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The Valuation Channel of External Adjustment in Small Open Economies

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Abstract

A common problem in international finance consists of the indeterminacy of the equilibrium asset portfolio in small open economy models. This paper develops a simple approach to compute this portfolio under the assumption of incomplete financial markets. The procedure involves the limiting allocation of a class of two-country world economies where the relative size of one of them tends to zero. Such approach allows to identify the effect of portfolio decisions on the dynamics of the net foreign asset position of a small open economy in a structural fashion. As an illustration, an approximated closed-form solution is obtained for a highly stylized model that is isomorphic to the class of Dynamic Stochastic General Equilibrium (DSGE) models typically used in the literature.

JEL Classification: F32.

Keywords: net foreign assets, endogenous portfolios, small open economies, DSGE models.

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Resumen

Un problema común en finanzas internacionales consiste en la indeterminación del portfolio de activos en equilibrio en modelos de economía pequeña y abierta. El presente documento desarrolla un enfoque simple para calcular dicho portafolio bajo el supuesto de mercado financieros incompletos. El procedimiento involucra la asignación límite de una clase de economías mundiales con dos países en la cual el tamaño relativo de una de ellas tiende a cero. Dicho enfoque permite identificar el efecto de las decisiones de portafolio sobre la dinámica de la posición de activos externos netos de una economía pequeña y abierta de manera estructural. Como ilustración, una solución explícita aproximada es obtenida para un modelo altamente estilizado e isomorfo a la clase de modelos dinámicos y estocásticos de equilibrio general (DSGE) típicamente usados en la literatura.

1 Introduction

The process of international financial integration of the last decades has notoriously increased the response of the countries' net foreign assets to capital gains and losses on external assets and liabilities, also known as the "valuation channel" of external adjustment (Lane and Shambaugh, 2010a), with effects on their corresponding international balance sheets. In particular, this was reflected by the last financial crisis and the rapid spread of its effects through the globalization of banking. Bénétrix et al. (2015) analyzed the recent evolution of international currency exposures, with a special focus on currency-generated valuation effects during the global financial crisis.

Although such effect has always been considered as plausible, its significance has recently grown along with the rapid growth in the volume of cross-border financial holdings. For instance, Bénétrix (2009) computes the valuation channel based on the accounting framework by Lane and Milesi-Ferretti (2007) and found that in advanced economies the international financial integration matters for episodes exhibiting a large valuation even when these economies do not have large net positions, whereas for emerging-market and developing economies such valuations episodes are determined by seizable net external positions and large rates of capital losses. Furthermore, related evidence by Lane and Shambaugh (2010b) on cross-country and time-series variation in aggregate foreign currency exposure reveals that the richer and more open an economy, the longer its foreign-currency position. They also report that a greater propensity for a currency to depreciate during bad times is linked to a longer position in foreign currencies, thus providing a hedge against fluctuations in domestic output.

It is in this regard that there exists a motivation to model the exposure of an economy's net foreign asset dynamics to its aggregate portfolio which in turn reflects the (foreign) currency positions. Indeed, a key requirement for such purpose consists of computing the endogenous country portfolio, although a strand of the literature assumes that portfolio decisions are exogenous (see, for example, Brzoza-Brzezina et al., 2017) for a sake of modeling simplicity.

Specifically, it is required to relax a common assumption in macroeconomics that states that there exist as many state-contingent assets as possible states of nature or, equivalently, that *financial markets for insurable risks are complete*. For economic environments that satisfy such assumption, Modigliani and Miller (1958) conclude that the equilibrium portfolio decisions of agents are irrelevant in the determination of the remaining equilibrium variables. Of course, such conclusion is at odds with the aforementioned empirical evidence.

Nonetheless, in the international macroeconomics literature, rather assuming that there are more risks than can be spanned by international trade in available assets (i.e. *financial markets are incomplete*) for the class of models based on King et al. (1988) has led to the indeterminacy of equilibrium asset portfolios. The reason is that (by construction) all the sources of uncertainty are removed and therefore any risk argument is ruled out in the portfolio determination.

To overcome such problem, Devereux and Sutherland (2011) provide a straightforward solution method that has been extended in several directions, excepting the study of small open economies. In this paper, we extend the aforementioned method to the case of a small open economy asset portfolio. The main appeal of our approach relies on its tractability as it characterizes a small open economy as part of a two-country general equilibrium setting where the other country behaves as a large closed economy in the spirit of Obstfeld and Rogoff (1995). The key result is that the minimum structure to pin-down the small open economy portfolio is given by a non-arbitrage condition for the (atomistic) representative agent of the large economy; which imposes additional structure on the rest-of-the-world variables of open macro models. Also, and rather than providing a general setting, we provide a stylized model which is isomorphic to the class of Dynamic Stochastic General Equilibrium (DSGE) models used by Clarida et al. (1999) for policy analysis. In this stripped-down example, by construction, the relative variability of the endowment shocks affects the asset portfolio (as pointed out by He et al., 2015) of the small open economy in an approximated closed-form expression that resembles the portfolio solution obtained by Merton (1969, equation 25).

Therefore, and related to the latter point, the same example illustrates a tractable way of introducing risk arguments into discrete-time models in a similar way to continuous-time models ranging, for example, from Grinols and Turnovsky (1994) to Bhamra et al. (2014).

The rest of this paper is organized as follows. Section 2 provides a (non-exhaustive) review of related literature. Section 3 describes in detail the economic setup and all the the assumptions therein. Section 4 defines and characterizes the equilibrium notion to be analyzed. Section 5 elaborates on the way the equilibrium is properly approximated. Section 6 explicitly solves the model and analyzes its main properties. Section 7 concludes.

2 Related Literature

In a wide sense, Tovar (2009) pointed out the importance of introducing modeling issues for small open economies or emerging market economies (EME) like relevant economic transmission mechanisms and/or sectors of the economy. According to this author, the way in which financial markets (i.e. financial vulnerabilities) are modeled and that portfolio choice in sticky price models under incomplete financial markets is another area that has not yet been successfully incorporated into mainstream DSGE models, although has become increasingly relevant with financial openness.

Among the recent efforts to incorporate endogenous portfolio choice in a modern macroeconomic DSGE framework, the solution method proposed by Devereux and Sutherland (2011) possesses two major advantages: its easiness of use and its integrability to tools already available to economists like Dynare (see Adjemian et al., 2011). For these reasons, such approach has been widely used in the open macroeconomics literature to compute the so-called steady-state portfolio and its response to the sources of steady-state risk for world economies composed of two equally sized countries.

Also, unlike the perturbation approach by Judd (1996) where the deterministic steady-state is defined as the equilibrium position of the system in absence of shocks (certain equivalence), the notion of steady-state portfolio employed by Devereux and Sutherland (2011) is related to the risky steady-state approach developed by Juillard (2011) where the risky steady-state is defined as the point where, in absence of shocks in the current period, agents decide to stay while expecting shocks in the future and knowing the probability distribution (the risky steady-state is affected by future uncertainty).[1] Finally, from a computational standpoint, the iterative algorithm by Juillard (2011) requires a second-order approximation of the entire dynamical system and, therefore, the risky steady-state is simultaneously determined with the other variables of interest. Such algorithm differs from the three-step method by Devereux and Sutherland (2011), although they deliver equivalent result when applied to portfolio choice problem.

Since its introduction, several extensions have been provided. For example, Okawa and van Wincoop (2012) extend the basic framework to a N-country version in order to study whether a theory of bilateral asset holdings that takes a gravity form can emerge. These authors conclude that very strong assumptions are needed to be made in order to derive such a theory whereas reasonable extensions of the N-country framework no longer generate a gravity form. Also, Bergin and Pyun (2016) generalize the solution method to a N-country setting with $N + 1$ assets and non-zero covariance structure on incomes; and Steinberg (2018) generalizes the solution approach to work for any portfolio choice problem within a many-country, many-asset environment. In a similar fashion, Yu (2015) explores the welfare implications for various countries in a center-periphery framework with endogenous portfolio choice (under several stages of financial integration) when the relative size of one of the economies equals 0.25 out of a unit-mass world. Finally, Heathcote and Perri (2013) employ a more general approach. Specifically, they apply a third-order approximation to the portfolio decision rules and a second-order approximation to the remaining equilibrium conditions as they focus on the portfolio dynamics.

[1] In an alternative interpretation, agents (banks) take the possibility that the worst-case scenario with regard to asset returns is realized into consideration. Consequently, the risks of holding an asset affect banks' portfolio in the steady state (Aoki and Sudo, 2012, 2013).

Nonetheless, the perturbation-based (local) portfolio solution method by Devereux and Sutherland (2011) is not exempt of limitations since, for instance, there is a difficulty with using the method under the presence of borrowing constraints and idiosyncratic income risk as pointed out by Broer (2017). Also, its performance has been compared to global solution methods by Rabitsch and Stepanchuk (2014) who report that the local method performs well at business cycle frequencies, both in the symmetric and asymmetric settings, while significant differences arise at long horizons in asymmetric settings. Moreover, Rabitsch et al. (2015) document that the method by Devereux and Sutherland (2011) 1) does not capture the direct effect of the presence of risk on portfolio holdings and 2) approximates the policy function around net foreign positions equal to zero, even in presence of cross-country differences. For these reasons, Dlugoszek (2017) proposes an algorithm that combines the bifurcation theory and the nonlinear moving average approximation and whose implementation is based on root-finding algorithms and fixed-point techniques.

It is also worth to mention that there exist alternative portfolio solution methods in the literature. For example, Evans and Hnatkovska (2012) propose a numerical procedure that combines both perturbation methods and continuous-time approximations that allows to capture the conditional heteroskedasticity of the state vector and therefore the endogenous non-stationarity that arises when financial markets are incomplete. Such two-step procedure first relies on log-linearization methods and uses an iterative technique afterwards. Gavilán and Rojas (2009) propose a global (projection) solution method that combines the Parametrized Expectations Algorithms (PEA) with the Samolyak algorithms as the standard PEA is computationally unfeasible. Unlike perturbation (local) methods that focus on the steady-state portfolio, this methods has the advantage of allowing for the study of the effect of permanent shocks. Tille and van Wincoop (2010) focus on the time-variation in portfolio allocation by computing a third-order expansion of the optimality conditions for portfolio choice that induces first-order changes in portfolio shares. Finally, Fanelli (2017) develops a technique to approximate the solution around the deterministic steady-state with locally incomplete markets for small open economies.

Given the previous exposition, and as far as we are concerned, from a methodological standpoint perhaps the closest work to ours is given by De Paoli (2009) who characterizes a small open economy framework as the limiting case of a two-country dynamic general equilibrium model, although this is done for a baseline framework exhibiting monopolistic competition, nominal rigidities, and home bias in consumption.

3 The Model

We describe our solution approach through a highly stylized two-country framework based on the seminal work of Obstfeld and Rogoff (1995). The main purpose of such approach is to explicitly show the way in which the agents of the small open economy have the incentive to hedge risks even when both economies (small and large) coincide in all their characteristics excepting for their relative sizes and their corresponding endowment shocks' distributions. Additionally, and for the sake of clarity, the (approximated) closed-form solution obtained illustrates the required steps and their corresponding implications in a transparent way.

Time is discrete ($t = 0, 1, 2, \ldots$) and the world economy is inhabited by a continuum of individuals indexed in the unit interval $[0, 1]$ and arranged into two countries: Home and Foreign. The mass of identical Home individuals equals n whereas the mass of identical Foreign individuals equals $1 - n$ with $0 < n < 1$.[2] Since the relative sizes of the Home and Foreign economies are denoted by n and $1-n$, respectively, the case of a small open economy arises whenever one of those measures tends to zero. For the sake of exposition, and without loss of generality, henceforth we focus on the case in which the Home country constitutes the small open economy ($n \to 0$).

The section A of Table 1 summarizes the decision problem faced by the representative agent of each economy. The corresponding preference relations are defined over streams of consumption in units of the unique good (henceforth, referred to as *in real terms*) and summarized by the summations of expected discounted instantaneous utilities (1) and (2).

[2] Notice that $n = 0$ is ruled out from the analysis.

For the representative Home (Foreign) individual's objective in (1) ([2]), the term C_t (C_t^*) denotes her individual consumption level in period t. Moreover, it is assumed that the instantaneous utility function $u : \mathbb{R}_+ \to \mathbb{R}$ is strictly increasing, strictly concave, twice continuously differentiable and satisfies the Inada conditions $\lim_{x\downarrow 0} u'(x) = +\infty$ and $\lim_{x\uparrow+\infty} u'(x) = 0$. The assumptions regarding the subjective discount factor of Home (Foreign) individuals θ_t (θ_t^*) closely follow Schmitt-Grohé and Uribe (2003). Namely, the specification (3) ([4]) is adopted to guarantee that all the variables are stationary in equilibrium, whereas the term $\bar{C}_t$ ($\bar{C}_t^*$) denotes the "average" consumption per Home (Foreign) individual. The parameters ω, ω^*, η and η^* are all assumed to be strictly positive. Without loss of generality, we further assume $\omega = \omega^*$ and $\eta = \eta^*$ to ensure that Home individuals are as patient as their Foreign counterparts.

The only consumption good is not tradeable once it is owned by individuals (i.e. international trade is ruled out). Nonetheless, there is a way to transfer resources across countries. Specifically, there exist two short-lived one-period assets: Home and Foreign. The gross rate of return on the Home (Foreign) assets is denoted by R_t (R_t^*). Also, let B_t (B_t^*) denote the net real amount of Home assets held by a Home (Foreign) individual at the beginning of period t. The family of budget constraints for each Home (Foreign) individual is displayed in (5) ([6]) where A_t (A_t^*) denotes the real amount of net assets a Home (Foreign) individual starts with at the beginning of period t.[3] The initial conditions A_0 and B_0 (A_0^* and B_0^*) for the Home (Foreign) individual's problem are given. Everyone makes her choices while taking the sequence of gross rates of return $\{R_t, R_t^*\}$ as given.[4] Finally, the term Y_t (Y_t^*) denotes the real endowment per period for a Home (Foreign) individual. Such endowment

[3]Let $\tilde{B}_t$ denote the net real amount of Foreign assets held by a Home individual when the period t starts. The corresponding budget constraint is then given by $C_t + B_{t+1} + \tilde{B}_{t+1} \leq R_t B_t + R_t^* \tilde{B}_t + Y_t$. Since $A_t \equiv B_t + \tilde{B}_t$, some algebraic manipulations allow to obtain (5). An analogous procedure is employed to obtain (6).

[4]For all t and $j \geq 0$, let the discount factor D_{t+j}^* be defined as 1 if $j = 0$ and $\prod_{k=1}^{j} R_{t+k}^{*-1}$ otherwise. For both problems to be well defined, the no-Ponzi game conditions $\lim_{j\uparrow+\infty} E_t \left[D_{t+j}^* A_{t+j+1}\right] \geq 0$ and $\lim_{j\uparrow+\infty} E_t \left[D_{t+j}^* A_{t+j+1}^*\right] \geq 0$ are imposed.

is measured in the same units across countries.

Within the above representation, it is worth to emphasize that the incompleteness of financial markets is reflected in this paper by two properties. First, expression (5) summarizes a collection of budget constraints, one for each realization $(R_t, R_t^*, A_t, B_t, Y_t)$ consisting of returns, a portfolio of assets and an endowment; for each period t. Second, the lack of (contingent) Arrow Securities implies that no individual is able to smooth consumption across states of nature. An identical argument applies to the family of restrictions in (6).

The Home (Foreign) asset is assumed to be a one-period-lived equity claim on a fraction $0 < \alpha < 1$ $(0 < \alpha^* < 1)$ of the Home (Foreign) endowment. The source of uncertainty for the Home (Foreign) economy is summarized by the endowment process $Y_t = Y\exp(u_t)$ $(Y_t^* = Y^*\exp(u_t^*))$ where Y (Y^*) is a positive constant. For the sake of exposition, we assume that $Y = Y^*$. Let $\{u_t\}$ $(\{u_t^*\})$ denote a sequence of independent and identically distributed random variables with zero mean and positive variance σ^2 (σ^{*2}). In period t, and once the uncertainty has been resolved, the real payoff to a claim on Home (Foreign) equity bought in period $t-1$ is given by αY_t $(\alpha^* Y_t^*)$ whereas its real price is denoted by Z_{t-1} (Z_{t-1}^*). Therefore, the gross rate of return on Home (Foreign) assets is given by $R_t = \alpha Y_t / Z_{t-1}$ $(R_t^* = \alpha^* Y_t^* / Z_{t-1}^*)$.[5] We also assume that there is no default risk in either economy.[6]

4 Competitive Equilibrium

The economic environment described above allows to consistently define the corresponding competitive equilibrium as follows (where prices and allocations are expressed in real terms.)

[5]This is implied by the one-period nature of assets whereas the case of a Lucas tree leads to $R_t = \left(Z_t + \alpha Y_t\right)/Z_{t-1}$. Also, the parameters α and α^* reflect the fact that the real return on assets is linked to the amount of (consumption) goods within each economy. In a more general setting this parameter may represent, for instance, the capital's share of output.

[6]Specifically, the conditions $R_t\left\{nB_{t-1} + (1-n)B_{t-1}^*\right\} = n\alpha Y_t$ and $R_t^*\left\{n\tilde{B}_{t-1} + (1-n)\tilde{B}_{t-1}^*\right\} = \left(1-n\right)\alpha^* Y_t^*$ hold for the Home and Foreign economies, respectively.

Definition 1. *A competitive equilibrium is given by sequences of asset prices* $\{Z_t, Z_t^*\}$*, gross rates of return* $\{R_t, R_t^*\}$*, individual allocations* $\{C_t, A_{t+1}, B_{t+1}\}$ *and* $\{C_t^*, A_{t+1}^*, B_{t+1}^*\}$*, and average allocations* $\{\bar{C}_t, \bar{C}_t^*\}$ *such that for all* t*:*

a) Given $\{\bar{C}_t\}$*,* $\{R_t, R_t^*\}$ *and* $\{Y_t\}$*, the Home individual allocations* $\{C_t, A_{t+1}, B_{t+1}\}$ *solve the utility-maximization problem (1) subject to the definition of the discount factor (3), the budget constraints in (5) and the initial conditions* (A_0, B_0)*,*

b) Given $\{\bar{C}_t^*\}$*,* $\{R_t, R_t^*\}$ *and* $\{Y_t^*\}$*, the Foreign individual allocations* $\{C_t^*, A_{t+1}^*, B_{t+1}^*\}$ *solve the utility-maximization problem (2) subject to the definition of the discount factor (4), the budget constraints in (6) and the initial conditions* (A_0^*, B_0^*)*,*

c) The gross returns obey $R_t = \alpha Y_t / Z_{t-1}$ *and* $R_t^* = \alpha^* Y_t^* / Z_{t-1}^*$*,*

d) World net assets equal zero: $nA_t + (1-n)\, A_t^* = 0$ *and* $nB_t + (1-n)\, B_t^* = 0$*, and*

e) For each economy, the average and individual consumption levels are consistent with each other: $\bar{C}_t = C_t$ *and* $\bar{C}_t^* = C_t^*$*.*

The conditions (7)-(18) in section B of Table 1 characterize the competitive equilibrium.[7] Specifically, the expressions (7) and (8) are no-arbitrage conditions that require the corresponding marginal utility of future consumption to be uncorrelated with the future exceeding return.[8] The conditions (9) and (10) are Euler equations where the marginal utility

[7]The complete characterization also requires the following transversality conditions under incomplete financial markets (see Magill and Quinzii, 1994) to hold:

$$\lim_{j \uparrow +\infty} E_t \left[\omega C_t^{-\eta} \frac{u'(C_{t+1})}{u'(C_t)} A_{t+j+1} \right] = 0 \text{ and } \lim_{j \uparrow +\infty} E_t \left[\omega^* C_t^{*-\eta^*} \frac{u'(C_{t+1}^*)}{u'(C_t^*)} A_{t+j+1}^* \right] = 0.$$

[8]There is an alternative interpretation of these conditions: since the Home and Foreign assets constitute competing ways of achieving next period's consumption, they must provide the same discounted expected marginal utility of future consumption. Otherwise, there exist an incentive for re-allocating the portfolio composition towards the asset that provides higher benefits in terms of future utility.

of current consumption equals the discounted expected marginal utility of next period's consumption. It is worth to notice that in equilibrium there is no distinction between individual and average consumption and therefore, by construction, there is also an impatience effect of consumption.[9] The equations (11) and (12) are the (binding) budget constraints that in equilibrium describe, given the equilibrium consumption and portfolio decisions, the evolution of the net asset position for each economy. The expressions (13) and (14) describe the exogenous endowment processes. The link between the (gross) rates of return on assets and their corresponding prices is made explicit in (15) and (16). The market-clearing condition (17) imposes the total amount world net assets to equal zero. Equivalently, any deficit in one economy must be financed by a surplus in the other economy and vice versa.[10] Without loss of generality, in (18) we further assume that the total amount of home net assets equals zero.[11] The reader must remember that, in general, a closed-form solution to these class of models is not feasible to be obtained. For this reason, the use of approximation methods has become customary.[12] Also, and since the distinctive feature of the present stripped-down model is the presence of two assets, henceforth we focus on the equilibrium properties of the sequence of net (real) amount of Home assets held by Home individuals $\{B_t\}$ and particularly on its *unconditional mean* or *steady-state* value B which has a direct effect on the real net asset dynamics. For such purpose, a special emphasis is placed on the implications of the Home and Foreign no-arbitrage conditions (7) and (8) which imply

$$E_t \left\{ \left[u'\left(C_{t+1}\right) - u'\left(C^*_{t+1}\right) \right] \left(R_{t+1} - R^*_{t+1} \right) \right\} = 0. \tag{31}$$

[9]In each case, the condition e of Definition 1 and the definitions of θ_t and θ^*_t are already embedded.

[10]That is, the entire world behaves as a closed economy for any $0 < n < 1$.

[11]This assumption is made as it allows, along with the no-default assumption, the budget constraints and the zero-world-net-assets identity, to derive the resource constraint for the entire world economy

$$nC_t + (1-n)\, C^*_t = nY_t + (1-n)\, Y^*_t.$$

[12]King et al. (1988) and Campbell (1994) adopt this approach within the business cycle literature. For the international macroeconomics literature, the study by Obstfeld and Rogoff (1995) constitutes a pioneer work.

Table 1: Model summary

A. Household problem			
$\max_{\{C_t,A_{t+1},B_{t+1}\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \theta_t u(C_t)$ subject to	(1)	$\max_{\{C_t^*,A_{t+1}^*,B_{t+1}^*\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \theta_t^* u(C_t^*)$ subject to	(2)
$\theta_{t+1}=\theta_t\omega\bar{C}_t^{-\eta}$, $\theta_0=1$	(3)	$\theta_{t+1}^*=\theta_t^*\omega^*\bar{C}_t^{*-\eta^*}$, $\theta_0^*=1$	(4)
$C_t+A_{t+1}\le R_t^*A_t+(R_t-R_t^*)B_t+Y_t$	(5)	$C_t^*+A_{t+1}^*\le R_t^*A_t^*+(R_t-R_t^*)B_t^*+Y_t^*$	(6)
B. Equilibrium			
Financial sector:			
$E_t\left[u'(C_{t+1})(R_{t+1}-R_{t+1}^*)\right]=0$	(7)	$E_t\left[u'(C_{t+1}^*)(R_{t+1}-R_{t+1}^*)\right]=0$	(8)
Non-financial sector:			
$u'(C_t)=E_t\left[\omega C_t^{-\eta}u'(C_{t+1})R_{t+1}^*\right]$	(9)	$u'(C_t^*)=E_t\left[\omega^* C_t^{*-\eta^*}u'(C_{t+1}^*)R_{t+1}^*\right]$	(10)
$C_t+A_{t+1}=R_t^*A_t+(R_t-R_t^*)B_t+Y_t$	(11)	$C_t^*+A_{t+1}^*=R_t^*A_t^*+(R_t-R_t^*)B_t^*+Y_t^*$	(12)
$Y_t=Y\exp(u_t)$	(13)	$Y_t^*=Y^*\exp(u_t^*)$	(14)
$R_t=\alpha Y_t/Z_{t-1}$	(15)	$R_t^*=\alpha^*Y_t^*/Z_{t-1}^*$	(16)
$nA_t+(1-n)A_t^*=0$	(17)	$nB_t+(1-n)B_t^*=0$	(18)
C. Equilibrium (approximation)			
Financial sector:			
$E_t[(r_{t+1}-r_{t+1}^*)-\rho c_{t+1}(r_{t+1}-r_{t+1}^*)]=0+\mathcal{O}(\epsilon^3)$	(19)	$E_t[(r_{t+1}-r_{t+1}^*)-\rho c_{t+1}^*(r_{t+1}-r_{t+1}^*)]=0+\mathcal{O}(\epsilon^3)$	(20)
Non-financial sector:			
$-\rho c_t=E_t\left[-\eta c_t-\rho c_{t+1}+r_{t+1}^*\right]+\mathcal{O}(\epsilon^2)$	(21)	$-\rho c_t^*=E_t\left[-\eta c_t^*-\rho c_{t+1}^*+r_{t+1}^*\right]+\mathcal{O}(\epsilon^2)$	(22)
$\frac{C}{Y}c_t+a_{t+1}=\frac{1}{\beta}a_t+\frac{B}{\beta Y}(r_t-r_t^*)+y_t+\mathcal{O}(\epsilon^2)$	(23)	$\frac{C^*}{Y^*}c_t^*+a_{t+1}^*=\frac{1}{\beta}a_t^*+\frac{B^*}{\beta Y^*}(r_t-r_t^*)+y_t^*+\mathcal{O}(\epsilon^2)$	(24)
$y_t=u_t+\mathcal{O}(\epsilon^2)$	(25)	$y_t^*=u_t^*+\mathcal{O}(\epsilon^2)$	(26)
$r_t=y_t-z_{t-1}+\mathcal{O}(\epsilon^2)$	(27)	$r_t^*=y_t^*-z_{t-1}^*+\mathcal{O}(\epsilon^2)$	(28)
$nYa_t+(1-n)Y^*a_t^*=0+\mathcal{O}(\epsilon^2)$	(29)	$nB+(1-n)B^*=0$	(30)

In (31), since (in equilibrium) the marginal utilities of consumption within each economy (Home and Foreign) are uncorrelated with the differential of returns (conditions [7] and [8]), it must be the case that the differential of marginal utilities of future consumption is in turn uncorrelated with the differential of returns. It is worth to emphasize that the condition (31) constitutes the key expression for computing the approximated equilibrium portfolio since it provides a necessary condition that filters out otherwise potential candidates.

5 Approximation

The previous characterization is isomorphic to the class of Dynamic Stochastic General Equilibrium (henceforth, DSGE) models as it comprises utility-maximizing agents and market-clearing conditions. Also, it is well known that the solution of the previous class of models is computed up to an approximation order chosen by the researcher. For such purpose, we take Taylor expansions around the *steady state* of the model, which is equivalent to applying conventional log-linearization methods (see Uhlig, 1999). Firstly, let

$$x_t \equiv \frac{X_t - X}{X}$$

denote, otherwise mentioned, the percent deviation of X_t from its steady state value $X > 0$. Also, for future reference, let $\mathcal{O}(\epsilon^j)$ denote "terms of j-th order and higher." The expressions (19)-(29) in section C of Table 1 summarize the approximation of the conditions (7)-(17) that characterize the competitive equilibrium, respectively, along with (30) which constitutes the steady state version of (18). Within such representation, $\rho \equiv -Yu''(Y)/u'(Y) > 0$ denotes the relative risk aversion coefficient evaluated at the steady state value of the endowment process and $\beta \equiv \omega Y^{-\eta} \in (0,1)$ denotes the steady state discount factor. Following Devereux and Sutherland (2011), a second-order approximation is taken for only the so-called "Financial sector" conditions (7) and (8) which leads to (19) and (20). The main argument is that a first-order approximation implicitly reduces economic agents to be risk-neutral and care only about expected future returns, regardless of risk. Nonetheless, risk-aversion arguments are needed to pin down the equilibrium portfolio.[13] Standard first-order approximations are taken for the remaining conditions (9)-(17) and lead to (21)-(29) where the net asset position deviations are written as $a_t \equiv (A_t - A)/Y$ and $a_t^* \equiv (A_t^* - A^*)/Y^*$.

Up to this point, the reader should notice that the approximated characterization in section C of Table 1 differs in certain ways from the standard approach used in the literature. However, the minimalist representation therein allows us to elaborate on the minimum structure required for computing the small open economy's equilibrium portfolio.

[13]For the case of the two-country framework, Tille and van Wincoop (2010) provide an alternative solution method that relies on fixed-point arguments.

6 Closed-Form Solution

In addition to the details of the previous section, we introduce a new insight into the analysis. Specifically, notice that a significant branch of the relevant literature has typically worked out models by directly imposing the small open economy assumption (that is, $n = 0$ is further assumed) along with exogenous processes for the rest-of-the-world variables (variables with a star superscript). Proceeding in such fashion is not innocuous as there is relevant structure that is implicitly and key to consistently solve the model for the variables of interest. On the contrary, the structure imposed on external variables becomes relevant.[14] To fully understand this, we compare it to other approaches. First, consider a situation in which we approximate the equilibrium such that it implicitly assumes risk-neutral agents and exogenous rest-of-the-world variables. Such case arises if we only relied on the *Uncovered Interest Parity* $E_t[r_{t+1} - r^*_{t+1}] = 0 + \mathcal{O}(\epsilon^2)$ instead of (19) and imposed exogenous autoregressive processes describing the external variables. It is easy to show that in this case the Home portfolio remains undetermined (i.e. there is still one degree of freedom) because it is implicitly assumed that the decision makers are risk neutral at the margin. Second, consider an approximation that considers risk-averse Home agents (condition [19]) and assumes an exogenous autoregressive process for the rest-of-the-world variables. Once again, it is easy to show that computing the solution requires the use of numerical methods as a non-linearity arises.

6.1 Solving the large closed economy's non-financial sector

Finally, we focus back on the structural framework with risk-averse Home and Foreign agents originally considered. As usual, the Foreign economy behaves like a closed economy as $n \to 0$ and therefore a closed-form solution can be obtained for the steady state ratio $B/(\beta Y)$. Specifically, for any $0 < n < 1$, substitute the Foreign holdings of Home assets $B^* = -[n/(1-n)]B$ from the market-clearing condition (30) into the Foreign economy's

[14] This has been previously done in the literature (for example, Faia and Monacelli (2008)), although with different purposes.

future net assets a^*_{t+1} in (24) to obtain

$$a^*_{t+1} = \frac{1}{\beta}a^*_t - \left(\frac{n}{1-n}\right)\frac{B}{\beta Y}(r_t - r^*_t) + y^*_t - \frac{C^*}{Y^*}c^*_t + \mathcal{O}(\epsilon^2), \tag{32}$$

and notice that, by construction, the effect of the portfolio composition $B/(\beta Y)$ of Home variables on a^*_{t+1} vanishes as $n \to 0$. Also, notice that this departs from the common practice of setting $n = 1/2$ based on previous studies (as mentioned by Trani, 2012). On the other hand, the market-clearing condition (29), after taking $n \to 0$, collapses to $a^*_t = 0 + \mathcal{O}(\epsilon^2)$ (i.e. world net assets are zero) which in turn reduces (32) to $c^*_t = y^*_t + \mathcal{O}(\epsilon^2)$ (i.e. the rest of the world only consumes its own endowment). To compute the equilibrium assets' returns and prices, substitute the former result into (22) to obtain $E_t r^*_{t+1} = -(\rho - \eta)u^*_t + \mathcal{O}(\epsilon^2)$ which in turn implies by (28) that $z^*_t = (\rho - \eta)u^*_t + \mathcal{O}(\epsilon^2)$.

Once a partial solution is computed for the rest of the world (a large closed economy), the solution procedure for the small open economy is summarized as follows:

> *Step 1.* Provided with the (already computed) solution for the rest-of-the-world variables, solve the small open economy's "Non-financial sector" conditions (21), (23), (25), (27) and (29) which are based on a first-order approximation. As expected, the results will depend on the still undetermined portfolio ratio $B/(\beta Y)$.
>
> *Step 2.* Use the results from *Step 1* to solve for the steady state portfolio ratio that satisfies the approximated version of (31) that is implied by the "Financial sector" conditions (19) and (20).

6.2 Solving the small open economy's non-financial sector

For the small open economy, the budget constraint (23) (after substituting the endowment process [25]) and the Euler equation (21) can be represented in compact form by

$$\begin{bmatrix} a_{t+1} \\ E_t c_{t+1} \end{bmatrix} = \underbrace{\begin{bmatrix} 1/\beta & -1 \\ 0 & 1-\eta/\rho \end{bmatrix}}_{\mathbf{A}} \begin{bmatrix} a_t \\ c_t \end{bmatrix} + \underbrace{\begin{bmatrix} 1 & 0 & 1 \\ 0 & -(1-\eta/\rho) & 0 \end{bmatrix}}_{\boldsymbol{\gamma}} \begin{bmatrix} u_t \\ u_t^* \\ \frac{B}{\beta Y}\xi_t \end{bmatrix} + \mathcal{O}(\epsilon^2) \quad (33)$$

where $\xi_t \equiv r_t - r_t^*$ denotes the exceeding return. Moreover, up to a first-order approximation the *Uncovered Interest Parity* $E_t[r_{t+1} - r_{t+1}^*] = 0 + \mathcal{O}(\epsilon^2)$ holds and in the particular case of this model the exceeding return is expressed as the differential of endowment shocks:

$$r_t - r_t^* = u_t - u_t^* + \mathcal{O}(\epsilon^2) \quad (34)$$

for all t (see Appendix A). In (33), since the entries of the principal diagonal of $\mathbf{A}$ satisfy $|1/\beta| > 1$ and $|1 - \eta/\rho| < 1$, and there is only one non-predetermined variable (Home consumption c_t), the conditions of Blanchard and Kahn (1980, Proposition 1) are met and the unique forward-looking solution for c_t is given by (see Appendix B)

$$\begin{aligned} c_t \;=\; & \left[\frac{1}{\beta} - \left(1 - \frac{\eta}{\rho}\right)\right] a_t + \left[1 - \beta\left(1 - \frac{\eta}{\rho}\right)\right] u_t \\ & + \beta\left(1 - \frac{\eta}{\rho}\right) u_t^* + \left[1 - \beta\left(1 - \frac{\eta}{\rho}\right)\right] \frac{B}{\beta Y}\xi_t + \mathcal{O}(\epsilon^2). \end{aligned} \quad (35)$$

As previously mentioned, such *partial* state-space representation for c_t still depends on a particular steady state value $B/(\beta Y)$ (i.e. there is one degree of freedom).

6.3 Non-stochastic steady state portfolio

On the other hand, it is worth to notice that the expressions (19) and (20) imply

$$E_t\left[-\rho\left(c_{t+1} - c_{t+1}^*\right)\left(r_{t+1} - r_{t+1}^*\right)\right] = 0 + \mathcal{O}(\epsilon^3). \quad (36)$$

which approximates the condition (31) that, once again, states that if each marginal utility of consumption (Home and Foreign) is uncorrelated with the exceeding return, then it has to be the case that the differential of marginal utilities of consumption across countries must be uncorrelated with the differential of returns as well. Notice that the left-hand side of (36) constitutes a second moment expressed as the product of two first order terms that can in turn be computed separately: $c_{t+1} - c^*_{t+1}$ and $r_{t+1} - r^*_{t+1}$. Given this property, substituting (34), (35) and the already obtained result for the consumption of the large closed economy $c^*_t = u^*_t + \mathcal{O}(\epsilon^2)$ into (36) and solving for $B/(\beta Y)$ leads to (see Appendix C)

$$\frac{B}{\beta Y} = -\frac{1}{1 + \sigma^2/\sigma^{*2}} + \mathcal{O}(\epsilon^3) \tag{37}$$

which is an expression that resembles the one obtained by Merton (1969, equation 25) under the case of instantaneous utility functions exhibiting a constant relative risk aversion coefficient.

Some comments are in order. First, since this constitutes a one-good world economy, the expression (37) suggests a bias towards Foreign assets. A simple explanation lies in the fact that, since (in steady state) the net assets are equal to zero and the fluctuations in asset prices are determined by the Foreign economy, the Home individuals have the incentive to hedge risks by holding long positions in Foreign assets that are financed with short positions in Home assets. However, such result is at odds with empirical evidence reporting that many country portfolios remain heavily biased toward domestic assets, a fact referred to as the *international diversification puzzle* (see, for example, Heathcote and Perri, 2013). Second, and given the previous description, the expression (37) allows to assert that *ceteris paribus* an increase in the volatility of the Home assets (higher σ^2) makes the Foreign assets relatively more attractive which in turn makes the short position in Home assets larger in absolute value. Finally, the prior results can be used to express the behavior of the relevant variables (c_t and a_{t+1}) through a state-space representation:

$$\begin{aligned} c_t &= \left[\frac{1}{\beta} - \left(1 - \frac{\eta}{\rho}\right)\right] a_t + \left[1 - \beta\left(1 - \frac{\eta}{\rho}\right)\right] u_t \\ &\quad + \beta\left(1 - \frac{\eta}{\rho}\right) u^*_t + \left[1 - \beta\left(1 - \frac{\eta}{\rho}\right)\right] \frac{B}{\beta Y}(u_t - u^*_t) + \mathcal{O}(\epsilon^2), \end{aligned} \tag{38}$$

$$a_{t+1} = \underbrace{\frac{1}{\beta} a_t}_{\text{wealth effect}} + \underbrace{\frac{B}{\beta Y}(u_t - u^*_t)}_{\text{composition effect}} + \underbrace{u_t}_{\text{endowment}} - \underbrace{c_t}_{\text{consumption}} + \mathcal{O}(\epsilon^2). \tag{39}$$

which provides a structural analysis of the small open economy's current account. In particular, in (39) it can be seen that besides the usual *wealth effect* (higher wealth leads to higher returns) the relative volatility of shocks has not only a direct effect through the so-called *composition effect* but also an indirect effect through the response of consumption in (38).

7 Conclusions

Although highly stylized, the two-country framework in this paper contains two key elements in the class of Dynamic Stochastic General Equilibrium (DSGE) models. Namely, an Euler equation and a law of motion for each economy. The main difference relies on the introduction of marginal conditions that pin down the equilibrium country portfolio. Within these margins, the risk component (contained in the second moments of real returns) is not neglected anymore. This so happens because the approximation order employed does not preclude that decisions are taken by risk-neutral agents. Therefore, the indeterminacy of the equilibrium portfolio no longer holds. Finally, from a macroeconomic standpoint, the present paper allows not only to assess the relevance of the "valuation channel" (as stressed out by Curcuru et al., 2011) but to make it consistent with the fact that fluctuations in financial wealth are also important.

Appendix A Exceeding returns

The conditions (19) and (20) lead to

$$E_t\left[r_{t+1}-r^*_{t+1}\right]=0+\underbrace{E_t\left[\rho c_{t+1}\left(r_{t+1}-r^*_{t+1}\right)\right]+\mathcal{O}(\epsilon^3)}_{\mathcal{O}(\epsilon^2)} \tag{A.1}$$

and

$$E_t\left[r_{t+1}-r^*_{t+1}\right]=0+\underbrace{E_t\left[\rho c^*_{t+1}\left(r_{t+1}-r^*_{t+1}\right)\right]+\mathcal{O}(\epsilon^3)}_{\mathcal{O}(\epsilon^2)} \tag{A.2}$$

which imply that, up to a first-order approximation, the sequence of future exceeding returns $\left\{r_{t+1}-r^*_{t+1}\right\}$ behaves as a sequence of zero-mean random variables.

For the specific model under consideration, the conditions (25), (26), (27) and (28) imply

$$r_{t+1} = u_{t+1}-z_t+\mathcal{O}(\epsilon^2) \tag{A.3}$$

$$r^*_{t+1} = u^*_{t+1}-z^*_t+\mathcal{O}(\epsilon^2). \tag{A.4}$$

Conditions (A.2), (A.3) and (A.4) imply that $z_t=z^*_t+\mathcal{O}(\epsilon^2)$ for all t which in turn implies

$$r_t-r^*_t=u_t-u^*_t+\mathcal{O}(\epsilon^2),\text{ for all } t. \tag{A.5}$$

Appendix B Equilibrium consumption

In equation (33), define

$$\mathbf{A}=\begin{bmatrix} 1/\beta & -1 \\ 0 & 1-\eta/\rho \end{bmatrix} \text{ and } \boldsymbol{\gamma}=\begin{bmatrix} 1 & 0 & 1 \\ 0 & -(1-\eta/\rho) & 0 \end{bmatrix}.$$

Then, it is easy to verify that $\mathbf{A} = \mathbf{BJC}$ where

$$\begin{aligned}
\mathbf{B} &= \begin{bmatrix} \mathbf{B}_{11} & \mathbf{B}_{12} \\ \mathbf{B}_{21} & \mathbf{B}_{22} \end{bmatrix} = \begin{bmatrix} \frac{1}{1/\beta-(1-\eta/\rho)} & 1 \\ 1 & 0 \end{bmatrix}, \\
\mathbf{J} &= \begin{bmatrix} \mathbf{J}_1 & 0 \\ 0 & \mathbf{J}_2 \end{bmatrix} = \begin{bmatrix} 1-\eta/\rho & 0 \\ 0 & 1/\beta \end{bmatrix} \text{ and} \\
\mathbf{C} &= \begin{bmatrix} \mathbf{C}_{11} & \mathbf{C}_{12} \\ \mathbf{C}_{21} & \mathbf{C}_{22} \end{bmatrix} \begin{bmatrix} 0 & 1 \\ 1 & -\frac{1}{1/\beta-(1-\eta/\rho)} \end{bmatrix}.
\end{aligned}$$

Also, define

$$\boldsymbol{\gamma} \equiv \begin{bmatrix} \gamma_1 \\ \hdashline \gamma_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1 \\ \hdashline 0 & -(1-\eta/\rho) & 0 \end{bmatrix}. \tag{B.1}$$

The forward-looking solution for c_t is implied by the equation (3) in Blanchard and Kahn (1980), which leads to equation (35) in text.

Appendix C Equilibrium portfolio

The solution in (35), along with $c_t^* = u_t^* + \mathcal{O}(\epsilon^2)$, implies that

$$\begin{aligned}
c_{t+1} - c_{t+1}^* &= \left[\frac{1}{\beta} - \left(1 - \frac{\eta}{\rho}\right)\right] a_{t+1} \\
&\quad + \left[1 - \beta\left(1 - \frac{\eta}{\rho}\right)\right] u_{t+1} - \left[1 - \beta\left(1 - \frac{\eta}{\rho}\right)\right] u_{t+1}^* \\
&\quad + \left[1 - \beta\left(1 - \frac{\eta}{\rho}\right)\right] \left(\frac{B}{\beta Y}\right) \left(u_{t+1} - u_{t+1}^*\right).
\end{aligned} \tag{C.1}$$

Plugging (C.1) into (36) and solving for $B/(\beta Y)$ leads to the expression (37) in text.

References

ADJEMIAN, S., H. BASTANI, M. JUILLARD, F. KARAMÉ, F. MIHOUBI, G. PERENDIA, J. PFEIFER, M. RATTO, AND S. VILLEMOT (2011): "Dynare: Reference Manual, Version 4," Dynare working papers, CEPREMAP.

AOKI, K. AND N. SUDO (2012): "Asset Portfolio Choice of Banks and Inflation Dynamics," Bank of Japan Working Paper Series 12-E-5, Bank of Japan.

——— (2013): "Bank's regulation, asset portfolio choice of banks, and macroeconomic dynamics," CARF F-Series CARF-F-323, Center for Advanced Research in Finance, Faculty of Economics, The University of Tokyo.

BÉNÉTRIX, A. (2009): "The anatomy of large valuation episodes," *Review of World Economics (Weltwirtschaftliches Archiv)*, 145, 489–511.

BÉNÉTRIX, A. S., P. R. LANE, AND J. C. SHAMBAUGH (2015): "International currency exposures, valuation effects and the global financial crisis," *Journal of International Economics*, 96, S98–S109.

BERGIN, P. R. AND J. H. PYUN (2016): "International portfolio diversification and multilateral effects of correlations," *Journal of International Money and Finance*, 62, 52–71.

BHAMRA, H. S., N. COEURDACIER, AND S. GUIBAUD (2014): "A dynamic equilibrium model of imperfectly integrated financial markets," *Journal of Economic Theory*, 154, 490–542.

BLANCHARD, O. J. AND C. M. KAHN (1980): "The Solution of Linear Difference Models under Rational Expectations," *Econometrica*, 48, 1305–11.

BROER, T. (2017): "The home bias of the poor: Foreign asset portfolios across the wealth distribution," *European Economic Review*, 92, 74–91.

BRZOZA-BRZEZINA, M., M. KOLASA, AND K. MAKARSKI (2017): "Monetary and macroprudential policy with foreign currency loans," *Journal of Macroeconomics*, 54, 352–372.

Campbell, J. Y. (1994): "Inspecting the mechanism: An analytical approach to the stochastic growth model," *Journal of Monetary Economics*, 33, 463–506.

Clarida, R., J. Galí, and M. Gertler (1999): "The Science of Monetary Policy: A New Keynesian Perspective," *Journal of Economic Literature*, 37, 1661–1707.

Curcuru, S. E., C. P. Thomas, F. E. Warnock, and J. Wongswan (2011): "US International Equity Investment and Past and Prospective Returns," *American Economic Review*, 101, 3440–3455.

De Paoli, B. (2009): "Monetary Policy under Alternative Asset Market Structures: The Case of a Small Open Economy," *Journal of Money, Credit and Banking*, 41, 1301–1330.

Devereux, M. B. and A. Sutherland (2011): "Country Portfolios In Open Economy Macro-Models," *Journal of the European Economic Association*, 9, 337–369.

Dlugoszek, G. (2017): "Solving DSGE Portfolio Choice Models with Asymmetric Countries," Annual Conference 2017 (Vienna): Alternative Structures for Money and Banking 168182, Verein für Socialpolitik / German Economic Association.

Evans, M. D. and V. Hnatkovska (2012): "A method for solving general equilibrium models with incomplete markets and many financial assets," *Journal of Economic Dynamics and Control*, 36, 1909–1930.

Faia, E. and T. Monacelli (2008): "Optimal Monetary Policy in a Small Open Economy with Home Bias," *Journal of Money, Credit and Banking*, 40, 721–750.

Fanelli, S. (2017): "Optimal Monetary Policy and Portfolio Choice," Tech. rep., Massachusetts Institute of Technology.

Gavilán, A. and J. A. Rojas (2009): "Solving Portfolio Problems with the Smolyak-Parameterized Expectations Algorithm," Working Papers 0838, Banco de España;Working Papers Homepage.

Grinols, E. L. and S. J. Turnovsky (1994): "Exchange rate determination and asset prices in a stochastic small open economy," *Journal of International Economics*, 36, 75–97.

He, D., P. Luk, and W. Zhang (2015): "The Internationalisation of the Renminbi as an Investing and a Funding Currency: Analytics and Prospects," Working Papers 012015, Hong Kong Institute for Monetary Research.

Heathcote, J. and F. Perri (2013): "The International Diversification Puzzle Is Not as Bad as You Think," *Journal of Political Economy*, 121, 1108–1159.

Judd, K. L. (1996): "Approximation, perturbation, and projection methods in economic analysis," in *Handbook of Computational Economics*, ed. by H. M. Amman, D. A. Kendrick, and J. Rust, Elsevier, vol. 1 of *Handbook of Computational Economics*, chap. 12, 509–585.

Juillard, M. (2011): "Local approximation of DSGE models around the risky steady state," wp.comunite 0087, Department of Communication, University of Teramo.

King, R. G., C. I. Plosser, and S. T. Rebelo (1988): "Production, growth and business cycles : I. The basic neoclassical model," *Journal of Monetary Economics*, 21, 195–232.

Lane, P. R. and G. M. Milesi-Ferretti (2007): "A Global Perspective on External Positions," in *G7 Current Account Imbalances: Sustainability and Adjustment*, National Bureau of Economic Research, Inc, NBER Chapters, 67–102.

Lane, P. R. and J. C. Shambaugh (2010a): "Financial Exchange Rates and International Currency Exposures," *American Economic Review*, 100, 518–40.

——— (2010b): "The long or short of it: Determinants of foreign currency exposure in external balance sheets," *Journal of International Economics*, 80, 33–44.

Magill, M. and M. Quinzii (1994): "Infinite Horizon Incomplete Markets," *Econometrica*, 62, 853–880.

Merton, R. C. (1969): "Lifetime Portfolio Selection under Uncertainty: The Continuous-Time Case," *The Review of Economics and Statistics*, 51, 247–57.

Modigliani, F. and M. H. Miller (1958): "The Cost of Capital, Corporation Finance and the Theory of Investment," *American Economic Review*, 48, 261–297.

Obstfeld, M. and K. Rogoff (1995): "Exchange Rate Dynamics Redux," *Journal of Political Economy*, 103, 624–60.

Okawa, Y. and E. van Wincoop (2012): "Gravity in International Finance," *Journal of International Economics*, 87, 205–215.

Rabitsch, K. and S. Stepanchuk (2014): "A two-period model with portfolio choice: Understanding results from different solution methods," *Economics Letters*, 124, 239–242.

Rabitsch, K., S. Stepanchuk, and V. Tsyrennikov (2015): "International portfolios: A comparison of solution methods," *Journal of International Economics*, 97, 404–422.

Schmitt-Grohé, S. and M. Uribe (2003): "Closing small open economy models," *Journal of International Economics*, 61, 163–185.

Steinberg, J. (2018): "International Portfolio Diversification and the Structure of Global Production," *Review of Economic Dynamics*, 29, 195–219.

Tille, C. and E. van Wincoop (2010): "International capital flows," *Journal of International Economics*, 80, 157–175.

Tovar, C. E. (2009): "DSGE Models and Central Banks," *Economics - The Open-Access, Open-Assessment E-Journal*, 3, 1–31.

Trani, T. (2012): "Funding under Borrowing Limits in International Portfolios," IHEID Working Papers 01-2012, Economics Section, The Graduate Institute of International Studies.

Uhlig, H. (1999): "A Toolkit for Analising Nonlinear Dynamic Models Easily," in *Computational Methods for the Study of Dynamic Economies*, ed. by R. Marimon and A. Scott, Oxford University Press, chap. 3, 30–61.

Yu, C. (2015): "Evaluating international financial integration in a center-periphery economy," *Journal of International Economics*, 95, 129–144.