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ABSTRACT

This paper investigates whether the international globalization of financial markets allows for significant cross-country risk-sharing at the business cycle frequency. We find that cross-country risk-sharing is still limited and this is unlikely to be the result of financial frictions that limit state-contingent contracts. Part of the limited international risk sharing could be the consequence of frictions that de-facto reduce the short-term mobility of financial capital. But even with these frictions we find significant divergence between model predictions and the data.

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1. Introduction

The globalization of capital markets that started in the 1980s created a regime of high international capital mobility across industrialized countries and several emerging economies. Indicators of international capital mobility, both *de-jure* and *de-facto*, show that capital mobility increased significantly since the early 1980s.[1] For example, in the United States—the largest industrialized country—the stocks of gross foreign assets and liabilities have more than tripled during the last thirty years. Because income fluctuations remain unsynchronized across countries—with the exception, perhaps, of the most recent crisis—a natural question to ask is whether the global integration of financial markets has facilitated international risk-sharing, particularly in reducing the impact of country-specific income fluctuations on the consumption of tradables goods.

The fact that the cross-country ownership of foreign assets has increased dramatically does not necessarily imply that countries are capable of better smoothing their consumption of tradable goods relatively to their idiosyncratic income over the business cycle. Even if countries experience large international capital flows at low frequencies, which in turn lead to large stocks of foreign assets, the *cyclical* dynamics of these flows may not generate greater consumption smoothing at the business cycle frequency. Thus, the first goal of this paper is to document whether the canonical model of optimal consumption and savings with complete markets and full capital mobility is consistent with the high frequency dynamics of consumption observed for a set of industrialized and emerging economies.

The canonical model includes two countries, each one endowed with stochastic income processes for tradable and nontradable goods. In the empirical application of this model, the first country is the "focus" country (for example the US) while the second represents the rest of the world (the aggregation of all remaining countries). We put together a sample of 21 countries including 18 OECD countries and three large emerging economies. We then solve the model for each of these countries, treating each one as the focus country and pairing it with its corresponding rest-of-the-world aggregate. In line with the structure of the model, we decompose the observed income of each country into tradable and nontradable components. We then estimate

[1] See Chinn and Ito (2008), Gourinchas and Rey (2007), Lane and Milesi-Ferretti (2007), and Obstfeld and Taylor (2005).

joint stochastic processes for the various components of income in the focus country and its corresponding rest-of-the-world aggregate, and use them to calibrate the model. Finally, we use numerical simulations to produce time series for consumption and compare these with their empirical counterparts.

Since our analysis focuses on the business cycle frequency, we abstract from forces that drive international capital flows and consumption smoothing at longer horizons, such as cross-country differences in medium- and long-term growth. In this respect, our study differs in a complementary way from Gourinchas and Jeanne (2011), who focus on growth differences across countries. Despite the different focus, we reach a similar conclusion: the canonical model with complete markets and capital mobility displays dynamics very different from the data.

The assumption of complete markets made in the canonical model is obviously very stylized and, at least in principle, raises the possibility that incomplete markets may bring the model closer to the data. In line with this argument, recent studies have emphasized the possible links between incomplete markets, frictions in financial markets and global imbalances (see Angeletos and Panousi (2011), Caballero et al. (2008), Fogli and Perri (2006), Mendoza et al. (2009)). Since these studies mostly focus on low-frequency movements in foreign asset holdings, it is natural to ask whether similar frictions can also be important for explaining the high-frequency comovement of tradable consumption and income within each country.

To address this question, we extend the model by introducing incomplete markets. We consider an environment where countries can trade only non-state-contingent assets, subject to a lower bound (or borrowing limit). We refer to this version of the model as the *Bond Economy*. We find that the dynamics of consumption in the Bond Economy are very similar to the dynamics predicted by the model with complete markets. This implies that, given the observed characteristics of income fluctuations, countries should achieve a high degree of risk sharing even if non-contingent bonds are the only assets traded in world asset markets. This result is reminiscent of results obtained in previous studies showing that non-contingent bonds already provide significant consumption insurance (see Baxter and Crucini (1995) and Heathcote and Perri (2002)).[2] This result also implies, unfortunately, that

[2]An earlier study in the finance literature by Telmer (1993) showed that trade in riskless bonds could approximate well complete-markets equilibria in closed-economy models with

the high-frequency dynamics of consumption predicted by the Bond Economy are quite different from the dynamics observed in the data because, as observed above, the latter differ sharply from the dynamics predicted by the complete markets model.

Our Bond Economy model shares some of the features of the model proposed by Bai and Zhang (2012) to study the effect of financial integration on international risk sharing. They consider a global economy with a continuum of heterogeneous small open economies trading non-state-contingent bonds exposed to default risk, and with country income fluctuations purely idiosyncratic. Our Bond Economy can be thought of as a two-agent variant of their model without default but enriched to include uninsurable risk in the form of nontradable goods and aggregate (global) shocks.[3] Moreover, our work also differs in that we focus on the time-series behavior of consumption, instead of the cross-country panel elasticity of consumption with respect to income in a stochastic stationary equilibrium.

Since the Bond Economy with borrowing limit can be considered one of the most restrictive forms of financial structure, our results cast doubt on the hypothesis that financial market frictions that limit state contingent contracts can explain the limited degree of international risk sharing at the business cycle horizon.[4] Notice that this does not imply that market incompleteness cannot explain low-frequency movements in foreign assets and international portfolio composition, or that financial frictions are not relevant for the transmission mechanism at work during global financial crises.[5]

The second type of frictions we consider as a potential mechanism to reconcile the empirical dynamics of consumption with the theory is the presence

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heterogeneous agents, and that the model does poorly at accounting for observed asset returns. The model we propose in the next section can be interpreted as a version of Telmer's model if we remove nontraded goods and re-label countries as agents.

[3]The consideration of nontradable goods and global shocks could be potentially important. The imperfect risk sharing captured in Bai and Zhang's estimate of the cross-country consumption elasticity of about 0.6 could reflect the combined effects of nontradable goods, aggregate shocks, and goods and assets trading costs, in addition to default risk.

[4]See Kehoe and Perri (2002) for a more sophisticated model of financial frictions that restrict cross-country risk sharing.

[5]See the recent literature on global imbalances by Angeletos and Panousi (2011), Caballero et al. (2008), Fogli and Perri (2006), Mendoza et al. (2009), and the recent literature on the global crisis by Dedola and Lombardo (2010), Devereux and Yetman (2010), Enders et al. (2011), Mendoza (2010), Mendoza and Quadrini (2010), Perri and Quadrini (2011).

of international portfolio rigidities. Starting from the Bond Economy as described above, we add a convex cost of changing the stock of foreign assets. This cost can be interpreted as capturing actual portfolio adjustment costs at the individual level and/or rigidities that limit the international mobility of financial investments.[6] With this friction, the ability of the model to replicate the empirical dynamics of consumption improves significantly, although there is still a sizable divergence between the predictions of the model and the data. Effectively, portfolio adjustment costs bring the economy closer to financial autarky. Thus, an interpretation of this result is that, although formal barriers to the mobility of capital have been lifted in most countries, international financial markets remain intrinsically segmented in the short term.

This paper is related to the large literature on international risk sharing and international real business cycles (IRBC). In particular, our findings are in line with the empirical work by Lewis (1996). She concluded that neither non-separability in tradable and nontradable consumption nor capital market restrictions could explain, separately, the observed consumption co-movements. When considered together, however, the risk sharing predictions of a model with consumption non-separability and capital markets restrictions cannot be rejected by the data. More recently, Kose et al. (2009) provide further empirical evidence of a limited degree of international risk-sharing in a large data set of industrialized and developing countries, and find little impact coming from financial globalization.

In the IRBC literature, our work is closely related to the studies by Stockman and Tesar (1995) and Benigno and Thoenissen (2008). Stockman and Tesar showed that non-tradeability of goods does not improve the ability of the IRBC model with complete markets driven by technology shocks alone to match the observed higher cross-country correlations of output relative to consumption. Benigno and Thoenissen showed that this remains the case even if complete markets are replaced with a riskless bond, although with this modification the model can explain the low correlation between the real exchange rate and relative consumption. The work of Aguiar and Gopinath (2007) is also relevant because they show that a business cycle model of a small open economy can produce consumption volatility in excess of in-

[6]Rigidities in international asset trading or capital controls have also been considered in Backus et al. (1992) and Mendoza (1991a).

come volatility as the result of shocks to growth rates or trends of income processes. Thus, a complementary explanation for the apparent lack of international risk sharing may derive from cross-country differences in trend and stationary components of income fluctuations.

The results of our analysis are also related to recent findings obtained by Corsetti et al. (2011) and Fitzgerald (forthcoming). The findings of these two studies suggest that an alternative force driving the lack of risk sharing in the data may be fluctuations in real costs of trading goods. Fitzgerald examined the extent to which cross-country variations in ratios of marginal utilities can be accounted for by variations in relative wealth (i.e. deviations from complete markets) versus other mechanisms that operate through relative goods prices, and found that the former alone cannot account for observed fluctuations in marginal utility ratios. Corsetti et al. showed that the observed low correlation between relative consumption and real depreciation, which IRBC models with complete markets cannot explain, tends to be particularly low at cyclical frequencies. This is similar to our finding that the complete markets model does a poor job at matching cyclical consumption risk sharing. They also showed that an incomplete markets model with nontradable goods can do better at accounting for this feature of the data if it incorporates income effects from output shocks to both tradables and nontradables, which can cause the international relative prices of a country to strengthen, together with a rise in relative consumption.

The rest of the paper is organized as follows. In Section 2 we illustrate some empirical regularities that we take as targets for the quantitative application of the model. Section 3 describes the theoretical model and Section 4 conducts the quantitative analysis. Sections 5 and 6 conduct some robustness checks and the final Section 7 presents concluding remarks.

2. Empirical regularities

We examine annual data for 18 major OECD economies and three major emerging economies.[7] We use output and consumption data from the OECD's *National Account Statistics* for the OECD countries and data from

[7]The OECD countries in our sample are: the United States, the United Kingdom, Japan, Germany, France, Italy, Spain, Canada, the Netherlands, Australia, Sweden, Finland, Norway, Denmark, Austria, Mexico, Turkey and Korea. The emerging economies are Brazil, China and India.

the World Bank's *World Development Indicators* for the three emerging economies. For all countries we draw population data from the United Nations' *Population Information Network*. All estimates reported here are based on annual data measured at constant prices, expressed in per capita terms, logged and detrended with the Hodrick-Prescott filter (using the smoothing parameter $\lambda = 100$). The sample period is 1970-2007.

Table 1 reports the standard deviations of total output, tradable output, and nontradable output, as well as the relative standard deviations and elasticities of total consumption to total output, and of tradable absorption to tradable output. Total output is defined as GDP and total consumption is final consumption expenditures of households. Tradable output is defined as the sum of value added in agriculture and industry. Nontradable output is defined as value added in services. Tradable absorption is defined as tradable output minus net exports. Nontradable absorption is by definition equal to nontradable output. We use absorption measures because breakdowns of consumption and investment data into tradables and nontradables are difficult to construct for some of the countries and years included in our sample. Appendix A provides further details about the data.

We emphasize three main patterns that emerge from Table 1:

1. Output fluctuations in emerging economies are generally larger than those observed in industrialized countries.
2. There is no obvious pattern in the variability of consumption relative to income. Across industrialized countries, the variability ratio ranges from 0.81 to 1.47 with a median of 1.05, while in emerging countries it ranges from 0.87 to 1.27 with a median of 1.14. The medians are consistent with Aguiar and Gopinath (2007) showing that emerging markets have higher consumption variability ratios, but the wider range for the industrialized countries shows that there are several economies with consumption variability ratios that are both higher than 1 and higher than the ratios observed in emerging economies.[8] Moreover, the

[8] Our limited sample of emerging economies excludes several countries that experienced financial crises in the 1980s or 1990s (e.g. Argentina, Indonesia, Malaysia, Russia, Thailand, etc). Table 2 in Durdu et al. (2009) reports consumption-GDP variability ratios for all emerging countries that had a crisis in the 1990s, and these ratios range from 0.54 to 2.25. This range is wider than the one we found for industrialized countries, but it is still the case that several industrialized economies in our Table 1 have variability ratios higher than 1 and higher than for several emerging economies in Table 2 of Durdu et al.

Table 1: Standard deviations of output, relative standard deviations of consumption/absorption and elasticities of consumption/absorption relative to output.

	Total			*Tradable*			*Nontr.*
	$\sigma(Y_i)$	$\frac{\sigma(C_i)}{\sigma(Y_i)}$	$\alpha(C_i, Y_i)$	$\sigma(Y_i^T)$	$\frac{\sigma(C_i^T)}{\sigma(Y_i^T)}$	$\alpha(C_i^T, Y_i^T)$	$\sigma(Y_i^N)$
A. Industrialized Countries							
United States	0.019	0.97	0.87	0.036	1.51	1.27	0.016
United Kingdom	0.023	1.28	1.12	0.027	1.70	1.31	0.018
Japan	0.021	0.84	0.75	0.034	1.35	1.15	0.018
Germany	0.016	0.99	0.75	0.028	1.33	0.95	0.015
France	0.015	0.86	0.75	0.021	2.06	1.39	0.013
Italy	0.016	1.21	0.98	0.028	2.15	1.36	0.012
Spain	0.026	1.14	1.09	0.038	2.32	1.89	0.026
Canada	0.021	1.05	0.86	0.042	1.59	0.96	0.016
Netherlands	0.016	1.42	1.09	0.019	2.37	1.00	0.015
Australia	0.015	0.81	0.31	0.024	2.16	1.22	0.019
Sweden	0.022	1.30	1.05	0.044	1.74	1.00	0.015
Finland	0.033	0.99	0.90	0.041	1.99	0.89	0.031
Norway	0.017	1.44	1.19	0.025	2.92	0.14	0.017
Denmark	0.018	1.47	1.01	0.031	3.27	1.95	0.014
Austria	0.015	0.93	0.71	0.023	1.71	0.90	0.012
B. Emerging Countries							
Mexico	0.032	1.19	1.09	0.036	2.39	2.00	0.033
Turkey	0.039	1.27	0.70	0.036	1.94	1.60	0.028
Korea	0.031	1.13	0.90	0.043	2.08	1.38	0.026
Brazil	0.038	1.08	0.34	0.048	1.62	1.41	0.039
China	0.034	1.15	0.96	0.033	-	-	0.048
India	0.023	0.87	0.70	0.031	1.25	1.12	0.015

cross-country average of the variability ratio is 1.11 across all countries.

3. Tradable output is more volatile than total output, but tradable absorbtion is proportionately even more volatile for a large majority of countries. This fact holds for all countries in the sample except Turkey. For most countries, the larger relative volatility of tradable absorption results in a larger elasticity of tradable absorption than for total con-

(e.g. Italy, the Netherlands, Norway, Denmark and the U.K. in our Table 1 v. Ecuador, Mexico, Peru, Hong Kong, Philippines and Thailand in their Table 2).

sumption.

Table A.1 in the appendix reproduces the same statistics as Table 1 but separately for the subperiods 1970-1990 and 1991-2007. The distinction between the two subperiods is of interest because the latter is commonly thought as being characterized by greater financial integration. The table shows that the patterns outlined above characterize both subperiods.

Table 2 reports international correlations for total output, total consumption, tradable output, and tradable absorption.[9] The correlations are between a variable in country i and the same variable in the corresponding estimate of the "rest of the world." The rest of the world is the aggregation of all countries included in the sample with the exception of country i (see Appendix A).

In accordance with the findings of existing studies on risk-sharing and IRBC, the consumption and absorption correlations are systematically and significantly lower than unity. They range from -0.15 to 0.77 for total consumption and from -0.16 to 0.72 for tradable absorption. These statistics contrast with the perfect consumption correlation predicted by the standard two-country model with complete markets. Furthermore, and again in line with earlier studies, output correlations are generally higher than consumption or absorption correlations, both for total consumption (for 15 out of 20 countries) and for tradable absorption (for 14 out of 20 countries).

Overall, the facts outlined in this section about consumption variability ratios and international correlations suggest that there is limited consumption risk sharing at the business cycle frequency. The next step is to examine these facts from the perspective of a general equilibrium model.

3. Model Economy

Consider a world economy with two countries indexed by $i = \{1, 2\}$. Each country is inhabited by a representative agent with identical preferences defined over consumption of tradable goods, $c_{i,t}^T$, and nontradable goods, $c_{i,t}^N$. Preferences are homogenous across countries with lifetime utility given by

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(C(c_{i,t}^T, c_{i,t}^N)\right).$$

[9] China is omitted from the calculations underlying Table 2 because imports and export data are unavailable prior to 1978.

Table 2: International correlation of consumption and output.

	Total		*Tradable*	
	$\rho(C_i, C_{i^*})$	$\rho(Y_i, Y_{i^*})$	$\rho(C_i^T, C_{i^*}^T)$	$\rho(Y_i^T, Y_{i^*}^T)$
A. *Industrialized Countries*				
United States	0.36	0.55	0.15	0.68
United Kingdom	0.65	0.70	0.69	0.75
Japan	0.43	0.43	0.52	0.43
Germany	0.55	0.53	0.61	0.54
France	0.69	0.70	0.68	0.56
Italy	0.42	0.71	0.51	0.64
Spain	0.63	0.62	0.58	0.59
Canada	0.77	0.71	0.72	0.73
Netherlands	0.59	0.73	0.47	0.62
Australia	0.34	0.50	0.40	0.65
Sweden	0.62	0.49	0.56	0.42
Finland	0.48	0.51	0.42	0.39
Norway	0.21	0.22	-0.02	0.01
Denmark	0.27	0.44	0.35	0.20
Austria	0.37	0.60	0.50	0.66
B. *Emerging Countries*				
Mexico	-0.12	-0.05	-0.03	0.11
Turkey	0.07	0.15	0.06	0.25
Korea	0.05	0.34	0.05	0.36
Brazil	-0.11	0.47	0.30	0.48
India	-0.05	-0.02	-0.16	-0.01

The function $U(.)$ is twice-continuously differentiable, concave and satisfies the Inada conditions. The function $C(.,.)$ is a CES aggregator of tradable and nontradable consumption.

Agents in each country i receive two types of income. The first is the income earned in the nontradable sector, $y_{i,t}^N$. The second is income earned in the tradable sector, $y_{i,t}^T$. The state of the world economy at each point in time is given by the vector $s_t = (y_{1,t}^T, y_{2,t}^T, y_{1,t}^N, y_{2,t}^N)$, which follows a first-order, discrete Markov process.

The resource constraints are

$$c_{i,t}^N = y_{i,t}^N,$$

$$c_{i,t}^T + \sum_{s_{t+1}} b_{i,t+1}(s_{t+1}) q(s_t, s_{t+1}) = y_{i,t}^T + b_{i,t}(s_t).$$

Each country's holdings of *potentially* state-contingent, one-period international claims, are denoted by $b_{i,t}(s_t)$. Their prices, denominated in tradable goods, are denoted by $q(s_t, s_{t+1})$. The clearing condition in the international asset market is

$$n \cdot b_{1,t+1}(s_{t+1}) + (1-n) \cdot b_{2,t+1}(s_{t+1}) = 0,$$

which must hold for all possible realizations of s_{t+1}. The variable n denotes the population share of country 1 in the world population. Thus, $1-n$ is the population share of country 2. As we explain later, the relative size of the two countries plays an important role because international risk sharing is more limited to the extent that a country is relatively large.

The international asset market structure can take different configurations depending on the degree of capital mobility and the ability of asset markets to provide insurance. We consider four alternative specifications.

3.1. Complete markets

When markets are complete, $b_{i,t+1}(s_{t+1})$ represents a complete set of classic Arrow securities contingent on s_{t+1}. Besides the imposition of a transversality condition that prevents Ponzi schemes, there are no restrictions on the contingencies that can be traded. Given that $c_{i,t}^N = y_{i,t}^N$, perfect risk-pooling implies that the ratio of marginal utilities from tradable consumption in the two countries stays constant over time, that is,

$$\frac{\frac{\partial U\left(C(c_{1,t}^T, c_{1,t}^N)\right)}{\partial c_{1,t}^T}}{\frac{\partial U\left(C(c_{2,t}^T, c_{2,t}^N)\right)}{\partial c_{2,t}^T}} = \kappa.$$

The constant κ depends on the relative wealth of the two countries defined as the expected present value of lifetime endowments in utility terms (see, for example, Backus (1993)). This condition, together with the global market-clearing condition for tradable goods,

$$n \cdot c_{1,t}^T + (1-n) \cdot c_{2,t}^T = n \cdot y_{1,t}^T + (1-n) \cdot y_{2,t}^T,$$

determines the equilibrium allocations for the global economy.

For the analysis that follows it will be convenient to remember that all agents face a common set of prices for the Arrow securities. Furthermore, expected intertemporal marginal rates of substitution are equalized across countries, that is,

$$E_t \left\{ \frac{\frac{\partial U\left(C(c^T_{1,t+1}, c^N_{1,t+1})\right)}{\partial c^T_{1,t+1}}}{\frac{\partial U\left(C(c^T_{1,t}, c^N_{1,t})\right)}{\partial c^T_{1,t}}} \right\} = E_t \left\{ \frac{\frac{\partial U\left(C(c^T_{2,t+1}, c^N_{2,t+1})\right)}{\partial c^T_{2,t+1}}}{\frac{\partial U\left(C(c^T_{2,t}, c^N_{2,t})\right)}{\partial c^T_{2,t}}} \right\}.$$

3.2. Bond economy

In this market structure, agents cannot trade assets that are state contingent. Therefore, $b_{i,t+1}(s_{t+1}) \equiv b_{i,t+1}$ and $q(s_t, s_{t+1}) = 1/R_t$ for all (s_t, s_{t+1}). International capital markets are limited to trades in bonds denominated in units of tradable goods and paying the risk free real interest rate R_t. The resource constraint in tradable goods in each country becomes

$$c^T_{i,t} + \frac{b_{i,t+1}}{R_t} = y^T_{i,t} + b_{i,t}.$$

The market clearing condition in the asset market is

$$n \cdot b_{1,t+1} + (1-n) \cdot b_{2,t+1} = 0.$$

In addition, each country faces the borrowing limit $b_{i,t+1} \geq \underline{b}$. With this constraint, the equilibrium allocation satisfies the optimality conditions

$$\frac{\partial U\left(C(c^T_{i,t}, c^N_{i,t})\right)}{\partial c^T_{i,t}} = \beta R_t E_t \left[\frac{\partial U\left(C(c^T_{i,t+1}, c^N_{i,t+1})\right)}{\partial c^T_{i,t+1}} \right] + \mu_{i,t} R_t,$$

$$\frac{\frac{\partial C(c^T_{i,t}, c^N_{i,t})}{\partial c^T_{i,t}}}{\frac{\partial C(c^T_{i,t}, c^N_{i,t})}{\partial c^N_{i,t}}} = P_{i,t},$$

where $\mu_{i,t}$ is the Lagrange multiplier associate with the borrowing constraint.

The first condition is the Euler equation for bonds while the second equation pins down the market-clearing (relative) price of nontradable goods, $P_{i,t}$. This price equals the marginal rate of substitution in consumption between tradables and nontradables.

3.3. Bond economy with costly portfolio adjustment

As in the previous environment, agents can trade only non-state-contingent bonds denominated in tradable goods. However, they face a quadratic cost in changing bond holdings, that is, $\varphi_i(b_{i,t}, b_{i,t+1}) = \phi_i(b_{i,t+1} - b_{i,t})^2$. The resource constraint for tradable goods becomes

$$c_{i,t}^T + \frac{b_{i,t+1}}{R_t} + \varphi_i(b_{i,t}, b_{i,t+1}) = y_{i,t}^T + b_{i,t}. \tag{1}$$

The equilibrium allocations must satisfy the world market-clearing condition for tradable goods, $nc_{1,t}^T + (1-n)c_{2,t}^T = ny_{1,t}^T + (1-n)y_{2,t}^T$, as well as the optimality condition equating the relative price of nontradables to the marginal rate of substitution between tradables and nontradables. The Euler equation for bonds now takes the form

$$\begin{aligned} &\frac{\partial U\left(C(c_{i,t}^T, c_{i,t}^N)\right)}{\partial c_{i,t}^T}\Big[1 + 2\phi(b_{i,t+1} - b_{i,t})R_t\Big] = \qquad (2)\\ &\qquad \beta R_t E_t \left\{ \frac{\partial U\left(C(c_{i,t+1}^T, c_{i,t+1}^N)\right)}{\partial c_{i,t+1}^T}\Big[1 + 2\phi(b_{i,t+2} - b_{i,t+1})\Big] \right\} + \mu_{i,t}R_t. \end{aligned}$$

As before, $\mu_{i,t}$ is the Lagrange multiplier for the borrowing constraint.

Before continuing, we would like to emphasize that in this economy the portfolio adjustment cost has implications similar to that of a convex cost of trading goods (cost to change net exports). We will return to this point in the quantitative analysis.

3.4. Financial autarky

In financial autarky, countries do not trade any assets. Therefore, $b_{i,t+1}(s_{t+1}) \equiv 0$ for all s_{t+1}. Autarky in capital markets also implies autarky in goods markets since there is a single, homogeneous tradable good. Thus, consumption of tradables must equal the income generated in the domestic tradable sector, that is, $c_{i,t}^T = y_{i,t}^T$.

The autarky outcome coincides with the limiting case of the bond economy with an infinitely high portfolio adjustment cost: when the adjustment cost is very high, countries do not trade even if they are allowed to.

4. Quantitative Analysis

The quantitative exercise involves solving and simulating the different versions of the model (Complete Markets, Bond Economy, Bond Economy with Portfolio Rigidities and Financial Autarky) for the 21 countries included in our sample as described in Section 2. A description of the numerical procedure is provided in Appendix C.

In each simulation we pair one country (the focus country) with its corresponding rest-of-the-world (ROW) aggregate. For example, in the first exercise, country 1 is representative of the United States and country 2 aggregates the remaining 20 countries. In the second, country 1 is representative of the United Kingdom and country 2 aggregates all countries in the sample but the United Kingdom. We then move to the third country, Japan, and repeat the exercise until we have covered all the 21 countries included in the sample. Notice that as we solve for the different versions of the model, we also find the corresponding equilibrium world real interest rate and relative prices of nontradable goods.

After solving for the decision rules in the general equilibrium, we feed the model with the actual realizations of tradable and nontradable incomes constructed from the data over the period 1970-2007 and find the equilibrium consumption time series implied by these particular realizations of income. We then compare the consumption series predicted by the model with the empirical absorption series over the same period and report statistics that summarize the goodness of the fit. Notice that we use the absorption measure from the data instead of consumption because the breakdowns of consumption and investment data into tradables and nontradables are difficult to construct for some of the countries and years included in the sample. In Section 5 we examine the robustness of our findings to the use of a more direct measure of tradable consumption which, however, is only available for a shorter sample period and a smaller set of countries. In order to start the simulation, we need to initialize the assets holdings b_t in 1970 (subsequent values are determined endogenously). It turns out that the simulation results are not significantly affected by the starting values of b_t. Given this, we set the initial values to zero for all countries.

4.1. Calibration

The parsimonious structure of the model implies that there are only a few parameters that need to be calibrated. Since we are using annual data, we choose the period in the model to be one year and set the discount factor to $\beta = 0.95$. The utility function with respect to aggregate consumption is of the constant-relative-risk-aversion form, that is, $U(C) = \frac{C^{1-\sigma}}{1-\sigma}$. We set $\sigma = 2$, which is a standard value in DSGE models. The consumption basket is a CES aggregator

$$C(c^T, c^N) = \left[\omega \cdot (c^T)^{-\epsilon} + (1-\omega) \cdot (c^N)^{-\epsilon}\right]^{-\frac{1}{\epsilon}},$$

where $1/(1+\epsilon)$ is the elasticity of substitution between tradable and nontradable consumption. The two parameters that enter this function are set to $\omega = 0.3$ and $\epsilon = 0.316$, in line with some empirical evidence and existing parameterizations in open economy business cycle models. We have also repeated the simulation for alternative values of ϵ with similar findings.[10]

Next we assign the lower bound for asset holdings. We set $\underline{b}$ to 50 percent of the mean value of tradable income, which is normalized to unity. As we document in Section 4.4, the results are not very sensitive to the value of $\underline{b}$. This holds as long as the parameter is not set to a value too close to zero, in which case the specification converges to the autarky model.

The stochastic processes for the endowments of tradables and nontradables are calibrated as follows. We start with the decomposition of GDP data into tradable and nontradable series as described earlier in Section 2. Then we organize these series into a set of pairs. In each pair, we treat a given country as the reference country i, or the 'home country,' and the other country is the corresponding ROW construct defined as the aggregate of all other countries included in the sample except country i. Hence, as we change the reference country i in each pair, we also change the corresponding ROW aggregate. To make this explicit, we use the index i^* to denote the ROW economy with respect to country i.

For tractability reasons, the stochastic structure of the model is simplified by assuming that tradable endowments, $s_t^T \equiv (y_{i,t}^T, y_{i^*,t}^T)$, and nontradable endowments, $s_t^N \equiv (y_{i,t}^N, y_{i^*,t}^N)$, follow two *independent* Markov processes, with each process including two realizations for each variable. Therefore, there are

[10]The value of $\epsilon = 0.316$ corresponds to an elasticity of substitution of $1/(1+\epsilon) = 0.76$. This is between the estimates of Ostry and Reinhart (1992) who find an elasticity of 1.28 and Stockman and Tesar (1995) who find an elasticity of 0.44. To check the robustness of our results, we have also simulated the model with $\epsilon = -0.219$ and $\epsilon = 1.27$, corresponding to elasticities of 1.28 and 0.44, respectively. The general findings do not change.

sixteen possible states of nature for the world economy $s_t = (s_t^T, s_t^N)$.

Let $\pi_{j,j'}$ be the transition probabilities for s_t^g, $g \in \{T, N\}$. Following Mendoza (1991b) we assume that these transition probabilities are given by the bi-variate version of the Simple Persistence Rule as follows:

$$\pi_{j,j'}^g = (1 - \theta^g)\Pi_{j'}^g + \theta^g p_{j,j'}, \tag{3}$$

where θ^g is a persistence parameter, $\Pi_{j'}^g$ is the long-run probability of the j' realization of state s_{t+1}^g, and $p_{j,j'} = 1$ if $j = j'$ and 0 otherwise. The transition probabilities naturally satisfy $0 \leq \pi_{j,j'} \leq 1$ and $\sum_{j'} \pi_{j,j'} = 1$. The stochastic structure is further simplified by imposing symmetry in the realization vectors and in the long-run probabilities of symmetric states. In addition, the Simple Persistence Rule imposes that the first-order autocorrelations of the two variables are the same. This is not a significant limitation because, as we show in Table A.2 in the Appendix, the first-order autocorrelations of the various income processes are not very different.

With the above restrictions in place, each Markov process can be characterized by four parameters: the unconditional standard deviations of the home and foreign income shocks, σ_i^g and $\sigma_{i^*}^g$, the unconditional contemporaneous correlation between home and foreign shocks, ρ_{i,i^*}^g, and the common first-order autocorrelation ρ^g of the home and foreign variables. See Appendix B for further details.

The parameters σ_i^g, $\sigma_{i^*}^g$ and ρ_{i,i^*}^g are set to match their empirical counterparts for each country and each good as reported in Table A.2 in the Appendix. Meanwhile, the parameter ρ^g is set to the average between the autocorrelation of the home shock, ρ_i^g, and that of the ROW shock, $\rho_{i^*}^g$.

4.2. Complete Markets and Bond Economy

Figure 1 plots two tradable consumption series. The first series is from the data (continuous line) while the second (dashed line) is generated by the model with complete markets. It is important to remember that the empirical series for consumption measure tradable income absorbtion, that is, tradable output minus the trade balance. The model does not feature capital accumulation, so in the model consumption coincides with absorption. In Section 5 we also use actual tradable consumption measurements which, however, are only available for fewer countries and for a shorter time period.

With complete markets, the ratio of marginal utilities from tradable consumption between country i and its corresponding ROW aggregate remains constant across time and states of nature. In the simulation, we choose this constant ratio based on the relative per-capita wealth of the two countries (focus country and the corresponding ROW aggregate). Notice that, even though the ratio of marginal utilities in tradable consumption is constant, the ratio of tradable consumption is not constant because marginal utilities also depend on nontradable consumption. As we can see from Figure 1, there is a significant divergence between the data and the model with complete markets.

To better understand the dynamics of tradable consumption predicted by the model, Figure 2 plots tradable income and tradable consumption for both countries in each simulation. The figure shows that the tradable consumption of country i follows closely the aggregate tradable output of the second country (ROW). Since the second country results from the aggregation of all remaining countries, its size is usually much larger than the size of country i. Effectively, the income of the ROW country approximates worldwide income whose fluctuations cannot be insured. Thus, it is not surprising that the tradable consumption of country i follows closely the tradable income (and consumption) of the ROW country, especially when country i is relatively small. This shows the importance of considering global shocks in the analysis of cross-country risk-sharing.

One of the goals of this paper is to investigate whether financial market frictions could explain part of the divergence between observed absorption and simulated consumption. Of course, there are different ways of capturing market incompleteness. As explained in the previous section, we consider the simplest characterization of incomplete markets in which countries can trade only non-contingent bonds (standard borrowing and lending).

As can be seen in Figure 3, the dynamics of tradable consumption generated by the Bond Economy are almost identical to the dynamics generated by the Complete Markets Economy. This implies that the ability of the Bond Economy to capture the empirical dynamics is also limited. From this we conjecture that, given the nature of national income fluctuations implicit in the data, financial market frictions that prevent trade in contingent claims do not play on average a crucial role in limiting international risk-sharing. As long as countries can trade non-contingent claims, they should be able to achieve a high degree of risk sharing.

The intuition for this result is that the borrowing constraints are not binding very often. And when the constraints are not binding, bonds are good insurance instruments against country income fluctuations with the characteristics observed in the data. The exception are episodes in which countries face binding borrowing constraints, as in the event of financial crises. But these episodes arise infrequently.

4.3. Portfolio Adjustment Cost Model

Since the Bond Economy can be considered one of the lowest forms of financial sophistication (high degree of financial frictions), the divergence between the cyclical consumption predicted by the model and its data counterpart must be explained by other frictions.

We now consider the economy with *Portfolio Adjustment Costs*. In this economy, agents can trade non-contingent bonds b_t. However, in re-adjusting their bond holdings, agents in country i incur the cost $\varphi(b_t, b_{t+1}) = \phi(b_{t+1} - b_t)^2$. Notice that it is not relevant for equilibrium allocations whether the cost is incurred by a country or by its ROW aggregate. Therefore, we assume without loss of generality that the cost is incurred only by country i.

This adjustment cost formalizes in reduced form several types of rigidities. For example, it could derive from actual costs in changing individual portfolios or from restrictions in international financial transactions. In the second case, the cost would capture formal and informal limits to international capital mobility. The cost could also reflect the effect of financial frictions that are not well captured by the Bond Economy, such as the implications of informational costs or the heterogenous liquidity and maturity profile of external assets. Of course, by taking this reduced-form approach, we do not provide a micro-foundation for this cost. Our interest is in studying whether the cost can reduce the gap between the observed absorption dynamics and those generated by the model.[11]

We would also like to emphasize that this type of rigidity has similar implications as trade costs, that is, rigidities that limit changes in imports and exports. Some studies have proposed these costs as a potential explanation for the observed lack of international risk sharing (e.g. Fitzgerald (forthcoming)). In fact, abstracting from interest payments, an increase in the stock of bonds held by country i is associated with an increase in net imports of the same magnitude.[12]

[11] As observed earlier, the adjustment cost does not imply that countries cannot have large net foreign asset positions. It only smooths their changes, affecting the short term dynamics (i.e. business cycle frequency).

[12] We are grateful to Mark Aguiar for pointing out this similarity.

Table 3: Portfolio adjustment cost parameter and sum of squared errors of tradable consumption between data and model.

	ϕ	*Portfolio Adj.Cost*	*Bond Economy*	*Complete Markets*
United States	10.0	0.038	0.073	0.076
United Kingdom	10.0	0.036	0.059	0.063
Japan	10.0	0.023	0.053	0.056
Germany	4.4	0.025	0.038	0.040
France	4.2	0.039	0.050	0.052
Italy	10.0	0.088	0.116	0.118
Spain	10.0	0.148	0.264	0.286
Canada	1.3	0.095	0.100	0.107
Netherlands	1.5	0.064	0.070	0.071
Australia	5.5	0.070	0.082	0.085
Sweden	4.2	0.146	0.176	0.196
Finland	10.0	0.193	0.235	0.253
Norway	0.7	0.203	0.211	0.217
Denmark	10.0	0.274	0.318	0.324
Austria	1.5	0.039	0.046	0.045
Mexico	10.0	0.142	0.334	0.344
Turkey	10.0	0.082	0.206	0.219
Korea	10.0	0.178	0.312	0.334
Brazil	10.0	0.073	0.212	0.230
China	10.0	0.047	0.113	0.131
India	10.0	0.012	0.067	0.075

To assign a value to the parameter ϕ, we proceed as follows. For each country we find the value of ϕ that minimizes the sum of squared differences between the tradable consumption series generated by the model for country i, and the tradable absorption series observed in the data. The feasible values of ϕ are constrained to be in the interval $[0, 10]$. With a value of $\phi = 0$ the specification coincides with the Bond Economy. At the other end, a value of $\phi = 10$ effectively brings the economy to financial autarky. The minimizing values of ϕ are reported in Table 3 and the series generated by the model are plotted in Figure 4.

For several countries, the introduction of the adjustment cost improves significantly the fit of the model. For these countries, the minimizing value of ϕ is at the upper bound. As stated above, this brings the economy close

Table 4: Elasticities of consumption to income.

	Tradable				*Total*			
	Data	*Portfolio Adj.Cost*	*Bond Economy*	*Complete Markets*	*Data*	*Portfolio Adj.Cost*	*Bond Economy*	*Complete Markets*
United States	1.270	0.955	0.563	0.528	1.160	0.987	0.794	0.773
United Kingdom	1.313	0.968	0.565	0.524	1.171	0.814	0.684	0.667
Japan	1.151	0.948	0.339	0.300	1.147	0.968	0.692	0.674
Germany	0.948	0.915	0.432	0.428	1.067	0.924	0.687	0.669
France	1.385	0.922	0.474	0.474	1.153	0.886	0.741	0.747
Italy	1.361	0.964	0.482	0.482	1.310	0.923	0.676	0.676
Spain	1.885	0.946	0.243	0.167	1.358	1.076	0.771	0.734
Canada	0.958	0.774	0.404	0.353	1.045	0.857	0.667	0.623
Netherlands	1.000	0.862	0.600	0.591	1.122	0.825	0.768	0.775
Australia	1.217	0.940	0.493	0.455	1.153	1.107	0.952	0.938
Sweden	0.997	0.876	0.274	0.176	1.236	0.852	0.602	0.527
Finland	0.888	0.934	0.192	0.111	1.197	0.900	0.694	0.656
Norway	0.136	0.531	0.093	-0.003	1.344	0.697	0.640	0.592
Denmark	1.950	0.938	0.206	0.095	1.425	0.841	0.653	0.615
Austria	0.902	0.835	0.568	0.580	1.061	0.812	0.663	0.662
Mexico	2.001	0.925	-0.060	-0.103	1.387	0.968	0.613	0.586
Turkey	1.601	0.933	0.046	-0.048	1.168	0.736	0.496	0.471
Korea	1.382	0.944	0.181	0.131	1.335	0.765	0.487	0.453
Brazil	1.414	0.938	0.151	0.063	1.197	1.014	0.717	0.688
China	0.991	0.921	-0.134	-0.308	0.951	1.068	0.769	0.715
India	1.120	0.930	0.018	-0.059	1.074	0.708	0.385	0.353

to a regime of Financial Autarky. Therefore, for a majority of countries, the Autarky equilibrium seems to better capture the 'high frequency' movements in tradable consumption. Again, this does not mean that countries cannot have large net foreign asset positions. However, these positions could be very sticky in the short term.

Another way to summarize the performance of the various versions of the model is to compute the elasticities of absorption and consumption to income. Table 4 reports the elasticities of both tradable consumption (tradable absorption in the data) to tradable income and total consumption to total income. The model with portfolio adjustment costs generates elasticities that are much closer to the data. This is another indicator of limited risk sharing at high frequency horizons.

Although portfolio rigidities improve the fit of the model, there is still significant divergence between the model and the data. Therefore, other factors not explicitly considered here must play some role. We leave the investigation of these other factors for future research.

4.4. Sensitivity to the borrowing limit

We now show that the results obtained so far are not sensitive to the borrowing limit. Table 5 reports the ϕ estimates and the associated sum of squared errors under a tighter borrowing limit, that is, $\underline{b} = -0.25$ compared to $\underline{b} = -0.5$ in the baseline calibration. The numbers reported in the table are almost identical to those reported in Table 3 for the baseline model. Therefore, the results are not sensitive to the borrowing limit. This holds as long as $\underline{b}$ is not too close to zero. The limiting case where $\underline{b} = 0$ is equivalent to the autarky specification, and therefore, also to the portfolio rigidity model with an infinitely large portfolio adjustment cost.

5. Alternative empirical benchmark

In Section 4 we used data on tradable goods absorption to measure the fit of our respective models. In this section, we repeat the analysis with an empirical measure of tradable goods consumption rather than tradable goods absorption. Following Stockman and Tesar (1995), we proxy non-tradable consumption with consumption of services and compute tradable consumption by subtracting nontradable consumption from total consumption. While we find this measure of tradable consumption a priori preferable to the absorption measure used in Section 4 to gauge the fit the model, we refrain from using it in our main analysis because of data availability. Complete consumption time series by type for the period 1970-2007 are indeed only available for a very small number of countries in our sample. For this reason, in this section we focus on the sample period 1985-2007. For this period, complete data series are available for 10 countries (see Appendix A for details).

Table 6 reports the sum of squared errors between the data and the model under this alternative empirical benchmark. The key findings of Section 4 do not change. In particular, it is still the case that the Bond Economy yields sum of squared errors that are very similar to the Complete Markets Economy. Furthermore, as for the baseline analysis based on an empirical absorption series, portfolio adjustment costs reduce the sum of squared errors

Table 5: Portfolio adjustment cost parameter and sum of squared errors of tradable consumption between data and model with tighter borrowing constraint.

	ϕ	*Portfolio Adj.Cost*	*Bond Economy*	*Complete Markets*
United States	10.0	0.038	0.073	0.076
United Kingdom	10.0	0.036	0.059	0.063
Japan	10.0	0.023	0.052	0.056
Germany	4.4	0.025	0.038	0.040
France	4.2	0.039	0.050	0.052
Italy	10.0	0.088	0.115	0.118
Spain	10.0	0.148	0.262	0.286
Canada	0.1	0.097	0.099	0.107
Netherlands	1.5	0.064	0.069	0.071
Australia	5.5	0.070	0.082	0.085
Sweden	3.1	0.146	0.173	0.196
Finland	10.0	0.193	0.229	0.253
Norway	0.1	0.206	0.209	0.217
Denmark	10.0	0.274	0.314	0.324
Austria	1.5	0.039	0.046	0.045
Mexico	10.0	0.142	0.332	0.344
Turkey	10.0	0.082	0.205	0.219
Korea	10.0	0.178	0.310	0.334
Brazil	10.0	0.073	0.211	0.230
China	10.0	0.047	0.110	0.131
India	10.0	0.012	0.066	0.075

for all countries and do so significantly for some of them.[13] Therefore, the finding that portfolio adjustment costs improve the fit of the model remains valid when we use a consumption time series as empirical benchmark.

6. Growth shocks

In this section we check whether our results are robust to the assumption that the endowment processes follow stochastic trends, in line with the shocks to growth rates or trends introduced by Aguiar and Gopinath (2007). The

[13]Notice that the magnitude of the sum of squared errors in Table 6 are not directly comparable to those of Section 4 because the sample period is different.

Table 6: Sum of squared errors of tradable consumption between data and model for alternative definition of tradable and nontradable consumption.

	ϕ	*Portfolio Adj.Cost*	*Bond Economy*	*Complete Markets*
United States	1.0	0.010	0.012	0.012
United Kingdom	10.0	0.014	0.021	0.023
Japan	-	-	-	-
Germany	-	-	-	-
France	2.8	0.005	0.011	0.013
Italy	-	-	-	-
Spain	-	-	-	
Canada	0.1	0.007	0.009	0.011
Netherlands	10.0	0.007	0.013	0.013
Australia	1.3	0.006	0.007	0.007
Sweden	-	-	-	-
Finland	0.8	0.033	0.041	0.048
Norway	1.7	0.019	0.030	0.034
Denmark	-	-	-	-
Austria	1.5	0.009	0.013	0.014
Mexico	-	-	-	-
Turkey	-	-	-	
Korea	10.0	0.042	0.085	0.093
Brazil	-	-	-	-
China	-	-	-	-
India	-	-	-	-

process for tradable endowment of country i is specified as follows:

$$y_{i,t}^T = y_{i,t-1}^T z_{i,t}^T,$$

where $z_{i,t}^T$ follows a stationary process. This variable is the gross growth rate of tradable endowment.

The process for the nontradable endowment is specified as

$$y_{i,t}^N = y_{i,t-1}^T z_{i,t}^N,$$

where $z_{i,t}^N$ also follows a stationary process. This specification guarantees that the ratio of tradable and nontradable endowments is stationary within each country even if the two endowments are not stationary. Thus, the growth rates of the two sectors converge to a common long-run average, in line with standard balanced growth assumptions. The variables $(z^T_{1,t}, z^T_{2,t}, z^N_{1,t}, z^N_{2,t})$ follow a joint first order Markov process.

In order to solve the model, we normalize the non-stationary variables by the lagged value of tradable endowment $y^T_{i,t-1}$ and use the tilde sign to denote the normalized variables. For example, normalized tradable consumption is $\tilde{c}^T_{i,t} = \frac{c^T_{i,t}}{y^T_{i,t-1}}$. Similarly, nontradable consumption is given by $\tilde{c}^N_{i,t} = \frac{c^N_{i,t}}{y^T_{i,t-1}}$. Using the normalized variables, the resource constraints are

$$\tilde{c}^N_{i,t} = \tilde{y}^N_{i,t},$$

$$\tilde{c}^T_{i,t} + \sum_{\tilde{s}_{t+1}} \tilde{b}_{i,t+1}(\tilde{s}_{t+1}) z^T_{i,t} q(\tilde{s}_t, \tilde{s}_{t+1}) = \tilde{y}^T_{i,t} + \tilde{b}_{i,t}(\tilde{s}_t),$$

where the vector $\tilde{s}_t$ contains $(z^T_{1,t}, z^T_{2,t}, z^N_{1,t}, z^N_{2,t})$.

The clearing condition in the international asset market is

$$\tilde{b}_{1,t+1}(\tilde{s}_{t+1}) \cdot \psi_t + \tilde{b}_{2,t+1}(\tilde{s}_{t+1}) \cdot (1 - \psi_t) = 0,$$

where $\psi_t = \frac{n y^T_{1,t}}{n y^T_{1,t} + (1-n) n y^T_{2,t}}$ is country 1's share of world tradable endowment.

Claims are subject to the borrowing limit

$$b_{i,t+1}(s_{t+1}) \geq y^T_{i,t} \underline{b},$$

which in normalized form becomes $\tilde{b}_{i,t+1}(\tilde{s}_{t+1}) \geq \underline{b}$.

Once normalized, the model can be solved using the same methodology used to solve the model with stationary endowments. The only complication is that we have an additional state variables. In addition to $\tilde{s}_t$ and $\tilde{b}_{1,t}$—which are the equivalent of s_t and $b_{1,t}$ in the version of the model with stationary endowments—we now also have country 1's endowment share $\psi_t \in [0, 1]$.

The Markov process for $(z^T_{1,t}, z^T_{2,t}, z^N_{1,t}, z^N_{2,t})$ is calibrated using the same approach used to calibrate $(y^T_{1,t}, y^T_{2,t}, y^N_{1,t}, y^N_{2,t})$ in the previous version of the model. The empirical counterparts of $z^T_{1,t}$ and $z^T_{2,t}$ are the growth rates of tradable incomes (rather than HP detrended tradable incomes). The empirical counterparts of $z^N_{1,t}$ and $z^N_{2,t}$ are the ratios of nontradable income to lagged tradable income, which we detrend using the HP filter.

The left section of Table 7 reports the sum of squared errors of tradable consumption growth for three versions of the economy: Portfolio Rigidities (with minimizing coefficient reported in the first column), Bond Economy and Complete Markets. As can be seen from the table, for the majority of countries, the model with portfolio rigidities still improves the fit of the model. The right section of the table reports the elasticities of tradable consumption growth (tradable absorption growth in the data) to tradable income growth. For the elasticity as well, we see that portfolio rigidities still improve the performance of the model for a majority of countries.

Table 7: Sum of squared errors in tradable consumption growth and elasticity of tradable consumption growth to tradable income growth.

		Sum of square errors			*Elasticities*			
	ϕ	*Portfolio Adj.Cost*	*Bond Economy*	*Complete Markets*	Data	*Portfolio Adj.Cost*	*Bond Economy*	*Complete Markets*
United States	1.6	0.553	0.779	1.118	1.676	1.665	1.065	0.521
United Kingdom	0.1	0.226	0.251	0.321	0.244	0.828	0.882	0.368
Japan	10.0	0.158	0.318	0.214	1.068	1.018	0.832	0.313
Germany	10.0	0.324	0.558	0.339	0.462	1.018	0.896	0.402
France	10.0	0.121	0.135	0.154	1.350	1.011	1.140	0.471
Italy	10.0	0.170	0.270	0.233	1.154	1.000	0.623	0.238
Spain	0.1	0.590	0.593	0.740	0.126	1.078	1.092	0.196
Canada	10.0	0.867	1.249	0.864	0.491	1.016	0.962	0.383
Netherlands	0.0	2.055	2.055	2.171	1.076	1.060	1.060	0.506
Australia	0.0	0.578	0.578	0.597	0.971	1.029	1.029	0.236
Sweden	10.0	1.865	2.237	1.626	-1.871	1.062	1.442	0.235
Finland	10.0	1.316	1.680	1.153	-1.271	1.051	1.367	0.219
Norway	2.2	5.588	5.806	5.825	2.174	1.061	0.910	-0.051
Denmark	3.3	2.366	2.430	2.427	1.321	1.037	1.130	0.017
Austria	10.0	0.759	0.815	0.805	0.690	1.010	1.122	0.386
Mexico	2.2	0.304	0.303	0.508	1.796	1.051	0.917	-0.022
Turkey	0.9	0.188	0.221	0.359	1.610	1.074	0.943	-0.162
Korea	0.0	2.265	2.265	2.496	1.033	0.905	0.905	0.060
Brazil	10.0	0.482	0.614	0.738	1.670	1.012	0.769	0.009
China	10.0	0.174	0.286	0.180	0.401	1.069	1.799	-0.156
India	0.1	0.055	0.055	0.188	1.115	1.292	1.303	-0.143

7. Conclusion

This paper investigates the extent to which international globalization of financial markets allows for cross-country risk-sharing at the business cycle frequency. Our analysis suggests that cross-country cyclical risk sharing is still limited and that this is unlikely to be the result of financial market frictions that limit the availability of state-contingent trades (insurance) and/or to sizable nontradable income fluctuations. Frictions that *de-facto* reduce the short-term mobility of financial capital or international portfolio adjustment costs play an important role but do not completely eliminate the gap between the predictions of the model and the data. We leave for future research the investigation of additional factors that could explain the still limited degree of international risk sharing.

Appendix A. Data sources and definitions

For all OECD countries (the United States, the United Kingdom, Japan, Germany, France, Italy, Spain, Canada, Netherlands, Australia, Sweden, Finland, Norway, Denmark, Austria, Mexico, Turkey, Korea), we use data from the OECD's *National Account Statistics*. Total output is GDP. Tradable output is the sum of value added in "agriculture, hunting and forestry, fishing" (sectors A and B) and "industry, including energy" (sectors C to E). Nontradable output is the sum of value added in "construction" (sector F), "wholesale and retail trade, repairs, hotels and restaurants" (sectors G to I), "financial intermediation, real estate, renting and business activities" (sectors J to K) and "other services" (sectors L to P).

For Brazil, China and India, we use data from the World Bank's *World Development Indicators*. Total output is again GDP. Tradable output is the sum of value added in "agriculture" and "industry." Nontradable output is value added in "services, etc".

We also considered a measure of tradable consumption for the analysis reported in Section 5. There, we proxy nontradable consumption with consumption of services ("final consumption expenditure of households on the territory, service") and compute tradable consumption by subtracting this proxy for nontradable consumption to total private consumption ("final consumption expenditure of households on the territory"). Since disaggregated consumption data is only available for a handful of countries for the whole sample period 1970-2007, we restrict the sample period to 1985-2007. For this subperiod, disaggregated consumption data is available for Australia, Austria, Canada, Finland, France, Korea, the Netherlands, Norway, the United Kingdom and the United States. Therefore, the simulation results are reported only for this sub-sample of 10 countries.

Rest of the world (ROW) aggregates. Let $Y^T_{j,t}$, $Y^N_{j,t}$ and $N_{j,t}$ respectively denote tradable output, nontradable output and population of country j. To construct the ROW aggregates relatively to the focus country i (indexed by i^*), we perform the following steps:

1. We compute tradable output, nontradable output and population of ROW with respect to country i as

$$Y^T_{i^*,t} = \sum_{j \neq i} Y^T_{j,t}, \qquad Y^N_{i^*,t} = \sum_{j \neq i} Y^N_{j,t}, \qquad N_{i^*,t} = \sum_{j \neq i} N_{j,t}.$$

2. We then compute per-capita tradable and nontradable outputs for country i and for its corresponding ROW as

$$\widetilde{Y}_{i,t}^{T} = \frac{Y_{i,t}^{T}}{N_{i,t}}, \qquad \widetilde{Y}_{i,t}^{N} = \frac{Y_{i,t}^{N}}{N_{i,t}}, \qquad \widetilde{Y}_{i^*,t}^{T} = \frac{Y_{i^*,t}^{T}}{N_{i^*,t}}, \qquad \widetilde{Y}_{i^*,t}^{N} = \frac{Y_{i^*,t}^{N}}{N_{i^*,t}}.$$

3. Next we log and detrend the per-capita variables $\widetilde{Y}_{i,t}^{T}$, $\widetilde{Y}_{i,t}^{N}$, $\widetilde{Y}_{i^*,t}^{T}$, $\widetilde{Y}_{i^*,t}^{N}$ using the Hodrik-Prescott filter with smoothing parameter $\lambda = 100$. The detrended cyclical components are denoted by $y_{i,t}^{T}$, $y_{i,t}^{N}$, $y_{i^*,t}^{T}$, $y_{i^*,t}^{N}$.

Table A.1: Standard deviations of output, relative standard deviations of consumption/absorption and elasticities of consumption/absorption relative to output, 1970-1990 and 1991-2007.

	Total			*Tradable*			*Nontrad.*
	$\sigma(Y_i)$	$\frac{\sigma(C_i)}{\sigma(Y_i)}$	$\alpha(C_i, Y_i)$	$\sigma(Y_i^T)$	$\frac{\sigma(C_i^T)}{\sigma(Y_i^T)}$	$\alpha(C_i^T, Y_i^T)$	$\sigma(Y_i^N)$
				1970-1990			
United States	0.023	0.94	0.84	0.041	1.47	1.26	0.016
United Kingdom	0.026	1.28	1.12	0.034	1.67	1.46	0.020
Japan	0.023	0.93	0.84	0.033	1.62	1.44	0.022
Germany	0.016	1.21	0.92	0.025	1.47	1.10	0.016
France	0.017	0.82	0.72	0.021	2.24	1.52	0.013
Italy	0.019	1.03	0.86	0.034	1.82	1.49	0.012
Spain	0.031	1.13	1.08	0.043	2.45	2.16	0.031
Canada	0.022	1.29	1.14	0.046	1.74	1.44	0.016
Netherlands	0.016	1.51	1.11	0.023	2.04	1.08	0.012
Australia	0.016	0.90	0.28	0.031	1.90	1.47	0.020
Sweden	0.021	1.49	1.13	0.041	2.10	1.17	0.012
Finland	0.032	1.08	1.01	0.036	2.67	1.48	0.029
Norway	0.018	1.70	1.46	0.024	2.96	-0.07	0.015
Denmark	0.021	1.51	1.11	0.033	2.79	1.77	0.016
Austria	0.015	1.05	0.87	0.022	1.98	1.50	0.012
Mexico	0.037	1.07	1.02	0.038	2.49	2.25	0.037
Turkey	0.037	1.46	0.37	0.030	1.33	0.91	0.024
Korea	0.034	0.61	0.48	0.048	1.20	0.76	0.024
Brazil	0.046	0.98	0.15	0.054	1.33	1.25	0.049
China	0.037	1.28	1.10	0.032	-	-	0.061
India	0.025	0.82	0.61	0.034	1.02	0.94	0.015
				1991-2007			
United States	0.013	1.05	0.95	0.029	1.57	1.24	0.017
United Kingdom	0.017	1.31	1.11	0.017	1.79	0.52	0.014
Japan	0.019	0.63	0.58	0.037	1.02	0.86	0.012
Germany	0.017	0.67	0.55	0.033	1.22	0.84	0.013
France	0.012	0.93	0.83	0.021	1.78	1.19	0.012
Italy	0.012	1.64	1.34	0.020	3.09	0.89	0.012
Spain	0.019	1.18	1.12	0.033	2.02	1.34	0.020
Canada	0.019	0.57	0.45	0.035	1.27	-0.07	0.015
Netherlands	0.017	1.32	1.06	0.014	3.30	0.76	0.018
Australia	0.013	0.65	0.34	0.012	3.59	-1.14	0.017
Sweden	0.021	1.10	0.98	0.047	1.39	0.82	0.017
Finland	0.032	0.88	0.76	0.044	1.23	0.28	0.032
Norway	0.017	0.96	0.81	0.026	2.88	0.42	0.018
Denmark	0.015	1.41	0.77	0.027	4.00	2.22	0.011
Austria	0.014	0.71	0.47	0.025	1.40	0.37	0.011
Mexico	0.026	1.45	1.24	0.035	2.22	1.63	0.029
Turkey	0.043	1.06	1.01	0.044	2.22	2.01	0.033
Korea	0.028	1.73	1.67	0.037	3.21	2.75	0.028
Brazil	0.024	1.48	1.25	0.040	2.18	1.86	0.023
China	0.031	0.87	0.71	0.035	1.17	0.91	0.026
India	0.021	0.94	0.86	0.027	1.62	1.48	0.016

Table A.2: Tradable and nontradable endowments: standard deviations, contemporaneous correlations and autocorrelations.

	Tradable			*Nontradable*			*Tradable*			*Nontradable*		
	σ_i^T	σ_{i*}^T	$\rho_{i,i*}^T$	σ_i^N	σ_{i*}^N	$\rho_{i,i*}^N$	ρ_i^T	ρ_{i*}^T	ρ^T	ρ_i^N	ρ_{i*}^N	ρ^N
United States	0.036	0.018	0.71	0.016	0.010	0.40	0.47	0.46	0.47	0.68	0.67	0.68
United Kingdom	0.027	0.021	0.76	0.018	0.010	0.47	0.49	0.46	0.47	0.74	0.64	0.69
Japan	0.034	0.021	0.43	0.018	0.011	0.29	0.52	0.50	0.51	0.61	0.66	0.64
Germany	0.028	0.021	0.48	0.015	0.011	0.32	0.48	0.48	0.48	0.65	0.66	0.66
France	0.021	0.021	0.47	0.013	0.010	0.70	0.56	0.47	0.52	0.71	0.64	0.68
Italy	0.028	0.021	0.62	0.012	0.010	0.74	0.36	0.47	0.42	0.57	0.65	0.61
Spain	0.038	0.021	0.50	0.026	0.010	0.49	0.78	0.45	0.62	0.83	0.64	0.73
Canada	0.042	0.020	0.72	0.016	0.010	0.64	0.54	0.46	0.50	0.75	0.64	0.69
Netherlands	0.019	0.021	0.58	0.015	0.010	0.71	0.47	0.46	0.47	0.63	0.65	0.64
Australia	0.024	0.021	0.63	0.019	0.010	0.43	0.43	0.46	0.44	0.62	0.65	0.63
Sweden	0.044	0.021	0.43	0.015	0.010	0.59	0.69	0.46	0.58	0.75	0.65	0.70
Finland	0.041	0.021	0.41	0.031	0.010	0.59	0.59	0.47	0.53	0.78	0.65	0.71
Norway	0.025	0.021	0.03	0.017	0.010	0.30	0.43	0.47	0.45	0.73	0.65	0.69
Denmark	0.031	0.021	0.23	0.014	0.010	0.66	0.57	0.46	0.52	0.42	0.65	0.54
Austria	0.023	0.021	0.63	0.012	0.010	0.31	0.42	0.46	0.44	0.50	0.65	0.57
Mexico	0.036	0.021	0.08	0.033	0.011	-0.03	0.60	0.48	0.54	0.55	0.67	0.61
Turkey	0.036	0.021	0.27	0.028	0.010	-0.00	0.49	0.45	0.47	0.54	0.65	0.60
Korea	0.043	0.021	0.33	0.026	0.010	-0.05	0.37	0.47	0.42	0.59	0.66	0.62
Brazil	0.048	0.021	0.52	0.039	0.010	0.24	0.63	0.45	0.54	0.61	0.65	0.63
China	0.033	0.022	-0.06	0.048	0.011	0.15	0.69	0.48	0.59	0.56	0.67	0.61
India	0.031	0.021	0.04	0.015	0.010	0.25	0.14	0.45	0.30	0.58	0.64	0.61

Appendix B. Calibration of Markov processes

Endowments for each of the two goods $g \in \{T, N\}$ have two realizations, resulting in four possible realizations for nontradable endowments and four possible realizations for tradable endowments (two in country i and two in country i^*). Therefore, the state of nature for the world economy has 16 possible outcomes. Denoting by $s_t^g = (y_{i,t}^g, y_{i^*,t}^g)$ the pair of endowments for $g \in \{T, N\}$ in countries i and i^*, the probability of a realization j' in the next period given the current realization j is denoted by $\pi_{j,j'}^g$. These probabilities are given by the "simple persistence rule"

$$\pi_{j,j'}^g = (1 - \theta^g)\Pi_{j'}^g + \theta^g p_{j,j'},$$

where θ^g is a persistence parameter, $\Pi_{j'}^g$ is the long-run probability of state $s^g(j')$, and $p_{j,j'} = 1$ if $j = j'$ and 0 otherwise. The transition probabilities satisfy $0 \leq \pi_{j,j'} \leq 1$ for $j, j' = 1, \ldots, 4$ and $\sum_{j'} \pi_{j,j'} = 1$ for $j = 1, \ldots, 4$. The stochastic structure is simplified further by assuming the symmetry conditions $\Pi(y_{i,H}^g, y_{i^*,H}^g) = \Pi(y_{i,L}^g, y_{i^*,L}^g) = \Pi^g$, $\Pi(y_{i,H}^g, y_{i^*,L}^g) = \Pi(y_{i,L}^g, y_{i^*,H}^g) = 0.5 - \Pi^g$, $y_{i,H}^g = -y_{i,L}^g = y_i^g$, and $y_{i^*,H}^g = -y_{i^*,L}^g = y_{i^*,}^g$. The long-run standard deviations of the shocks are equal to $\sigma_i^g = y_i^g$ and $\sigma_{i^*}^g = y_{i^*}^g$. The contemporaneous correlation is $\rho_{i,i^*}^g = 4\Pi^g - 1$ and the common first-order autocorrelation is $\rho_i^g = \rho_{i^*}^g = \rho_g = \theta^g$.

Appendix C. Computational procedure

We describe here the computational procedures used to solve for the competitive equilibrium in the Complete Markets Economy, in the Bond Economy and in the Costly Portfolio Adjustment Economy. The autarky equilibrium is trivial to compute since each country consumes its own endowments of tradables and nontradables.

Complete Markets Economy. The computation of the allocation under complete markets solves a sequence of static equations. Given $y_{i,t}^T$, $y_{i^*,t}^T$, $y_{i,t}^N$, $y_{i^*,t}^N$, we find $c_{i,t}^T$ and $c_{i^*,t}^T$ by solving the two (nonlinear) equations

$$\frac{\frac{\partial U\left(C(c_{i,t}^T, y_{i,t}^N)\right)}{\partial c_{i,t}^T}}{\frac{\partial U\left(C(c_{i^*,t}^T, y_{i^*,t}^N)\right)}{\partial c_{i^*,t}^T}} = \kappa, \tag{C.1}$$

$$n_i \cdot y_{i,t}^T + (1 - n_i) \cdot y_{i^*,t}^T = n_i \cdot c_{i,t}^T + (1 - n_i) \cdot c_{i^*,t}^T, \tag{C.2}$$

where κ is a constant pinned down by the relative wealth of the two countries in the initial simulation period and n_i is the population share of country i. The first equation imposes that the ratio of marginal utilities stays constant over time while the second equation is the worldwide resource constraint.

Bond Economy. The computation of the equilibrium in the Bond Economy is more complex since the borrowing constraints are occasionally binding. The solution is based on a Projection Method. We first discretize the bond holdings of country i, $b_{i,t}$. We choose a grid of 51 equally spaced points in the interval $\left[\underline{b}\,,\,-(n_i/(1-n_i))\underline{b}\right]$. The stochastic endowments are also discretized as described in the calibration section. We then find the values of $c^T_{i,t}$, $c^T_{i^*,t}$, $b_{i,t+1}$, $b_{i^*,t+1}$ and R_t at each grid point of the state space by solving the system

$$c^T_{i,t} + \tfrac{b_{i,t+1}}{R_t} = y^T_{i,t} + b_{i,t}, \tag{C.3}$$

$$c^T_{i^*,t} + \tfrac{b_{i^*,t+1}}{R_t} = y^T_{i^*,t} + b_{i^*,t}, \tag{C.4}$$

$$n_i \cdot b_{i,t+1} + (1-n_i)\cdot b_{i^*,t+1} = 0, \tag{C.5}$$

$$\tfrac{\partial U\left(C(c^T_{i,t},y^N_{i,t})\right)}{\partial c^T_{i,t}} \geq \beta R_t E_t \tfrac{\partial U\left(C(c^T_{i,t+1},y^N_{i,t+1})\right)}{\partial c^T_{i,t+1}}, \quad (= \text{if } b_{i,t+1} > \underline{b}), \tag{C.6}$$

$$\tfrac{\partial U\left(C(c^T_{i^*,t},y^N_{i^*,t})\right)}{\partial c^T_{i^*,t}} \geq \beta R_t E_t \tfrac{\partial U\left(C(c^T_{i^*,t+1},y^N_{i^*,t+1})\right)}{\partial c^T_{i^*,t+1}}, \quad (= \text{if } b_{i^*,t+1} > \underline{b}). \tag{C.7}$$

The first and second equations are the budget constraints for each country. The third equation is the market clearing condition for bonds. The last two equations are the optimality conditions for the choice of bonds. The inequality signs account for corner solutions (binding borrowing constraint).

In order to solve the last two equations we need to compute the expectations on the right hand side of these equations. This requires an iterative procedure where we guess the (approximate) functions

$$\varphi_i(s_t) \approx E_t \tfrac{\partial U\left(C(c^T_{i,t+1},y^N_{i,t+1})\right)}{\partial c^T_{i,t+1}}, \tag{C.8}$$

$$\varphi_{i^*}(s_t) \approx E_t \tfrac{\partial U\left(C(c^T_{i^*,t+1},y^N_{i^*,t+1})\right)}{\partial c^T_{i^*,t+1}}. \tag{C.9}$$

The approximation functions for the expectation terms are given by linear interpolations of the values assigned to these terms at each grid point of the state space. Therefore, the guess for these functions consists of values assigned to the expectation terms at each grid point for s_t.

Once we have the guessed functions $\varphi_i(s_t)$ and $\varphi_{i^*}(s_t)$, we can solve the above five equations at each grid point using a nonlinear solver. The solutions are then used to compute the expectation terms one period earlier at each grid point. This provides the new guesses for $\varphi_i(s_t)$ and $\varphi_{i^*}(s_t)$. We repeat the procedure until convergence.

Costly Portfolio Adjustment Economy. The procedure is analogous to the Bond Economy after replacing the budget constraint (C.3) and the Euler condition (C.6) for country i with equations (1) and (2).

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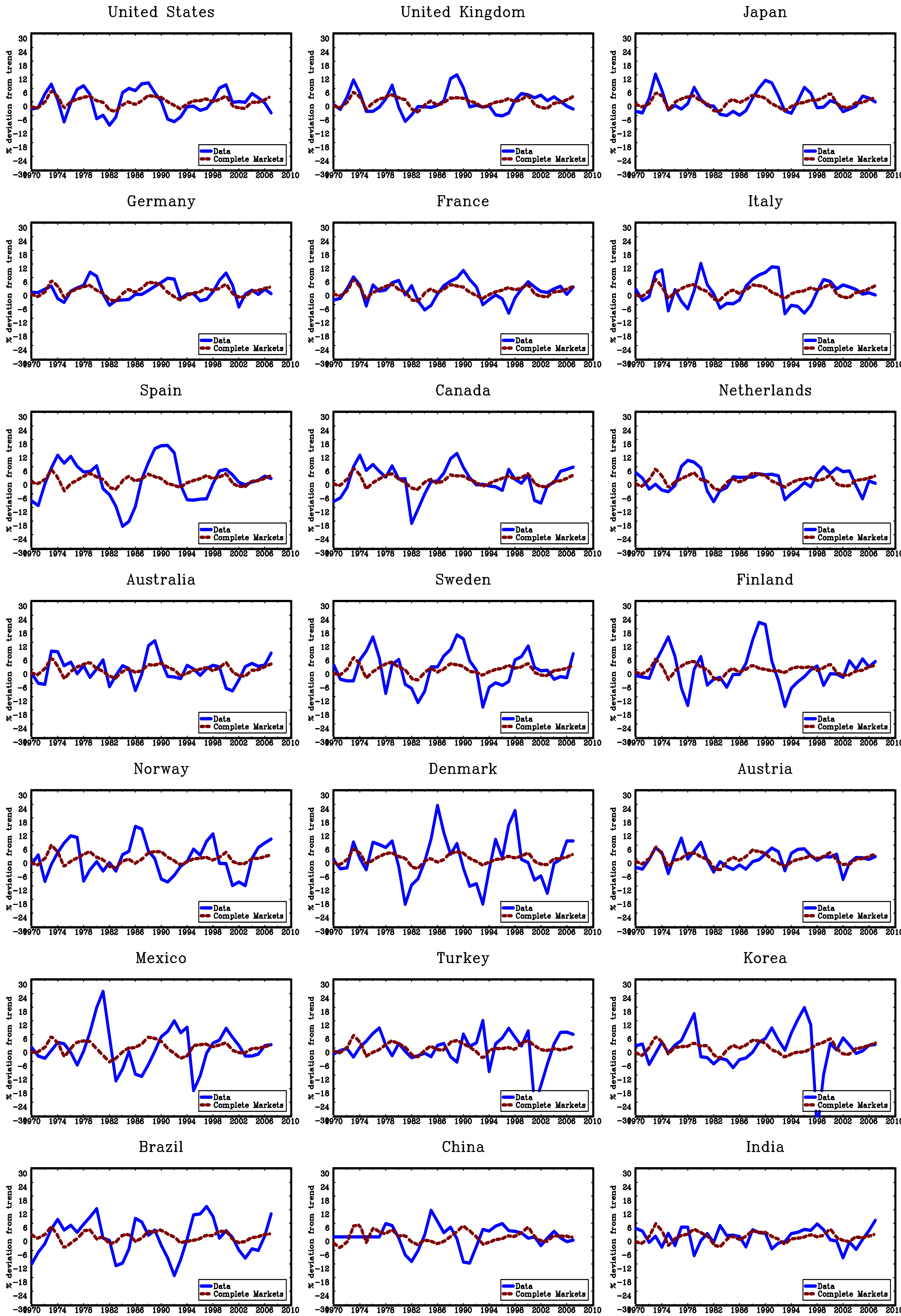

Figure 1: Absorption of tradables: Data and Complete Markets Economy.

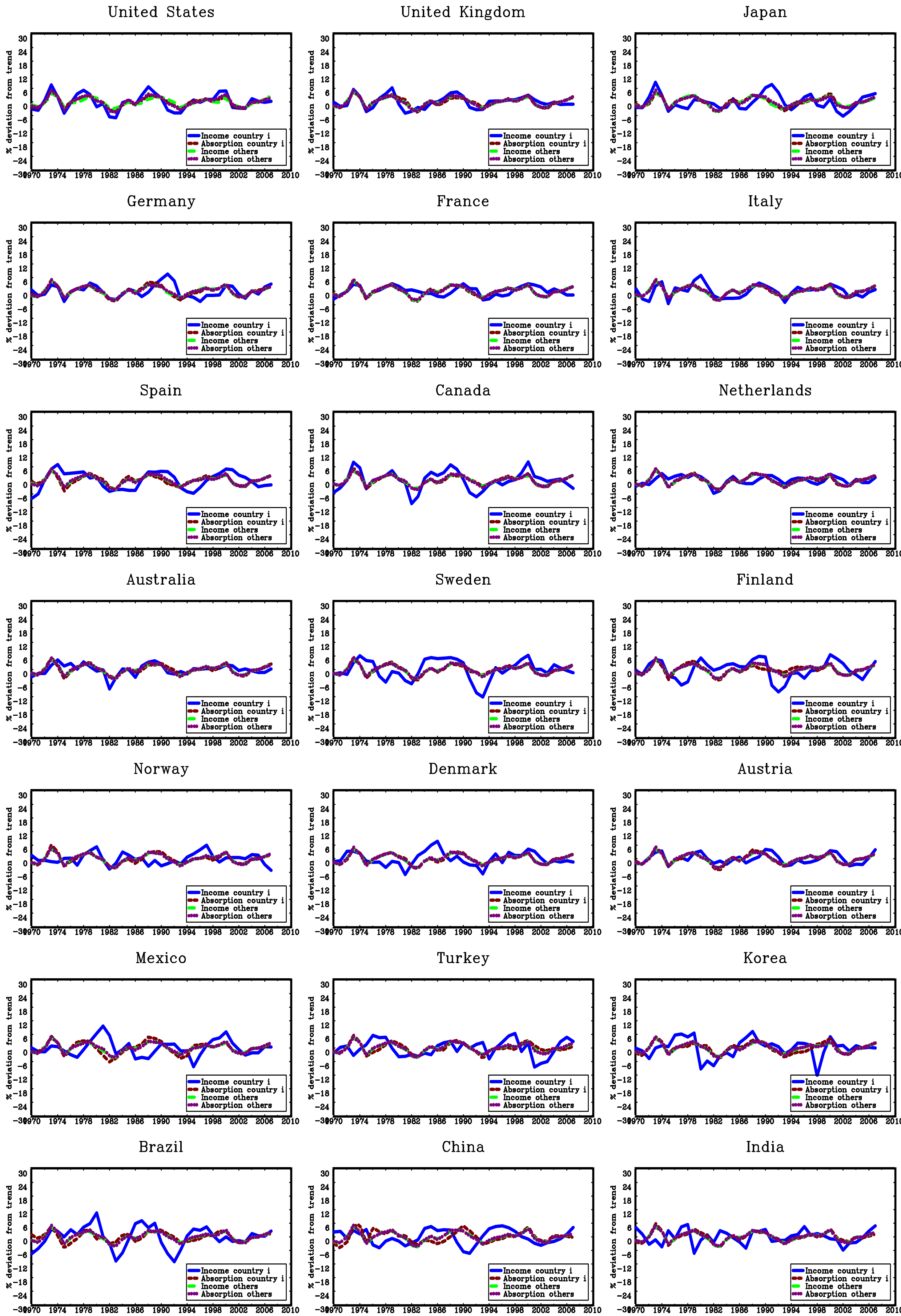

Figure 2: Output and absorption of tradables: Data and Complete Markets Economy.

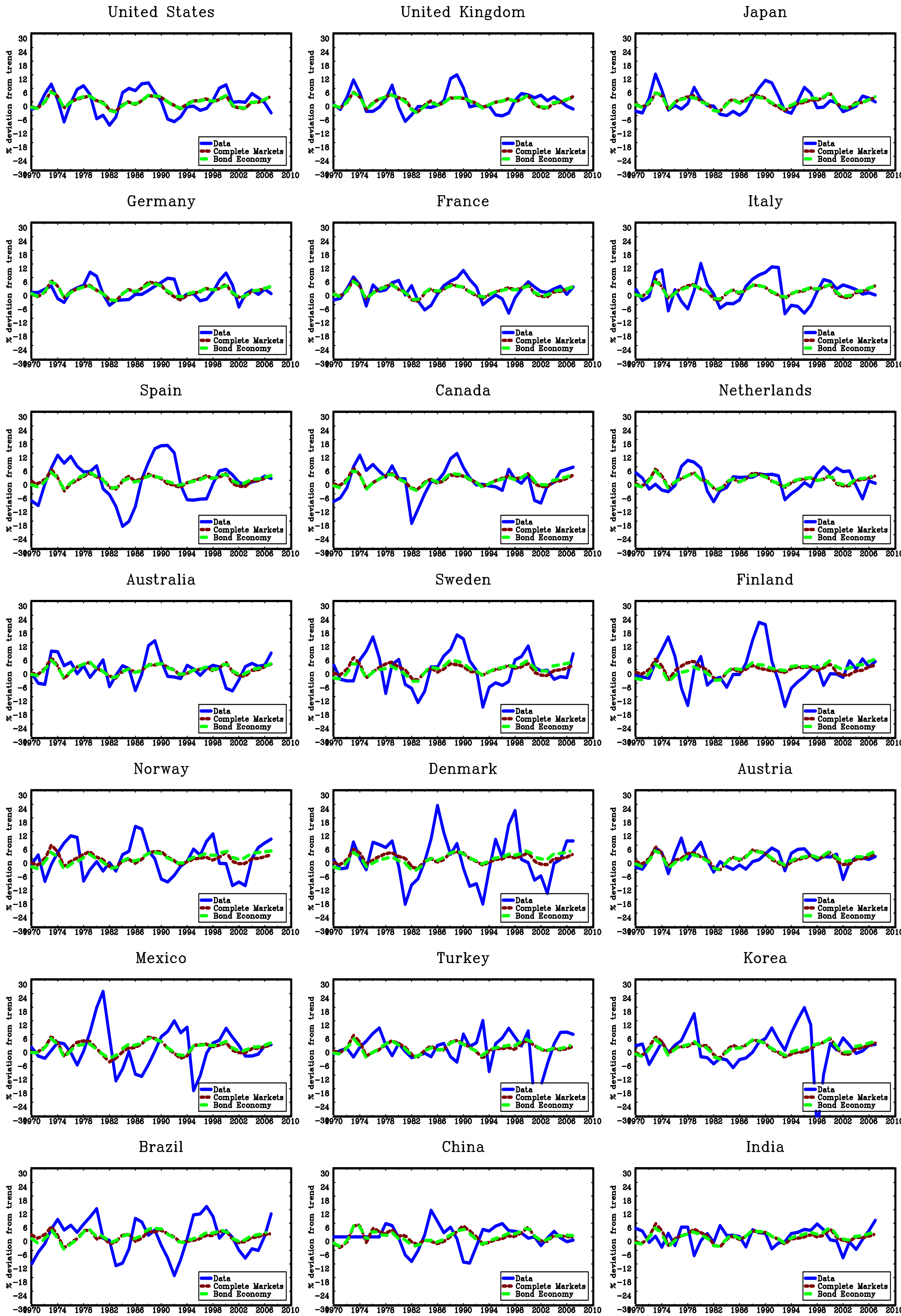

Figure 3: Absorption of tradables: Data, Complete Markets and Bond Economy.

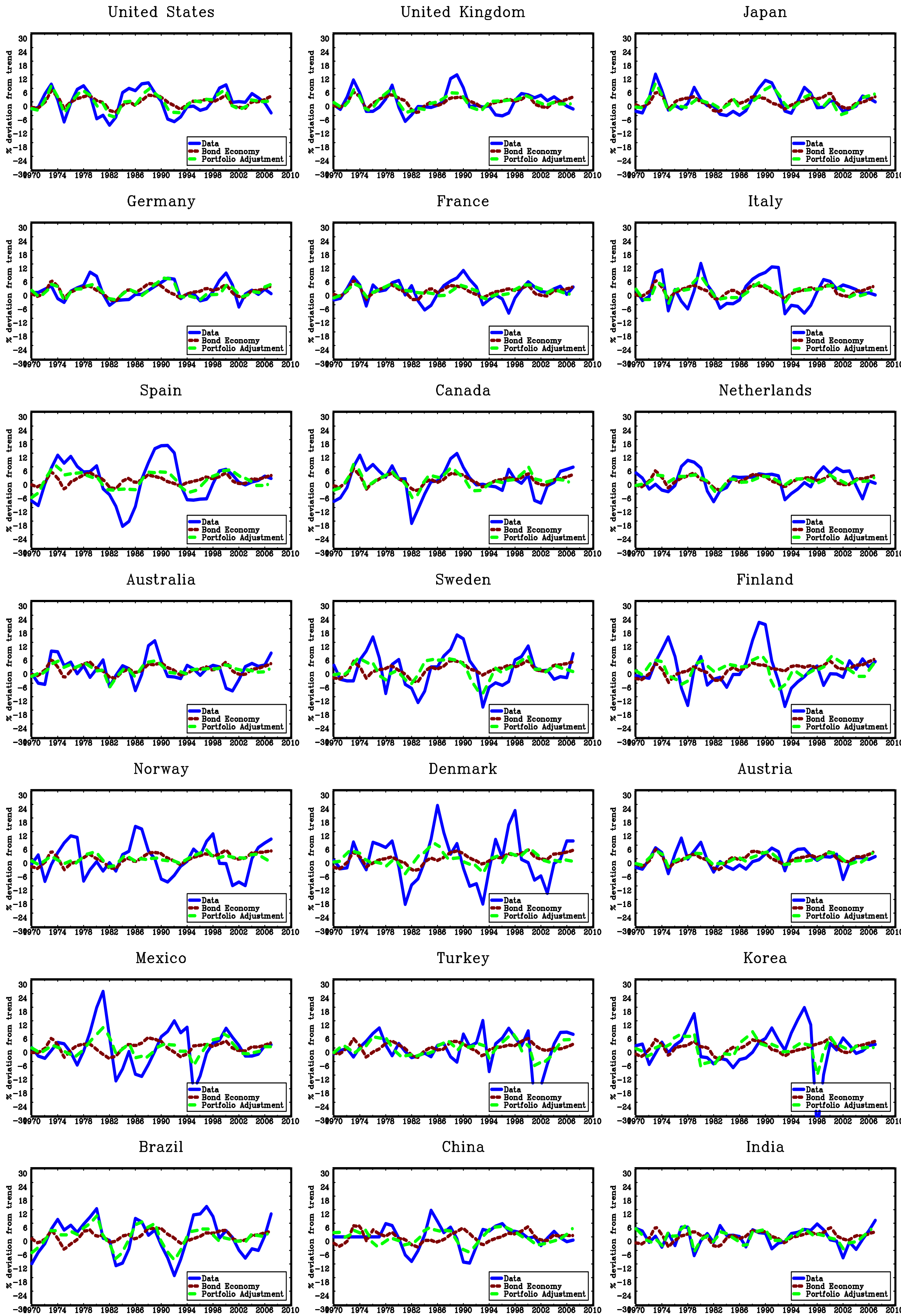

Figure 4: Absorption of tradables: Data, Bond Economy and Portfolio Adjustments.