considering that a fraction $(1-\theta)$ exits the banking sector and an equal fraction of bankers enters the banking sector with starting capital proportional to the assets of the typical incumbent, $\mathcal{N}_{n,t} = \omega\mathcal{W}_{t-1}$. Aggregate net worth in each country (denoted by $\mathcal{N}_t, \mathcal{N}_t^*$) then follows:

$$\mathcal{N}_t = \theta\left[\left[(R_{k,t}-R_{t-1}) - \frac{Q^*_{t-1}s^f_{t-1}}{\mathcal{W}_{t-1}}(R_{k,t}-R^*_{k,t})\right]\phi_{t-1} + R_{t-1}\right]\mathcal{N}_{t-1} + \mathcal{N}_{n,t},$$

and

$$\mathcal{N}^*_t = \theta\left[\left[(R^*_{k,t}-R^*_{t-1}) - \frac{Q_{t-1}s^{h*}_{t-1}}{\mathcal{W}^*_{t-1}}(R^*_{k,t}-R_{k,t})\right]\phi^*_{t-1} + R^*_{t-1}\right]\mathcal{N}^*_{t-1} + \mathcal{N}^*_{n,t},$$

where $s^{h*}_{t-1}(s^{f*}_{t-1})$ represents the amount of loans extended by the typical Foreign bank to Home (Foreign) firms.

Finally, market clearing in the loan markets requires that the value of installed capital be equal to funds provided by banks:

$$Q_t S_t = Q_t(s^h_t + s^{h*}_t)$$
$$Q^*_t S^*_t = Q^*_t(s^f_t + s^{f*}_t)$$

2.4.1. Cross-border financial integration in banking

Here we spell in detail the possible configurations of banking integration across countries we consider in our analysis. On the bank liability side, there are only two possible configurations: (i) country specific deposit rates, when households are restricted to autarky holding only national deposits (and also government bonds); (ii) a common interest rate, when households can hold deposits with foreign and domestic banks, implying that $R_t = R^*_t$.

On the bank asset side, we can also consider the following two polar situations: (i) banks can only lend to firms in their own country; (ii) banks can directly lend to firms in either country. In this latter case we can also introduce the possibility that the agency problem could be more severe for all assets depending on the country origin of the bank (i.e. whether Home or Foreign, $\lambda_t \neq \lambda^*_t$) or on the location of the asset (i.e. whether loans to Home or Foreign firms). This could happen for instance if the fraction of the Foreign assets held by Home banks that can be recovered by depositors in case of default (say, $1-\lambda^f_t$) is lower than the fraction that can be recovered for assets held domestically (i.e. $1-\lambda^h_t$, with $\lambda^f_t > \lambda^h_t$). As we show below, when assets are symmetric in this dimension (i.e. $\lambda^f_t = \lambda^h_t = \lambda_t$), the composition of banks assets is determined according to a standard portfolio choice problem. However, when we look at financial shocks, we will consider cases in which agency problems are not symmetric across countries, namely $\lambda_t \neq \lambda^*_t$.[5]

Clearly, under complete autarky on both assets and liabilities sides, there will be no linkage across countries, whereas the strength of cross-country interdependence will vary with the other configurations. The closest integration will occur when banks have access to the same funding and lending markets, the case on which we focus.

When the incentive constraint for the Home bank is the same as above,

$$V_t \geq \lambda_t(Q^*_t s^f_t + s^h_t Q_t) = \lambda_t \mathcal{W}_t,$$

namely it does not differentiate between assets held domestically and abroad, the FOC with respect to the share of foreign assets in the bank's portfolio, $\alpha^P_t = Q^*_t s^f_t / \mathcal{W}_t$, is given by

$$\alpha^P_t : E_t\{\Omega_{t+1}(R_{k,t+1} - R^*_{k,t+1})\} = 0. \tag{11}$$

[5] We conjecture that, in addition to the asymmetry across banks located in different countries (i.e. owned by households of different nationality), the only other feasible asymmetry could be across assets located in different countries (i.e. loans to firms operating in different countries), implying $(\lambda^f_t - \lambda^h_t)(\lambda^{*f}_t - \lambda^{*h}_t) > 0$.

This equation is a standard portfolio choice condition, dictating the equalization of the risk adjusted return of two assets. As discussed above, the intermediary discount factor Ω_t differs from the household one because of the presence of financial frictions.

From (11) we have that up to first order:

$$E_t(R_{k,t+1} - R^*_{k,t+1}) \simeq 0,$$

so that the portfolio is indeterminate. Note that the foreign country will have an equivalent condition, i.e.

$$E_t\{\Omega^*_{t+1}(R_{k,t+1} - R^*_{k,t+1})\} = 0.$$

By taking the difference between home and foreign asset-pricing equation we have

$$E_t\{(\Omega_{t+1} - \Omega^*_{t+1})(R_{k,t+1} - R^*_{k,t+1})\} = 0. \tag{12}$$

We can find the steady-state portfolio by choosing α^P that makes condition (12) hold true, up to second order of approximation (see Devereux and Sutherland, 2011; Tille and Van Wincoop, 2010). The first order dynamics of the model are affected only by this constant portfolio.

Finally, recall that from the bank first order conditions we have that

$$E_t\{\Omega_{t+1}(R_{k,t+1} - R_t)\} = \nu_t$$
$$E_t\{\Omega^*_{t+1}(R^*_{k,t+1} - R^*_t)\} = \nu^*_t,$$

where ν_t and ν^*_t represent the discounted excess value of bank assets, and

$$E_t\{\Omega_{t+1}\}R_t = \eta_t$$
$$E_t\{\Omega^*_{t+1}\}R^*_t = \eta^*_t,$$

where η_t and η^*_t represent the saving in deposit costs from another unit of net worth. Therefore, when domestic and foreign banks face the same deposit rate $R_t = R^*_t$ and can lend across borders (so that up to first order $E_t(R_{k,t+1} - R^*_{k,t+1}) \simeq 0$), we will have that, up to first order, $\nu_t \simeq \nu^*_t$ and $\eta_t \simeq \eta^*_t$. In turn this implies that also leverage ϕ_t and ϕ^*_t will be equalized up to first order, net of variations in λ_t and λ^*_t:

$$\phi_t - \phi^*_t \simeq \lambda_t - \lambda^*_t.$$

As we illustrate in the next section, this equalization of the endogenous leverage ratio is a crucial cross-border propagation mechanism in this model of financial frictions. As already argued by Dedola and Lombardo (2012), this property is not unique of this specific framework of financial frictions but it is shared by many others (see e.g. Devereux and Yetman, 2010; Perri and Quadrini, 2011).

2.5. Government

Following the standard approach in the public finance literature on government policy, we consider a consolidated government budget constraint, thus abstracting from modeling the specific agency that implements the unconventional policies. Government expenditures, denoted G_t, include (constant) government consumption G and the potential resource costs Γ_t incurred in undertaking unconventional policies such as government purchases of private assets. We denote the outflow due to unconventional policies with AP_t. These outflows are financed through one-period riskless bonds (B_t) held by domestic households, and (lump-sum and potentially distortionary) tax revenues T_t and $\tau_t(1-\alpha)Y_t$:

$$G + \Gamma_t + R_{t-1}B_{t-1} + \tau_t(1-\alpha)Y_t + AP_t = T_t + B_t + \mathcal{L}_t, \tag{13}$$

where recall that $\tau_t \lesseqgtr 0$, depending on whether it is a labor tax or a subsidy. A further source of (net) revenues, L_t, denotes gains or losses from unconventional policies. In Section 4 we will specify functional forms for AP_t, L_t and Γ_t depending on the kind of financial market policy we will consider.

This formulation is standard in the modern public finance literature analyzing government policy, whether monetary policy or fiscal policy or both, see e.g. Chari et al. (2005). However, it is important to recognize that this approach sidesteps many important issues concerning unconventional policies, such as the reason why in fact they have been undertaken mainly by central banks rather than by fiscal authorities. Many of these issues go back to the classic study by Sargent and Wallace (1981), and revolve around coordination problems between fiscal and monetary policy, which are clearly beyond the scope of this paper (see Goodfriend, 2011 for a recent discussion in the context of unconventional policies).

2.6. Aggregate resource constraint and equilibrium

Aggregate world output comprises world household consumption world investment expenditures including investment adjustment costs, and world government consumption, i.e.

$$Y_t + Y^*_t = C_t + C^*_t + G_t + G^*_t + [1 + f_\iota(\cdot)]I_t + [1 + f^*_\iota(\cdot)]I^*_t. \tag{14}$$

By imposing this condition we impose full international trade integration.

3. The international transmission of real and financial shocks

In this section we present impulses responses from the model log-linearized around the steady state, focusing on two kinds of country-specific shocks to the Home country: a real negative shock to the quality of capital, and an unexpected increase in the agency cost parameter λ_t. The first kind of shock is used in a closed economy setting by GK and GKQ to mimic the effects of a "financial crisis"; financial shocks are studied in two-country models by Perri and Quadrini (2011) and Dedola and Lombardo (2012) — the latter look at net-worth and premium shocks in a financial accelerator model) to generate a global recession similar to that observed in 2008–2010 (see e.g. Imbs, 2010).

The stories relating the two shocks to the genesis of the recent financial crisis are as follows. The quality shock can be interpreted as implying that the crisis was really precipitated by the sudden realization that much of the capital (e.g. housing) installed before its inception was of lower quality and much less productive than previously thought. Interestingly, this view implies that because the shock is "efficient" as it shifts inwards the production function, potential output in the aftermath of the crisis is also lower, although not as low as actual output because of financial frictions. Any policy intervention should not result in complete output and employment stabilization in this case.

Conversely, the shock to the fraction of bank assets that can be diverted λ_t, could be viewed as involving a sudden shift of confidence in the financial sector: depositors believe that it is more attractive for bankers to divert funds to themselves and thus default—Perri and Quadrini (2011) actually show how to obtain a sunspot shock to the loan-to-value ratio in a related setting when financing constraints are occasionally binding. Banks respond by restricting both the amount of deposits and loans that they issue out of a fear that depositors would lose confidence and take their money elsewhere. Depositors would do so in the (correct) anticipation that too high a level of bank leverage would cause bankers to abscond with bank assets. From this perspective, a sharp cut in loans that lowers current asset prices and increases banks' expected returns allays the fears of depositors by raising banks' expected profits and providing bankers with an incentive to continue doing business normally. However, the contraction in deposits and loans (often referred to as *deleveraging*) precipitates a credit crunch, a fall in investment and a recession. Clearly, this shock is totally inefficient, and it could turn out to be optimal to stabilize output and employment, particularly if this policy course involved no other cost.

The implications for the international propagation of the shocks of different degrees of financial and banking integration are stark. The key point is that while the country-specific capital quality shock cannot generally induce a truly global recession, even when banks hold a lot of foreign loans on their books, the financial shock instead does bring about a very high degree of macroeconomic synchronization across countries when both deposits and loans markets are integrated. On the other hand, under the latter shock financial flows such as bank assets and deposits always display negative international comovements. These variables instead can be highly correlated across countries in the wake of capital quality shocks when banks hold diversified asset portfolios with a sizable amount of loans abroad. These results thus confirm those in Dedola and Lombardo (2012) and Perri and Quadrini (2011) for TFP shocks vis-à-vis financial shocks, and extend them to capital quality shocks.

3.1. Parameterization

In this subsection we first present our first pass parameterization of the economy and of the shocks, shown in Table 1. Most are quite standard preference and technology parameters, for which we use fairly common values in line with the values used in GK. Indeed a feature of our model is that, assuming a steady state with zero net foreign assets, we do not need to use any open-economy information to calibrate it.

Parameters governing preferences and technology are quite standard. We set $\sigma = 1$, implying that at this stage we use a standard separable utility function with logarithmic consumption, with habit parameter $h = 0.815$; the inverse of the Frisch elasticity is set to 0.276 and the time rate preference $\beta = 0.99$. The capital share in production is $\alpha = 0.33$ and the depreciation rate $\delta = 0.025$. For reasons that will be clear below, in our benchmark economy we assume that adjustment costs of investment take the functional form with $\iota = 0$ and are proportional to past capital stock; however we will also look at results with $\iota = 1$, where adjustment costs are proportional to past investment. In either case, the inverse elasticity of investment to the price of capital is set to 1.728 (as in GK). Finally, the steady state share of government spending is set to 0.2.

The parameters specific to the model are those shaping financial frictions and the properties of the two shocks we consider. Following again GK, we first set the survival probability θ so that the implied average banker's tenure is around 8 years. Second, the values of λ in the nonstochastic steady state, and the value of ω, determining the start up transfer to new bankers are set to target the following values: the spread earned by banks on their assets over deposits is set to be 100 basis points per year, whereas the leverage ratio ϕ is set to 4. Moreover, in the steady state the incentive constraint is binding with equality. Finally, the two shocks to ξ and λ are assumed to follow country-specific, uncorrelated AR(1) processes with autoregressive coefficients equal to 0.66 and 0.8, respectively, and the same standard deviation of innovations, set to 0.05. The parameterization for the capital quality shock is the same as in GK, implying a persistent decline in the marginal product of capital. The parameterization for the lambda shock is such that a one standard deviation shock yields a similar impact response of the spread as the capital quality shock. Note that the empirical evidence seems to attribute most of the variation in credit spreads to shocks specific to the financial sector (see e.g. Gilchrist et al., 2009).

Table 1
Parameterization.

Discount factor	β	0.99
Risk aversion	σ	1
Habits	h	0.815
Relative utility weight of labor	χ	3.40
Inverse Frisch-elasticity of labor supply	φ	0.276
Capital share	α	0.33
Depreciation rate	δ	0.025
Inverse elasticity of investment to the price of capital	η_i	1.728
Government share in GDP	G/Y	0.2
Starting up transfer	ω	0.002
Divertible fraction	λ	0.382
Banker continuation probability	θ	0.972
Standard deviation financial shock	σ_λ	0.05
Standard deviation quality shock	σ_ξ	0.05
Persistence financial shock	ρ_λ	0.8
Persistence quality shock	ρ_ξ	0.66
Steady-state leverage	ϕ	4
Steady-state premium	$(R_K-R)400$	1.00

3.2. Impulse response analysis

We focus on results for the case of full financial integration, in which both the loan and deposit markets are integrated. As a result, there is a common risk-free rate and returns on loans are equalized ex-ante, up to first order of approximation, as explained above. The optimal portfolio composition displays a high degree of diversification, with banks holding roughly half of their assets abroad. For a comparison, foreign assets held by euro area banks (claims against nonneuro area residents) were close to 30% of total assets in 2011. The optimality of a perfectly diversified portfolio is intuitive, as capital quality shocks are not perfectly correlated across countries, while assets pay off are denominated in the same consumption good. However, what is key for propagation is the return equalization and thus the perfect comovement in the credit spreads under full integration. The portfolio holdings will only affect the synchronization in banking assets and liabilities in response to the capital quality shock. Moreover, as it will be clear below, the portfolio composition has no implications for the financial shock, which acts endogenously as a common shock.

Figs. 1 and 2 present the responses to one standard deviation shocks to capital quality ξ_t and to the financial friction parameter λ_t. Importantly, in these experiments we assume there is no policy in place to stabilize financial markets in response to the shocks. This is exemplified by the zero response of the share of government intermediation (ψ_t).

Capital quality shock: Starting first with the negative capital quality shock in the Home country (whose variables are denoted with H) the plain line in Fig. 1 presents the responses of key variables under the optimal bank portfolio composition. To highlight the transmission channels via spread equalization and balance sheet effects, the figure also reports the responses under an ad-hoc portfolio, with banks holding all assets domestically (the circled line). It is clear that this adverse shock brings about a deep and persistent recession, in line with earlier results in GK and GKQ. Highly leveraged Home banks are quite susceptible to the effects on their net worth of the declines in domestic asset values (Tobin's Q) and returns caused by the unexpected decline in capital quality. As a consequence, in the wake of the shock, the spread jumps by around (annualized) 200 basis points and their total loans (assets) fall dramatically. This in turn increases the cost of capital, which leads to a sharp contraction in domestic investment, output and, with a short delay, employment. The trough contraction in domestic output is in excess of 5% of steady state, that in investment over 10%, larger than it would be without financial frictions. The difference of course is due to the sharp widening of the spread that arises in the model with financial frictions. The spread further is slow to return to its steady state value as it takes time for banks to repair their balance sheets and rebuild their net worth—with the latter dropping by around 20% on impact under the optimal portfolio composition. As net worth falls more than bank assets, leverage has to increase. The economy thus recovers slowly: after 40 quarters output is still around 4 per cent below its steady state value. The decline in output and investment is accompanied by a persistent fall in consumption.[6] Also the risk-free rate falls, contributing to widening the spread over the return on investment.

Concerning the spillover to the Foreign country (whose variables are denoted with F), the forces of financial integration bring about an increase in the spread which, has explained above, has to be the same as in the Home country. Note that as a result leverage is also endogenously equalized across countries. However, the same increase in the spread transpires into a smaller (by an order of magnitude) fall in investment, as the Foreign economy is not experiencing any exogenous reduction in the capital stock. Moreover, employment and output instead rise persistently after a small impact decline.

[6] Because of incomplete markets for households and banks, variables slowly converge to a new steady state, where their values though are not very different from the initial ones.

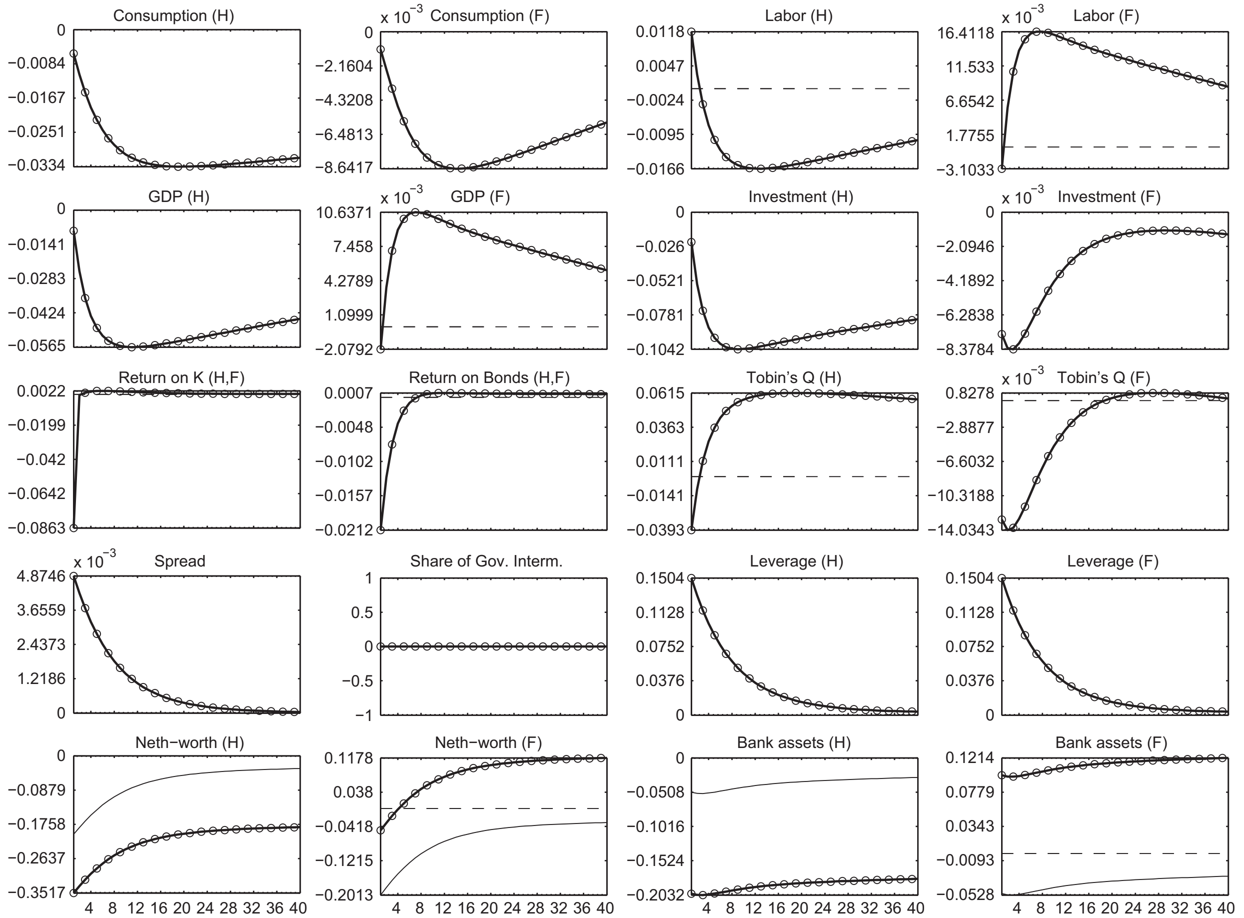

Fig. 1. Response to Home capital quality shock.

Foreign consumption mimics the fall in domestic consumption, implying that the Home country runs a current account deficit. This allows it to cushion the negative consequences of the shock in the Home country, in comparison to what would happen in a closed economy. It is important to stress that the behavior of Home and Foreign bank net worth and assets is a direct consequence of the cross-border composition of their loans. The more diversified internationally their loans, the more similar the behavior across countries of these financial quantities, with little impact however on macroeconomic outcomes. Indeed, when banks are assumed to lend essentially to local firms only (circled line), their net worth and thus their assets move in different directions. Foreign banks in this case increase their total assets and thus replace Home banks in lending to Home firms to some extent. Therefore, the price effects due to financial integration result in synchronization of credit spreads regardless of the share of assets held abroad. The latter mainly affects the international synchronization in financial quantities, when the shock has asymmetric effects across countries.[7]

These results are obtained with the benchmark investment adjustment costs ($\iota = 0$). Adopting the alternative specification ($\iota = 1$) does not have a qualitative impact—the main difference being that the foreign price of capital now increases on impact before falling.[8]

Despite the introduction of financial frictions, the model thus displays an international transmission remarkably similar to frictionless models, particularly concerning the so-called "quantity" puzzle (see Backus et al., 1995). Namely, output and employment comove negatively across countries conditional on the capital quality shock, whereas they tend to be positively (unconditionally) correlated in the data. The correlation in cross-country consumption has the right sign but is counterfactually stronger than correlation of output. Notably, this result occurs in a model with incomplete markets and financial frictions, in contrast with the standard result obtained in frictionless, complete-market economies. The introduction of financial frictions results in a deeper recession in the country experiencing the negative capital quality shock, yet this is not enough to generate a global recession, despite the common increase in the credit spreads.

[7] As documented by Dedola and Lombardo (2012), the composition of balance sheets plays a more substantive role when financial integration is less than perfect, e.g. because $R_t \neq R_t^*$.

[8] Results are not included to save on space, but are available upon request.

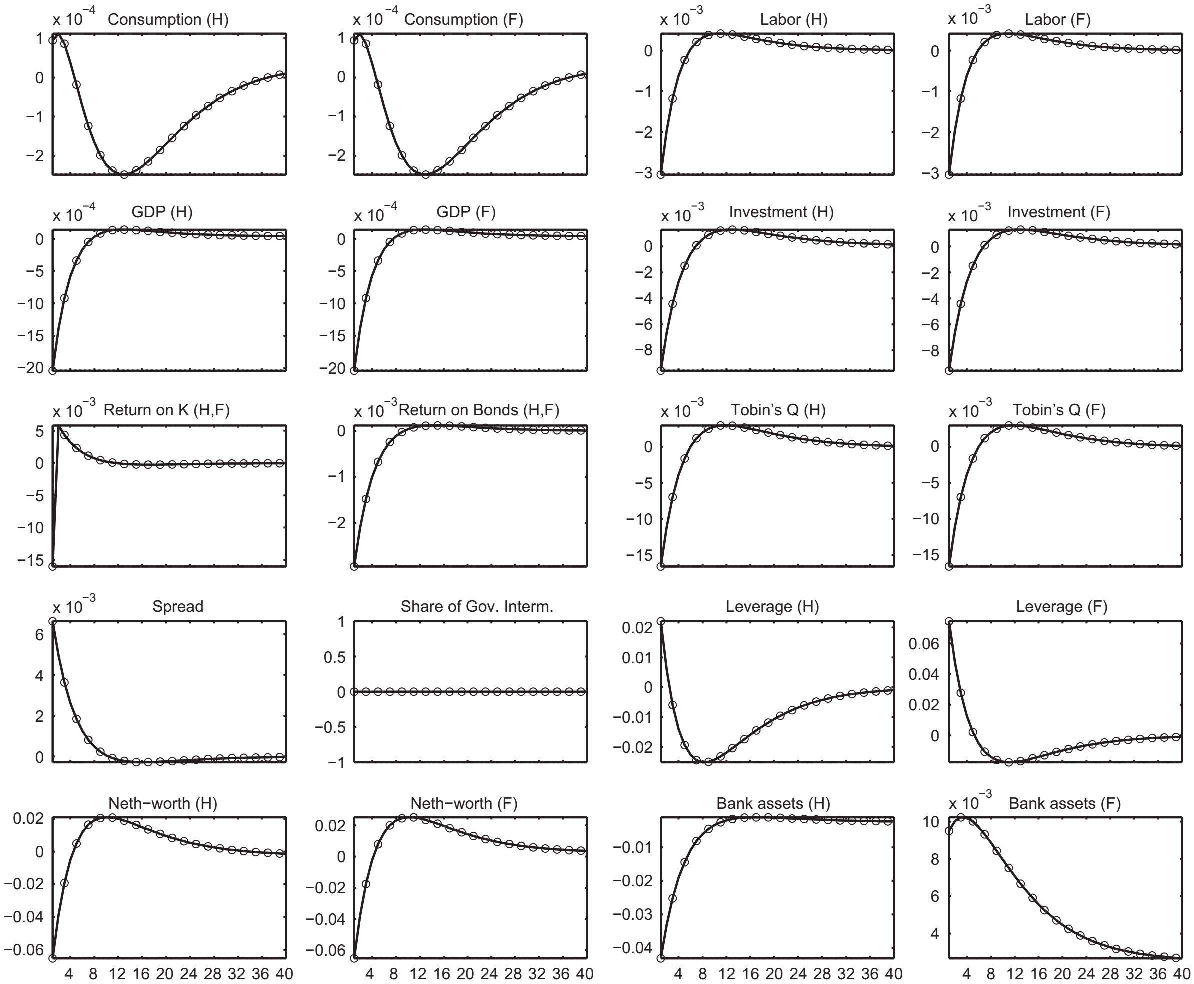

Fig. 2. Response to Home financial shock.

Financial shock: Fig. 2 reports the impulse responses for an adverse (positive) shock to λ_t in the Home country, under (optimal) perfect portfolio diversification only. In contrast with the results above, this idiosyncratic shock now brings about a recession perfectly synchronized across countries. As discussed above, the confidence loss in the Home banking sector due to the perceived increase in the incentive to divert assets sets in motion a process of reduction of financial intermediation, leading to a fall in the amount of deposits and thus also of loans that banks can issue. While the spread they require has to go up to restore the viability of their business, the disintermediation process puts downward pressure on the price of domestic capital. However, because of the tendency to equalization due to financial integration, the climb in the Home spread has to be matched by an equivalent climb abroad. This requires a fall in Foreign asset prices and the result is a global slump in investment, employment, consumption and output which are all perfectly synchronized across countries. However, while the spread is equalized, the (ϕ measure of) bank leverage differs across countries, reflecting the (exogenous) difference in λ_t and λ_t^*, as discussed in the previous section. Foreign leverage has to rise by more than Home leverage, and this can only occur if Foreign banks increase loans and deposits abroad. Since there is no current account deficit, these flows are completely offset by reductions in deposits and loans of Home banks to Home firms.[9] Therefore, the perfect synchronization in credit spreads and macroeconomic variables is not associated with an equally perfect synchronization in banks asset and liabilities, as argued by Perri and Quadrini (2011).[10] These results are independent of the composition of banks assets between domestic and foreign loans. As it should be clear from the above results concerning their transmission, financial shocks effectively act as a global factor, implying that the bank portfolio

[9] Given that the shock has different effects only on bank balance sheet components, these are the only variables that converge to a new steady state.

[10] It would be interesting to consider a shock that makes easier to divert funds invested in assets in the Home country, rather than funds intermediated by Home banks. For instance, this could be justified as reflecting an increase in the perceived "complexity" in the design of the assets, that makes less transparent to distinguish between actual losses or opportunistic behavior by the intermediary.

composition is irrelevant, including for welfare. The assets in our world economy provide no hedge against this kind of aggregate risk. Results are also robust to adopting the alternative specification for investment adjustment costs.

Finally, it is important to stress the different magnitude of the responses to the capital quality shock relative to the financial shock: despite the similar dynamics in credit spreads, the latter have smaller macroeconomic repercussions—-Gilchrist et al. (2009) obtain similar results in an estimated DSGE model á la BGG when comparing the effects of shocks to the credit spread with those of shocks to entrepreneurs net worth. The differences in macroeconomic volatility and international transmission documented so far may have important implications for the desirability of unconventional policies, and for the optimal degree of international coordination of these policies. We turn to the analysis of these policy implications in the next section.

4. Cooperative and self-oriented unconventional policies

We present numerical experiments with a view to illustrate how unconventional policies may be designed to mitigate consequences of shocks in open economies, depending on their degree of international coordination. Intuitively, the presence of financial frictions results into two inefficiencies which can be consequential for welfare. First, the long run level of the capital stock and thus of consumption and hours will be distorted because of the presence of financial frictions. In particular, we know that the capital stock (and consumption) is inefficiently low in the nonstochastic steady state, as we assume that the financial constraint is binding with a positive credit spread. However, what is relevant for (unconditional) welfare is the mean level of variables in the stochastic steady state. The latter will also be affected by volatilities. This brings up the second source of inefficiency, fluctuations in the credit spread in response to both financial and capital quality shocks. On the one hand, these fluctuations may induce excessive volatility relative to the efficient equilibrium without financial frictions, depressing welfare. On the other hand, in the second-best environment we consider, some volatility in the spread can interact with financial frictions to support capital accumulation in a welfare-improving way (e.g. Kolasa and Lombardo, 2011).

Consistent with the binding incentive constraint, we assume policies to be ineffective in the nonstochastic steady state, so that benevolent policymakers cannot do anything directly about this source of distortions. However, the policy tools we consider will affect both the unconditional mean and volatility of the spread, and thus in a stochastic environment they can impinge on both the mean level and the volatility of variables directly relevant for welfare. Hence volatility-reducing policies may also reduce the average level of distortions, such as the unconditional mean of the credit spread. But in our second-best environment, the opposite could also happen, namely that policy-makers face a trade-off, to the extent that a reduction in volatility would result in a lower mean of endogenous variables such as the capital stock. Therefore, there is no ground to a priori expect that unconventional policies are uniformly desirable, making our analysis somehow nontrivial.

Finally, some discussion about the welfare metric we use is in order. We measure welfare consequences of the different policies looking at unconditional measures, as in GKQ.[11] This approach represents an important difference from GK, who instead consider welfare conditional on the realization of an (unexpected, zero probability) adverse shock. This means that the class of policies we consider should be thought of as being in place regardless of the sign and size of the shocks and their effects on credit spreads. However, by introducing appropriate convexity in the shock processes, we could study unconventional policies in environments in which on average shocks are expected to be worse than their steady state values. Credit spreads would be higher relative to their nonstochastic steady state counterparts. Nevertheless, if one is interested in the welfare consequences of unconventional policies in response to adverse shocks that for sure, rather than in expectations, result in wider credit spreads, our analysis would provide a lower bound at best. From such a perspective then, our results could be viewed as still useful to the extent that we find that these policies are unconditionally welfare improving.

4.1. Modeling unconventional policies

Here we analyze the impact of outright public asset purchases (or direct lending to nonfinancial firms) as a mean to mitigate the negative consequences of shocks. Following GK and GKQ, we assume that governments in each country can intermediate a fraction ψ_t of the overall *domestic* funding needs: in terms of the flow budget constraint in Section 2.5, at each point in time government net asset purchases are set so that $AP_t = \psi_t Q_t S$. This implies that we need to amend the market clearing conditions for capital as follows:

$$(1-\psi_t)Q_t S_t = Q_t(s_t^h + s_t^{h*})$$
$$(1-\psi_t^*)Q_t^* S_t^* = Q_t^*(s_t^f + s_t^{f*}).$$

[11] While we share the same unconditional welfare measure as GKQ, we differ in the way we compute it. We use a standard second order approximation around the *nonstochastic* steady state, as e.g. in Benigno and Woodford (2011), which is valid for the small shocks we consider. GKQ instead use a different approach and compute a second order approximation around the *stochastic* steady state (see the appendix in their working paper version).

In turn, the fraction ψ_t of private assets intermediated by the government is adjusted as a function of the difference between the spread $E_t(R_{k,t+1}-R_{t+1})$ and its *nonstochastic* steady state value $(\overline{R}_k-\overline{R})$. Namely in the Home country we assume the following simple feedback rule:

$$\psi_t = \kappa[E_t(R_{k,t+1}-R_{t+1})-(\overline{R}_k-\overline{R})],$$

where a symmetric rule is posited for ψ_t^* in the Foreign country

$$\psi_t^* = \kappa^*[E_t(R_{k,t+1}^*-R_{t+1}^*)-(\overline{R}_k-\overline{R})],$$

The main advantage of modeling credit policy with such a feedback rule is that it is intuitive and parsimonious. It maintains the number of parameters to a minimum, an important advantage when studying noncooperative equilibria.[12] Moreover, the rule captures the fact that the focus of policymakers has been on credit spreads, and that action has been taken by carrying out unconventional policies in response to the emergence of abnormal levels and fluctuations in spreads in various financial market segments. In this respect, to the extent the mean spread is higher than $(\overline{R}_k-\overline{R})$, the rule also aims at acting on the level of credit spreads—beyond the effects induced by reducing volatility. However, the degree to which such a rule would approximate the solution to a (constrained-efficient) Ramsey program could be questioned.

Given our interest in evaluating the consequences from coordinated vs unilateral unconventional policies, we model the policy decision making about the intensity of the reaction to spread fluctuations as follows. In the cooperative equilibrium, the parameters κ and κ^* are jointly chosen to maximize the equally weighted sum of Home and Foreign households lifetime utility, as to fully internalize any policy spillovers across countries. Conversely, we model noncooperative policies by assuming that each government maximizes the domestic agent lifetime utility while taking as given the rule followed by the other country. The equilibrium is thus the Nash outcome. In both cases we use a standard second-order approximation about the nonstochastic steady state to lifetime utility and the model equilibrium conditions to evaluate *ex-ante* global and national welfare for each value of κ and κ^*.

4.1.1. Cost of intervention and government budget constraint

In the benchmark case, the government finances its net asset purchases $\psi_t Q_t S_t$ through government bonds held by households. It also finances its other expenditures through lump-sum taxes, implying the following flow budget constraint:

$$G+\Gamma_t+\psi_t Q_t S_t = T_t+(R_{k,t}-R_{t-1})\psi_{t-1}Q_{t-1}K_{t-1}. \tag{15}$$

It is important to stress that the government policy we consider is such that the so-called Barro–Wallace irrelevance proposition does not apply (see Christiano and Ikeda, 2011). This is so because the government is assumed to be able to purchase private assets without being subject to the same incentive constraint as banks, while raising funds at the same risk-free rate. The government would make extra returns from this policy since the credit spread is positive on average. This aspect is consistent with the observation that unconventional policies have been conducted mainly by central banks, whose relevant counterpart of the model's risk free rate concept would be the rate of remuneration on reserves (their liabilities).[13]

We discussed earlier the possibility that this class of policies may not be optimal in this second best environment, despite the assumed asymmetry in favor of the government. Nevertheless, as a further counterweight we also introduce a cost Γ_t that, as in GKQ, is quadratic in the size of the purchases $\psi_t Q_t S_t$:

$$\Gamma_t \equiv \tau_1\psi_t Q_t S_t+\tau_2(\psi_t Q_t S_t)^2. \tag{16}$$

The benchmark parameterization assumes $\tau_1 = 0.00001$, and $\tau_2 = 0.0001$, implying much smaller costs than in e.g. GKQ. Below, we document the sensitivity of our results to increasing costs more in line with GK and GKQ. The formulation of these costs as (wasteful) government expenditures which absorb output implies they cannot be readily interpreted as reflecting an increase in sovereign borrowing costs due to a rise in government debt – the latter would show as a transfer directly to households. Rather, the interpretation is in terms of resource costs stemming from the (inefficient) public activism in private financial markets.

Alternatively, as suggested by Gertler and Kiyotaki (2010), these costs can be modeled as implying the need to raise part of the funds through distortionary taxes to keep government debt from increasing too much according to some (exogenous) rule. For instance, if we assumed a balanced budget each period we would have the following formulation:

$$G+\psi_t Q_t S_t = R_{k,t1}\psi_{t-1}Q_{t-1}K_{t-1}+\tau_t(1-\alpha)Y_t+T_t, \tag{17}$$

where again $\tau_t \lesseqgtr 0$, depending on whether it is a labor tax or an employment subsidy (see e.g. Brendon et al., 2011).

[12] See e.g. Coenen et al. (2009) for an analysis and comparison of closed-loop and open-loop noncooperative policies in a DSGE model.

[13] Goodfriend (2011) argues that paying an interest rate on reserves has allowed central banks to conduct unconventional policies independently of conventional, interest-rate setting monetary policy.

4.1.2. Liquidity facilities

The above policy of private asset purchases could be thought of as a good first order approximation of measures taken by the Federal Reserve System. As an alternative policy more in line with what central banks like the ECB have done, we could think of the government providing loans $\mathcal{D}_t$ directly to banks at a rate R_t^g, leading to the following modification of the intermediary flow of funds constraint:

$$\mathcal{W}_t = Q_t s_t^h + Q_t^* s_t^f = N_t + D_t + \mathcal{D}_t.$$

Assuming that only the fraction $(1-\lambda^g)\lambda_t$ of assets purchased with government loans $\mathcal{D}_t$ to banks can be diverted

$$V_t \geq \lambda_t(\mathcal{W}_t - \lambda^g \mathcal{D}_t), \tag{18}$$

where $0<\lambda^g \leq 1$ and $\lambda_t(1-\lambda^g)<\lambda_t$, Gertler and Kiyotaki (2010) show that the rate R_t^g should be set according to the following equation:

$$E_t\{\Omega_{t+1}(R_{k,t+1} - R_t^g)\} = (1-\lambda^g)\nu_t, \tag{19}$$

The assumption $\lambda_t(1-\lambda^g)<\lambda_t$ can be rationalized with a superior power by the government to recover the funds in case of bank default. Intuitively, because borrowing public funds allows a bank to expand assets by a greater amount than private deposits, it is willing to pay a premium over the latter.

Assuming the incentive constraint binds, bank assets will be now proportional to net worth and government deposits according to

$$\mathcal{W}_t = \phi_t N_t + \lambda^g \mathcal{D}_t, \tag{20}$$

while the evolution of bank's net worth is given by

$$\begin{aligned} N_t &= Q_{t-1} s_{t-1}^h R_{k,t} + Q_{t-1}^* s_{t-1}^f R_{k,t}^* - R_{t-1} D_{t-1} - R_{t-1}^g \mathcal{D}_{t-1} \\ &= \left[(R_{k,t} - R_{t-1}) - \frac{Q_{t-1}^* s_{t-1}^f}{\mathcal{W}_{t-1}}(R_{k,t} - R_{k,t}^*)\right]\mathcal{W}_{t-1} \\ &\quad -(R_{t-1}^g - R_{t-1})\mathcal{D}_{t-1} + R_{t-1} N_{t-1}, \end{aligned} \tag{21}$$

where recall that the term $(R_{t-1}^g - R_{t-1})$ is positive. In turn, the amount of government funds could be determined according to a feedback rule similar to the one for asset purchases:

$$\begin{aligned} \mathcal{D}_t &= d_t Q_t S_t \\ d_t &= \kappa_d[E_t(R_{k,t+1} - R_t) - (R_k - R)], \end{aligned} \tag{22}$$

resulting in the following obvious modification of the government budget constraint:

$$G + \Gamma_t + d_t Q_t S_t = T_t + (R_{t-1}^g - R_{t-1}) d_t Q_{t-1} K_{t-1}. \tag{23}$$

There is an interesting relation between the policy of asset purchases described above and the liquidity provisions. The former can be thought of as a specific case of a policy of direct lending to banks at a (state-contingent) rate $R_{k,t+1}$, under the assumption that assets bought with public funds cannot be diverted by intermediaries ($\lambda^g = 1$). Therefore, banks only benefit indirectly from the policy via higher asset prices. For values of $0<\lambda^g<1$, banks will further benefit from the possibility of earning a return in excess of the rate on public funds. We leave to future research the analysis of these alternative funding and intervention policies.

4.2. Results for unconventional policies: credit policy rules

Here we report results for the optimized credit policy rules described above, under both cooperation and Nash. Since moderate asset purchases can be welfare improving, unless associated costs are sufficiently large, under cooperation global welfare is in general maximized by positive values of the rule coefficients, κ and κ^*. Conversely, under Nash the degree of intervention is generally lower and could happen that in equilibrium no unconventional credit policies are sustained, resulting in lower welfare than in the cooperative solution. Following GK and GKQ in imposing ad-hoc costs of government intermediation, our model falls short of providing a microfounded source of intervention costs. Nevertheless, it should be apparent that the precise definition of these costs is a key determinant of the quantitative results concerning the optimal credit policy. We find in particular that the quadratic term in the cost function governs the slope (concavity) of the welfare function and hence plays an important role in determining the welfare difference between the Nash and cooperative equilibrium. As we don't have hard evidence on the cost of unconventional policies, we focus on the baseline (small) values for the parameters of the cost function for illustration purposes, and discuss the consequences of changing these values.

To preview our main results, we find that for costs of government intermediation for which credit policy is undertaken, under cooperation generally credit spreads are more stabilized (i.e. larger κ) than the Nash equilibrium, for both capital quality shocks and financial shocks. The welfare gains seem modest, although, as explained above, a more precise quantification of these gains should rely on less ad-hoc measures of the cost of intervention. Moreover, if welfare is initially declining in the credit policy coefficients, the Nash equilibrium can display no intervention, potentially generating larger gains from cooperation.[14]

4.2.1. Capital quality shocks

Starting first with capital quality shocks, for the baseline parameterization we find that cooperative credit policy results in a great deal of stabilization of the spread volatility. Conversely, under the Nash equilibrium the spread is not stabilized at all. Fig. 3 shows the welfare function under the benchmark, where the mean of the capital quality shock is equal to its steady state value of 1. In this case we find that (even for the very small intervention costs we consider) in the Nash equilibrium $\kappa = \kappa^* = 0$. Under cooperation $\kappa = \kappa^* = 140$, and public asset purchases amount to 26% of the capital stock on average. However, the difference in welfare is small (amounting only to 0.002).[15]

The gap between the cooperative and unilateral policy stems from the fact that welfare is not monotone in κ and κ^*. It is initially decreasing for small values of the rule coefficients, but then it starts rising until the costs associated to the implied size of public intermediation become too large. As a result, there is a well defined maximum under cooperation. Relative to the nonintervention case, both the capital stock and consumption are higher on average, the credit spread is lower and closer to its nonstochastic steady state value, and is volatility is basically nil.

It is also useful to examine the impulse responses to the capital quality shock under the cooperative and Nash credit policy, shown in Fig. 4—obviously those under the latter (the circled line) are the same as in Fig. 1. The cooperative credit policy aggressively curb fluctuations in spreads about their averages, amounting to purchases of 4% of the capital stock on impact. However, it does not result in a great deal of macroeconomic and financial stabilization relative to the economy with no unconventional policy. While the spread barely responds to the shock, fluctuations in consumption, hours and output are not too dissimilar from those under Nash. The main impact of the policy on macroeconomic quantities is registered on Foreign investment and asset prices, which now increase initially. The credit policy has a more significant effect on bank balance sheets, cushioning the fall in net worth in the short run and limiting the increase in leverage.

The difference between the Nash and the cooperation outcome is the result of a classic free-riding problem: because asset purchases in the other country entail positive spillovers, they reduce the incentive to undertake costly credit policy domestically. The result is under-provision of financial and macroeconomic stabilization at the global level, for the assumed cost parameterization. As discussed above, the severity of the free-riding problem, and the resulting degree of relative policy inaction, depend on the interplay between the costs of public intermediation and the nonmonotonic shape of welfare.[16]

The fact that welfare initially falls for positive but small values of the policy rule coefficients deserves further discussion. This feature could be entirely accounted for by the behavior of the average spread and its volatility, and by their opposite effects on welfare (negative and positive, respectively). Since both mean and variance of the spread fall monotonically, but not proportionally with respect to the size of the credit policy parameters, their opposite effect on welfare results in the latter being nonmonotonic in κ. For small policy coefficients the detrimental fall in the volatility of the spread dominates the beneficial reduction in the average spread, while the opposite is true for larger coefficients. To understand why this is the case, recall that a key distortion brought about by financial frictions is that too large a spread between the return on capital and the risk free rate depresses capital accumulation. Therefore, reducing the spread on average is welfare improving to the extent that the average capital stock increases. On the other hand, conditional on a positive spread, reducing its volatility could reduce welfare if it results in a lower capital stock (for given variance of the underlying shocks). Indeed this is consistent with the fact that the U-shaped welfare is mirrored by a U-shaped average capital stock, also initially decreasing in the policy coefficient. Therefore, spread volatility seems to be somehow beneficial for the process of capital accumulation in our economy with financial frictions. In particular, in our economy the amount of capital intermediated by the banking sector falls with the average spread and its volatility, reflecting a decline in bank net worth, only partially offset by a rising leverage. Thus, the sustained fall in private intermediation is more than offset only when public intermediation is large enough to result in an increasing capital stock.[17]

Two implications follow. First, although in the benchmark model the trade-off is especially relevant for relatively small values of the rule coefficients, raising the parameters of the cost function of asset purchases, τ_1 and τ_2 (for instance using the values in GKQ), makes the credit policy rule welfare decreasing for any positive value of its coefficients.[18] Second, it turns out that a key

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[14] Given the set-up of the policy game there is no guarantee that the Nash equilibrium be unique. Indeed, by setting intervention costs slightly larger than in our benchmark (but still one order of magnitude smaller than in GKQ), we found two Nash equilibria: the first one with no intervention, and the second one with moderate intervention but implying an even lower welfare. The main conclusion of our analysis would carry over to the case of multiple Nash equilibria: Lack of cooperation can generate welfare-costly policy under-reaction. Therefore, and for ease of exposition, we limit our discussion to a unique Nash equilibrium example.

[15] Given log preferences in consumption, welfare losses are directly interpretable as percentages of permanent nonstochastic steady-state consumption.

[16] In the limit with zero costs the Nash and cooperative policy rule will coincide with the maximum amount of intermediation allowed. Increasing the intermediation costs will decrease the rule coefficients in both cases, but proportionally more for the Nash equilibrium. At some point the Nash rule coefficients will show a discrete change and jump to zero, while they will be still positive under cooperation. Further costs increases will not affect the Nash rule anymore but will reduce the cooperative coefficients, up to the point where they will also jump to the corner at zero.

[17] Unfortunately at this stage we could not disentangle any separate effects of spread mean and variance on bank behavior, as this would require to be able to identify a policy tool to eliminate the steady state distortions arising from financial frictions.

[18] These findings are different from those in GK. In the absence of explicit costs of intervention, larger values of the policy parameter κ imply larger levels of welfare. Some analysis shows that a key difference concerns different assumptions on nominal prices, as GK consider an economy with sticky prices where monetary policy is assumed to follow a conventional Taylor rule. Conversely, the case of flexible prices studied in this paper would correspond in their model to a policy of price stability.

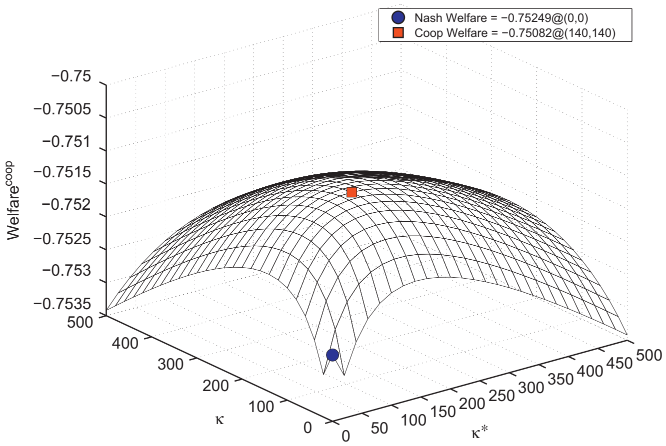

Fig. 3. Welfare under capital quality shocks.

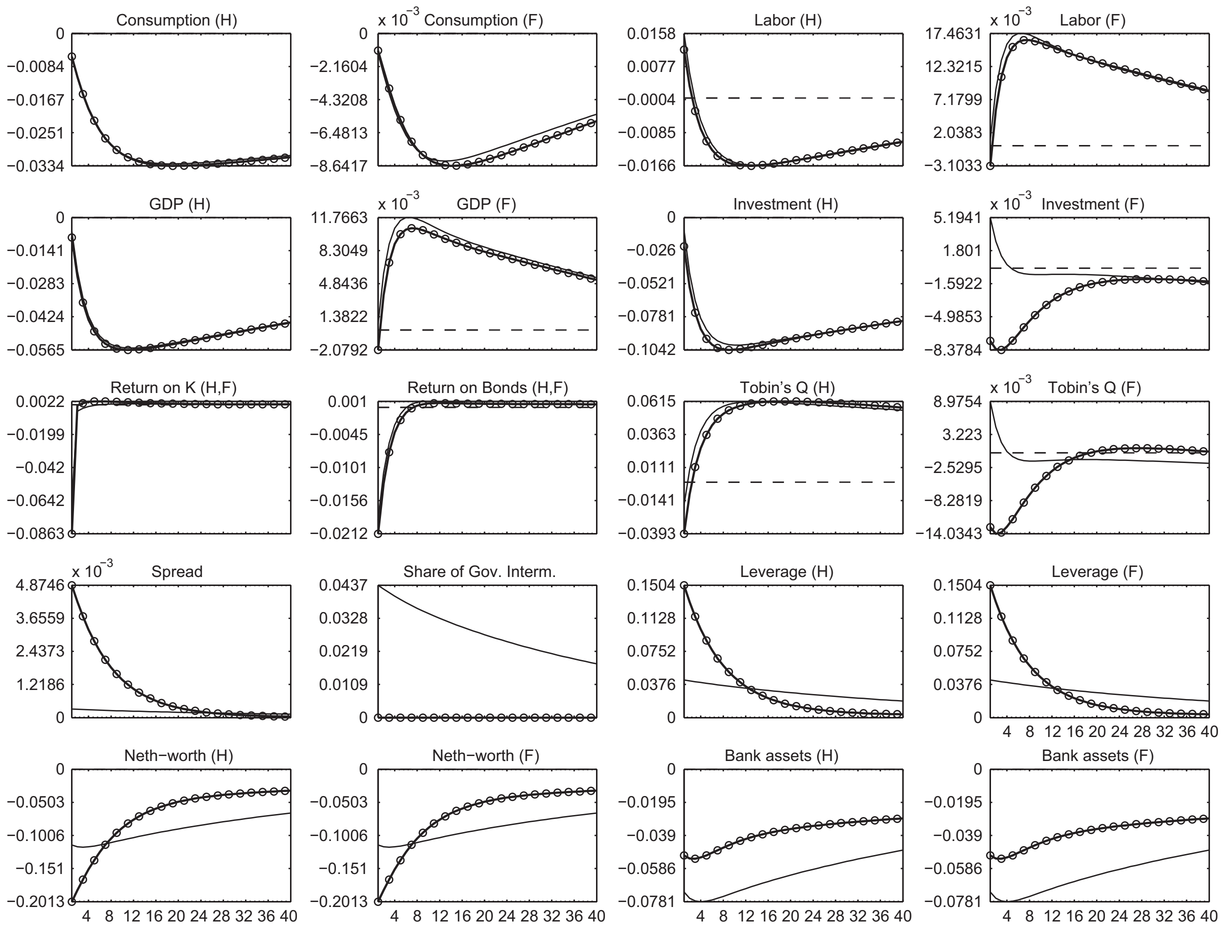

Fig. 4. Cooperative (solid) and Nash (circled) policy under Home capital quality shock.

determinant of the strength of the trade-off is the assumed form of investment adjustment costs. When we model the latter using the specification in Christiano et al. (2005), we find that the trade-off is so pervasive that stabilizing the spread is welfare decreasing in response to capital quality shocks, even with no direct costs (i.e. $\tau_1 = \tau_2 = 0$).[19]

[19] Nevertheless, the logic underlying our findings seems to indicate a simple way to try and modify the rule for asset purchases so as to make it welfare improving (as suggested by our discussant Nobuhiro Kiyotaki, whom we thank for this suggestion). A limit on the amount of funds banks

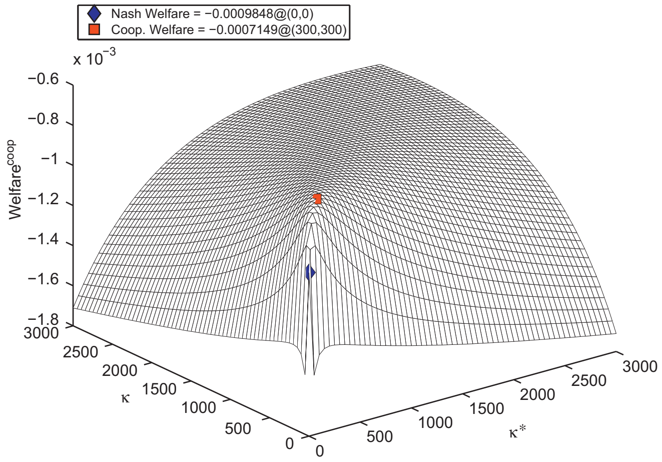

Fig. 5. Welfare under financial shocks.

4.2.2. Financial shocks

Turning to financial shocks, the main finding is that stabilization of the credit spread is welfare improving. Therefore, unless associated costs are large, under cooperation global welfare is in general maximized by positive values of the rule coefficients κ and κ^*. Conversely, under Nash the degree of intervention is generally lower and could happen that in equilibrium $\kappa = \kappa^* = 0$, resulting in lower welfare than in the cooperative solution. However, welfare differences will be generally small. Interestingly, these results do not depend on the form of investment adjustment costs. Moreover, direct costs (τ_1,τ_2) could be as large as those assumed in the literature.

Fig. 5 illustrates the welfare function for the benchmark parameterization with $\iota = 0$, but for higher direct costs $\tau_1 = 0.000125$, $\tau_2 = 0.0012$, similar to GKQ's baseline. In this case, we find that under Nash $\kappa = \kappa^* = 0$, while under cooperation $\kappa = \kappa^* = 300$. Welfare is initially decreasing in κ as before, and start increasing again for relatively small values as the spread volatility falls quickly, along with its average. Because of the associated increasing costs, welfare start decreasing again when the intermediation fraction becomes larger. As a result, there is a well defined maximum under cooperation. Both the capital stock and consumption are larger under the cooperative rule parameters than under Nash, more than compensating for the higher labor effort. The spread is close to nonstochastic steady state level and its volatility is basically zero, while the average fraction of loans intermediated by the government is nil. However, welfare gains are relatively small again.

Fig. 6 presents the impulse responses to the shock λ_t under the cooperative policy—obviously those under Nash (the circled line) are the same as in Fig. 2. By aggressively curbing fluctuations in spreads about their averages, coordinated credit policies lead to a great deal of macroeconomic and financial stabilization relative to the economy with no intervention. The spread barely increases to around (annualized) 2 basis points, while fluctuations in consumption and hours are an order of magnitude smaller than in Fig. 2. This is so with a relative small size of public lending, which amounts to around 2.5% of the steady state capital stock on impact. Bank assets still converge to a new steady state, but to values barely different from the initial ones.

These difference between the Nash and the cooperation outcome results form the same forces discussed above for the capital quality shock, namely the initial nonmonotonicity in welfare and the shape of the cost of asset purchases. However, in the case of the financial shock, the form of the investment adjustment cost does not seem to be a key determinant of these results. Indeed they are qualitatively the same when we adopt the functional form in Christiano et al. (2005). However, also welfare gains from cooperation remain relatively small across specifications, as our financial shocks, while greatly affecting credit spreads, do not bring about large (and costly) macroeconomic fluctuations.

(*footnote continued*)
intermediate could offset the adverse effects of the credit policy. However, this limit should be active only in the stochastic environment and preserve the steady state. We thus consider the following modification to the policy rule by introducing a constant term proportional to the volatility of the capital quality shock σ_ψ^2:

$$\psi_t = \kappa[E_t(R_{k,t+1} - R_{t+1}) - (R_k - R) - \varpi\sigma_\psi^2],$$

where κ is still chosen by maximizing the appropriate welfare criterion under either cooperation and Nash. To the extent that the constant term $\varpi\sigma_\psi^2$ makes the unconditional mean of ψ_t negative, this would act as a sort of capital requirement, by reducing the amount of intermediation per unit of net worth carried out by banks. Unfortunately, even with this modification we have not been able to find a parameterization for which the credit policy is welfare improving for an average reasonable fraction of public intermediation ψ, with investment adjustment costs as in Christiano et al. (2005).

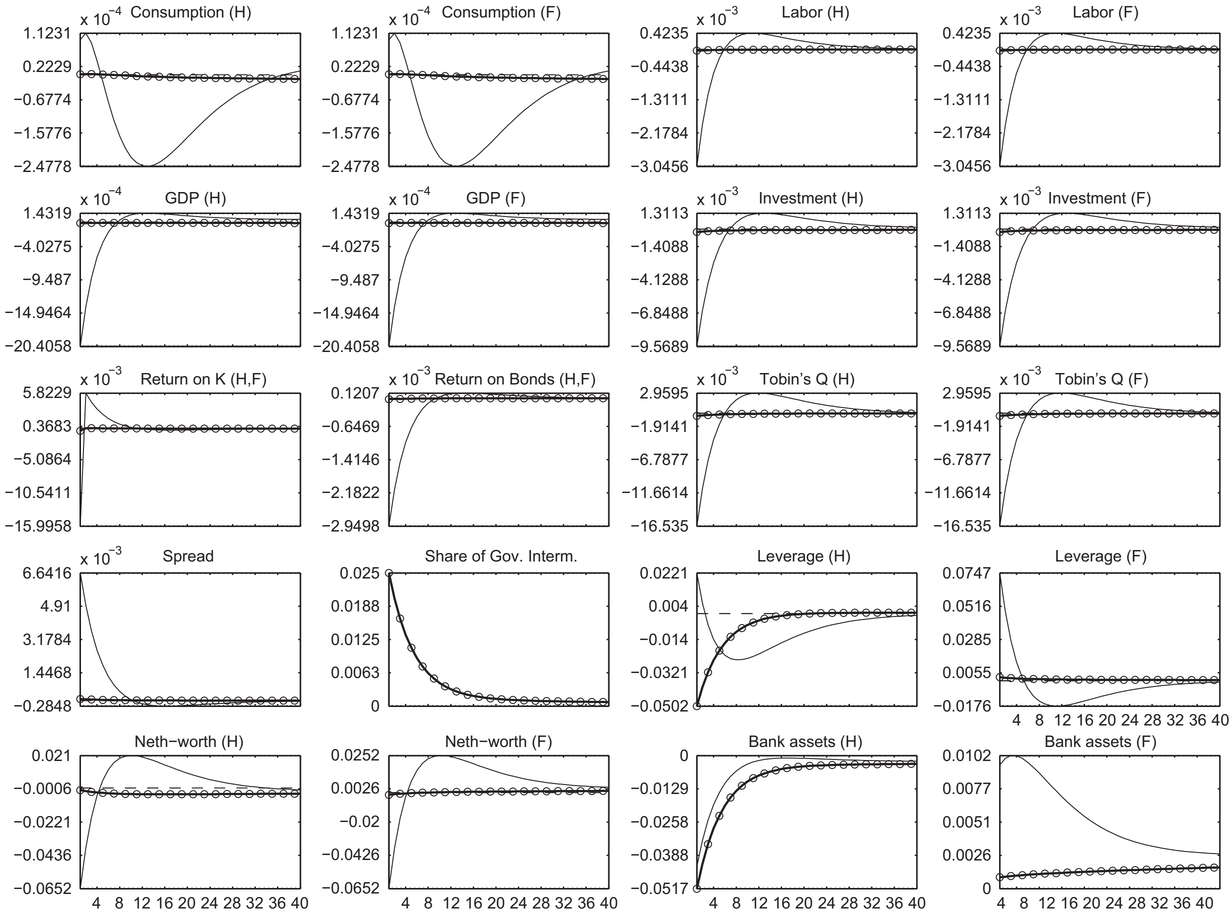

Fig. 6. Cooperative (circled) and Nash (solid) policy under home financial shock.

5. Concluding remarks

There is a presumption that the increasing degree of financial integration spurred on by globalization has resulted in a strengthening of financial channels of international transmission. These channels arguably have featured prominently in precipitating the recent global financial crisis. However, their role is seldom discussed in the analysis of the unconventional policy measures adopted by major central banks and governments in response to the crisis. This paper has argued that a simple model in which financial integration results into more powerful international transmission of country specific shocks has some interesting implications for the global dimension of these unconventional policies. In particular, the very same factors that strengthen the international transmission also imply that, under some circumstances, international coordination of unconventional policies may be especially important. National policies that ignore these transmission channels and do not internalize their international effects may result in an insufficient degree of stabilization in the face of adverse shocks. These findings seem consistent with the observation that international cooperation in the recent crisis has appeared particularly close, including for instance significant coordination among central banks in liquidity management. On the other hand, gains from cooperation should not be expected to be much larger for unconventional policies than for more standard policies. This result however reflects in part the lack of macroeconomic amplification of financial shocks in this model of financial of frictions. A question we leave to future research is to investigate which additional features may improve the model in this dimension.

A key determinant of the welfare differences between outcomes under cooperation and noncooperation turns out to be the direct costs of unconventional policies, which we have modeled in a reduced form. As unfortunately no hard evidence seems so far to be available on these costs, an important avenue for future research would be not only to better quantify these costs, but also to model them endogenously. This is a key step in moving from modeling unconventional policies with simple feedback rules, as we have done in this paper, to an analysis of full-blown constrained-efficient optimal policies.

Another finding that requires further discussion concerns the optimality of asset purchases in response to capital quality shocks. As argued above, we suspect that a key source of discrepancies from influential earlier contributions, e.g. GK, revolves around the presence of other distortions in addition to financial frictions, such as nominal rigidities. In addition, these further distortions could also increase the gains from cooperation. To the extent that unconventional policies may be considered as an alternative to standard monetary policy, such as interest rate setting, rather than as complementary, it may be important to consider how their desirability may depend on the specific objectives of monetary policy, and on their feasibility. From this perspective, a limitation of the analysis of unconventional policies, in this paper, as well as in most of the literature, is that it abstracts from the complex interactions between monetary and fiscal authorities. Obviously, a further interesting aspect would be to investigate how the presence of different national actors interacts with international cooperation.

Of course the paper has not touched upon many other important issues. These would include, for instance, a thorough analysis of the many different policy measures adopted in reality by governments and central banks, such as direct bank liquidity provisions; the potential moral hazard problems raised by the kind of financial market interventions studied here. Regarding the former, we have already sketched a way to study liquidity facilities in our setting. However, an open issue concerns the trade-offs between different kinds of financial and credit market policies. For what concerns the latter, we have already shown that the anticipation of government action to stabilize bank returns may result in higher leverage and financial distortions, even in our simple setting, to the extent that such a credit policy would be suboptimal. These are all important topics for future research.

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