

International Business Cycles with Multiple-Input Investments*

P. MARCELO OVIEDO[†]

RAJESH SINGH[‡]

Iowa State University

Iowa State University

April 15, 2011

Abstract

This paper studies a two country model with economies disaggregated into traded and non-traded sectors and in which investment goods as in practice are produced by combining inputs from all sectors. The model also accounts for nontraded distribution services employed in retailing traded goods to consumers. The results show that the model with multiple input investments outperforms the standard model in which sectoral output also serves as its capital. In particular, it substantially improves (a) the movements of trade balance and relative prices, (b) within country comovements of sectoral aggregates, and (c) the relative cross-country comovement of aggregate output and consumption.

KEYWORDS: International business cycles; Quantity anomaly; Distribution costs; Cross-country correlations.

JEL CLASSIFICATION: F32, F34, F41

*We thank Joydeep Bhattacharya, Harvey Lapan, B. Ravikumar, and Shiva Sikdar, as well as seminar participants at Iowa State University, the 2006 North American Econometric Society meetings, and the 2007 Midwest Macroeconomics Meetings, for their comments. We also thank two anonymous referees and the editor whose suggestions have helped us improve the paper substantially. The usual disclaimer applies.

[†]*Oviedo*: Department of Economics, 260 Heady Hall, Iowa State University, Ames IA 50011-1070; Phone 515-294-6740; Fax: 515- 294-0221.

[‡]*Singh* (Corresponding author): Associate Professor, Department of Economics, 281 Heady Hall, Iowa State University, Ames IA 50011-1070; Phone 515-294-5213; Fax: 515- 294-0221; Email: rsingh@iastate.edu

1 Introduction

International business cycle models typically make simplifying assumptions on the composition of capital goods. In the two country single good model introduced by Backus, Kehoe, and Kydland (1992), consumption and capital by construction are identical goods. Even in its two goods extensions, for example in Backus, Kehoe, and Kydland (1994) and Heathcote and Perri (2003), a country specific consumption good also serves as capital. In models that include a nontraded sector, such as Stockman and Tesar (1995) and Mendoza (1995), a sector's output serves as its own capital. Some others, for example Burstein, Neves, and Rebelo (2003) and more recently Corsetti, Dedola, and Leduc (2008), assume that capital is produced only by the traded sector but is perfectly mobile across traded and nontraded sectors.

In practice, capital goods compose of both traded and nontraded goods. Based on a multi-country panel data on *aggregate* investments, Bems (2008) estimates that about 54% - 62% of the expenditure is on nontraded goods. These shares however vary across sectors on further disaggregation. For example, over 1947-2004, the average US investment expenditure in the traded sector is about 69% on Equipment and Software (i.e., traded goods) while the remaining 31% is on Structures (i.e., nontraded goods); the corresponding shares for the nontraded sector are 39% and 61%, respectively. Further disaggregation informs that the import content of the investment expenditure on traded goods is 37% and 36% respectively in the traded and the nontraded sector. Altogether, thus, US investment expenditure shares in the traded sector on its exportables, imports, and nontraded goods are 43%, 26%, and 31%, respectively, whereas in the nontraded sector these shares are 25%, 14%, and 61%, respectively.¹

This paper adopts the above compositional shares into an otherwise standard two-country complete-markets international business cycle model as in Stockman and Tesar (1995) in which each country produces a distinct traded (exportable) good and a nontraded good and consumption preferences are defined over exportable, importable, and nontraded goods.

¹After accounting for the relative sizes of the two sectors, input share estimates are broadly consistent with those reported by Bems (2008).

The motivation for detailing investment composition is simple. Since investment is the most volatile aggregate in the national accounts, modeling its composition correctly within the business cycle framework will significantly impact model-generated moments. First, a sector’s investment demand from other sectors is likely to align their output, employment, and investment movements and thus help explain their observed positive correlations in the data.² Second, as output is either invested or consumed, any movements in the former will mirror in the latter as well, and thus inhibit cross-country consumption comovements encountered in standard models.

The results substantiate these conjectures. The model with investments composed of multi-sectoral inputs outperforms the model with sectoral output serving as its own capital on many dimensions. First, it brings the volatility of trade balance, terms of trade, relative price of non-traded goods, and real exchange rates closer to the data. Second, internal correlations of output with other aggregates, particularly the trade balance, are much improved. Within country correlations of sectoral aggregates come closer to the data. Finally, cross-country consumption correlation falls below that of output; that is, the *quantity anomaly* does not exist in the model with multi-input composition of sectoral investments.³

How do investments comprising multisectoral inputs improve model performance? Consider a positive supply shock in either exportable or nontraded sector in one of the countries. Compared to the model in which this sector would use its own output for investment, it instead demands more of all the three inputs: nontraded, exportables, and imports. A higher demand for the other home good as well as imports has three direct consequences. First, it raises their relative prices more. As a result, terms of trade, relative price of nontraded goods, and real exchange rates are

²In a closed economy model, Hornstein and Praschnik (1997) show that the use of intermediate inputs in production helps explain within country positive crosssectoral output and employment comovements. Their two sectors are durables and nondurables. Durables produce capital for use in both sectors, while nondurables produce consumption and intermediate inputs for durables’ production.

³That cross-country consumption correlation substantially exceeds output correlation in an international business cycle model, at complete variance with the data, was first highlighted and dubbed as the “quantity anomaly” by Backus, Kehoe, and Kydland (1992). Their model economy comprised of two countries, a single consumption good, and complete financial markets.

relatively more volatile. Second, a higher import expenditure on investment leads to a higher trade variability and countercyclicality of the trade balance. Third, within-country sectoral outputs and therefore their employments and investments are more aligned.

As for cross-country consumption comovements, consider first a positive productivity shock in the exportable sector in, say, country 1. In the model with a sector's output serving as its own capital, a part of the increased exportable output will be used for investment and the remaining shared between the two countries' consumption. A higher traded consumption raises demand for non traded goods as well. Both countries' nontraded prices and output respond to increased consumption demand symmetrically. When investments instead comprise multisectoral goods, country 1's investment demand for its nontraded goods now crowds out its nontraded consumption demand. Consumption's compositional responses are not symmetric across countries any more, thus inhibiting their aggregate comovements. Now consider a positive shock to the nontraded sector of country 1. With nontraded sector's investment not solely absorbing its own output, more of it is left for consumption that by its very nature can not be shared across countries. Moreover, country 1's investment demand for imports is supported by cutting country 2's traded consumption. Cross-country consumption comovement is further inhibited. As a result, the quantity anomaly disappears once multisectoral composition of investments is introduced.

The last result is of particular significance because the anomaly has puzzled international macroeconomists for about two decades. Researchers have resorted to various strategies to resolve this puzzle, restricting asset trades and introducing nontraded goods in particular, since tradability of goods and assets is at the heart of consumption sharing across countries.⁴ These strategies have met with only partial success. Table 1 summarizes the relative success of past studies in this respect.

Table1

Merely restricting asset trade does not help. Baxter and Crucini (1995) show that with trend-

⁴The anomaly has also been addressed by incorporating (a) multiple sectors with trade in intermediate inputs (see, for instance, Ambler et al. (2002), Kouparitsas (1997), and Huang and Liu (2004)), and (b) multiple countries (see, for instance, Yakhin (2005)).

stationary shocks a sole riskless bond is almost as good as complete markets in letting countries pool consumption intertemporally; one needs unit root shocks in addition to hinder consumption sharing in the bond economy. Kollman (1996) in a bond economy with shocks more persistent than those estimated by Backus, Kehoe, and Kydland (1992) thus obtains a much lower cross-country consumption correlation than previous studies. Kehoe and Perri (2003) endogenize market incompleteness by introducing ‘enforcement constraints’ and with shocks as persistent as Kollman (1996) obtain a substantial improvement in the relative ordering of quantity correlations. Heathcote and Perri (2002) completely eliminate assets trade. Still, the consumption correlation largely exceeds the output correlation.

Stockman and Tesar (1995), while retaining market completeness, introduce nontraded goods into the model hoping to restore internal consumption-output comovement and to inhibit cross-country consumption comovement. But the model solely driven by technology shocks obtains a high cross-country correlation (0.94) between consumption of traded goods and as a result the cross-country aggregate consumption correlation exceeds that of the aggregate outputs. Then they bring in taste shocks which lowers cross-country correlation of consumption, yet the quantity anomaly survives.

What does help is a consumption bias towards exportable good relative to the imported good and/or a low elasticity of substitution between the two (i.e., low trade elasticity).⁵ Thus, to match data correlations, Heathcote and Perri (2003) assume home bias in a two traded-goods model with limited asset trade and unit root shocks. As for a low trade elasticity, Pakko (1997) argues that a higher *compositional* risk aversion than the aggregate induces consumers to let aggregate consumption fluctuate in order to stabilize its composition. This inhibits cross-country consumption sharing. With a low trade elasticity as well as home bias, Corsetti, Dedola, and Leduc (2008) study risk sharing in a two-country world with both traded and nontraded goods and asset trade restricted to a single bond. The quantity anomaly does not appear in their results.⁶

⁵There is no clear consensus however on the magnitude of these trade elasticities. While micro studies pose it to be as high as 4, in macro literature it is found anywhere between 0.5 - 2.

⁶The main intent of their paper is to resolve Backus-Smith puzzle by showing that a low elasticity of substitution

This paper thus contributes to the above literature by highlighting a novel transmission mechanism. It shows that merely accounting for a realistic input output structure in the production of capital goods eliminates quantity anomaly from the workhorse two-sector international business cycle model without restricting shocks or trade in assets.

Another point of departure from Stockman and Tesar (1995) in this paper is in the role of distribution services.⁷ While Stockman and Tesar (1995), due to data constraints, classify distribution and transportation services as traded goods, the present study counts them as part of nontraded output. In the data used in this paper, the ratio of traded to nontraded output is about 0.44 while the corresponding ratio of consumption expenditures is about 0.62. These ratios can be reconciled only if distribution costs entailed in retailing traded goods are explicitly recognized. The benchmark model accordingly incorporates a distribution sector that, as in the data, utilizes inputs of exportables, importables, and nontraded goods to produce its services.⁸ Following past studies, it is assumed that a fixed per unit distribution cost is incurred in retailing traded goods.

Burstein, Neves, and Rebelo (2003) conjecture that introducing distribution costs may help preclude quantity anomaly. The rationale is that distribution services can be equivalently thought of as consumption preferences with stronger complementarity between traded and nontraded goods, i.e., a higher compositional risk aversion; then the desire to smooth aggregate consumption becomes less pressing. Thus an obvious question arises: To what extent are the resolution of quantity anomaly and other improvements in this paper's model *vis-à-vis* Stockman and Tesar (1995) model predicated by an *explicit* role for distribution services?

The results change marginally when the model somewhat *counterfactually* abstracts from distribution services. A reconciliation of sectoral consumption expenditures with respective outputs and home bias in consumption in a bond economy leads to wealth effects that require terms of trade appreciation in case of a positive output shock (and vice versa).

⁷In recent years, researchers have explained several international relative-price puzzles by explicitly modeling distribution services, i.e., the transportation, wholesaling, and retailing services, as nontraded component of traded consumption. See, for example, Burstein, Neves, and Rebelo (2003), Corsetti and Dedola (2005), and Corsetti, Dedola, and Leduc (2008).

⁸See Campa and Goldberg (2006) who provide a detailed break up of the inputs utilized to produce distribution services in a large set of countries.

is only possible if distribution and transportation services are classified as traded output, as in Stockman and Tesar (1995). The relative size of traded to nontraded output then inflates to 0.72. A recalibration of the model leads to two key changes in preferences. Since distribution services are bundled with exportables, the share of imports within traded consumption falls leading to an increase in home bias. Second, the elasticity of substitution between traded and nontraded consumption falls as conjectured by Burstein, Neves, and Rebelo (2003). A larger traded sector calls for a higher cross-country consumption comovement, but a higher home bias and a lower elasticity counteract it. The result is only a marginal rise in cross-country consumption correlation from 0.27 to 0.28, while that of output rises from 0.45 to 0.46. The other changes in the results are equally minor. The exercise thus unambiguously establishes that a careful accounting of the input composition of investments is the key to improvements that benchmark model achieves over its competing versions.

The remainder of the paper is organized as follows. The next section summarizes the main characteristics of the data that the model attempts to explain. Section 3 provides a simple two-goods extension of Backus, Kehoe, and Kydland (1992) model. It shows how cross-country consumption comovements are lowered when investments are relatively more import intensive. The full model is then presented in Section 4. Section 5 first estimates input shares for producing capital goods and distribution services in the US. Armed with these share, the rest of this section calibrates the remaining parameters of the model. The results are presented in Section 6. This section compares the benchmark model with (a) its version in which sectoral outputs serve as their own capital, (b) its version that abstracts from distribution services, and (c) the Stockman and Tesar (1995) model. Section 7 offers some concluding remarks.

2 Business cycle statistics

This section presents empirical regularities of some key variables that the paper's model attempts to reproduce. Since the model economy consists of traded and nontraded sectors, the empirical

moments presented here include sectorwise cross-country and domestic cross-sectoral moments. The set of moments presented here are later in Section 6 compared with the data generated by alternative versions of the theoretical model.

The data relating to the G7 and an European aggregate EU15 span 1970-2003 at annual frequency.⁹ Industrywise data on output, prices, and employment have been obtained from Groningen Growth Development Center (GGDC); sectorwise consumption data is from OECD Statistics (National Accounts) and investment is from OECD Structural Analysis (STAN) database. The data on trade balance, real exchange rate, and terms of trade are obtained from International Financial Statistics. Further details are provided in an appendix. All moments reported below are computed after detrending the data with HP filter.

2.1 Volatilities and internal correlations

Table 2 presents standard deviations of output, consumption, investment, and employment. Barring UK and Canada, traded output is more volatile than its nontraded counterpart. In particular, for EU15 and the US, the differences are much larger. Table 2 confirms that consumption is generally less volatile than the output, not only in the aggregate but also sectorwise. Also, as with output, traded consumption is more volatile than nontraded consumption.

Table 2

As is well known, investment exhibits a much higher volatility than the output (2.4 to 3.5 times in Table 2). Within investment, the traded sector component is substantially more volatile than its nontraded counterpart. Next, employment is about as volatile as output except in Japan where it is less than half of its output. As with other aggregates, traded sector employment is more volatile than the nontraded sector.

The volatilities of trade variables are reported in Table 3. Trade balance is much less volatile

⁹G7 includes Canada, France, Germany, Italy, Japan, UK and USA. The countries under EU15 are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and the UK.

than the output; for the US it is about a quarter, while for the rest it is close to a half of the output. Terms of trade, except for the UK, are more volatile than output; for the US it is about the same, while for the EU15 it is almost two and a half times. Finally, real exchange rates, as is well known, are highly (about 3 - 8 times) volatile relative to output.

Table 3

Table 3 also reports domestic correlations of aggregate consumption, investment, employment, and trade balance with output. As is well known, the first three are highly procyclical,¹⁰ and the last (trade balance) is significantly countercyclical. As for internal comovements, sectoral outputs exhibit high positive comovement; in UK, Japan, Germany and Canada the correlation is 0.99. Sectoral consumptions, except in Japan, exhibit strong positive comovement. The same holds for sectoral employments. The correlation of sectoral investments, however, is lower than the other three; for Germany it is negative.¹¹

Many properties of the data discussed above have been reported in the previous studies. What has not particularly been highlighted earlier is that (a) volatilities of traded sector aggregates are relatively higher and (b) sectoral outputs, consumption, and employment comove strongly together; the comovement of sectoral investments is weaker. These data moments will be set as performance targets in Section 6, while comparing results from theoretical alternatives.

2.2 Cross-country comovements

Table 4 reports correlations of output, consumption, investment, and employment of US *vis-à-vis* other G7 countries and EU15. As evident, aggregate consumption is less correlated than the output. In particular, the aggregate output correlation is 0.61 for the US-EU15; that of consumption it is 0.47.¹² The comovement of US sectorwise outputs and consumptions with that of other

¹⁰As one can conjecture from Japan's low employment volatility, its employment correlation with output at 0.48 is much lower than in other countries.

¹¹It is worth noting that for Germany the data spans only 1991 - 2003.

¹²The correlations for the entire set of country pairs is reported in the working paper version, Oviedo and Singh (2011). The averages of crosscountry output and consumption correlations for the entire set of countries is 0.56 and

countries (barring Japan and Italy) are positive and somewhat similar in magnitude to aggregate comovements; no clear pattern emerges on their relative magnitudes.¹³

Table 4

Cross-country investment correlations are generally low. As reported in Table 4, it is 0.27 for US-EU15, while the average between US and others is 0.32.¹⁴ Sectorwise correlations exhibit wide variations and frequently switch signs. For traded and nontraded sectoral investments, the average correlation between US and others is 0.13 and 0.32, respectively.¹⁵

Finally, barring US-Italy and US-Germany, the correlation pattern of aggregate as well sectoral employments are somewhat similar to that of output. In particular, the ES-EU15 correlations are 0.61, 0.37, and 0.42, respectively, for aggregate, traded and nontraded output; their employment counterparts are 0.43, 0.33, and 0.49.

The above correlations, in particular of US-EU15 whenever available, will be set as performance targets for the quantitative evaluation of alternative theoretical models in Section 6.

3 Cross-country correlations of output and consumption in a world economy with two goods

In the model economy calibrated in Section 5, traded consumption expenditure is about 37.5% of total consumption. After accounting for the expenditure on distribution services, the import content of total consumption turns out to be only 10%. As for investments, the expenditure on imports in the traded sector is 26%, while in a relatively (2.25 times) larger nontraded sector

0.48, respectively.

¹³Japan turns out to be an outlier with its traded consumption substantially negatively correlated with the rest of the world except Germany.

¹⁴Given its large variability, a better indicator for crosscountry investment correlation may be the average for the entire set of country pairs, which turns out to be 0.43.

¹⁵Since the only five available US-others sectoral investment correlations exhibit large variability, a more reliable proxy is the average for the entire set of country pairs: it is 0.26 and 0.38 for the traded and nontraded sectors, respectively.

it is 14%. Altogether, thus, total investment expenditure on imports is about 18%. Investment demands commanding a larger output sharing across countries relative to consumption demands in part explains why the quantity anomaly disappears in this paper's model. Below a two-goods extension of Backus, Kehoe, and Kydland (1992) model is presented to illustrate this point. The full model that explicitly includes a nontraded sector is developed in the next Section.

There are two symmetric countries, indexed by 1 and 2. Each of them produces a distinct exportable good. The good exported (imported) by country 1 is denoted as the x -good (m -good). The symmetry across countries lets economize on notation by only describing country 1's problem and recognizing that country 2 exports (imports) the m -good (x -good). When necessary, country 2's variables are referred by using asterisks.

In Backus, Kehoe, and Kydland (1992) model, a single homogenous good is perfectly mobile across countries for both consumption and investment. In its two-goods extension, for example in Backus, Kehoe, and Kydland (1994) and Heathcote and Perri (2003), each country produces a unique intermediate good which is then combined to produce a final good for *within-country* consumption and investment. Specifically, the goods market equations are

$$x_t + x_t^* = y_t \equiv z_t f(k_t), \quad (1a)$$

$$c_t + \underbrace{k_{t+1} - (1 - \delta) k_t}_{i_t} = x_t^\theta m_t^{1-\theta}, \quad (1b)$$

where z , k , and c denote productivity, capital stock, and consumption, respectively; $\theta \in (0, 1)$ is the expenditure share of exportables in the final good production. For simplicity it is assumed here that labor is inelastically supplied. Equation (1a) represents the division of country 1's output of intermediate goods between the two countries. Equation (1b) shows how country 1's share of its own output is combined with imports from country 2 to produce the final good.

A similar set of equations exist for the country 2 where x^* and m^* combine to produce a final good for its consumption and investment. Let $u(\cdot)$ denote a standard utility function. Under

complete markets, the allocation problem boils down to maximizing

$$\sum_{t=0}^{\infty} \beta^t (u(c_t) + u(c_t^*)),$$

subject to (1a) and (1b) and its country 2 equivalents.

Optimality commands that for both intermediate goods, x and m , the MRT into final (consumption) good of country 1 and 2 equal their MRS for consumption. That is,

$$\frac{u'(c_t)}{u'(c_t^*)} = \frac{\frac{(1-\theta)x_t^* m_t^{*1-\theta}}{x_t^*}}{\frac{\theta x_t^\theta m_t^{1-\theta}}{x_t}} = \frac{\frac{\theta x_t^* m_t^{*1-\theta}}{m_t^*}}{\frac{(1-\theta)x_t^\theta m_t^{1-\theta}}{m_t}},$$

which gets

$$\frac{\theta}{1-\theta} \frac{m_t}{x_t} = \frac{1-\theta}{\theta} \frac{m_t^*}{x_t^*}.$$

If the final goods technology has no input bias, i.e., $\theta = \frac{1}{2}$, then

$$c_t = c_t^*;$$

consumption is perfectly shared across countries. The intuition is simple. With no home bias in inputs, efficient (constant) scale of final goods production is obtained by identically apportioning both intermediated goods. This allows the planner to give equal consumption to both and then choose the relative investments as governed by the productivity process. In a more plausible scenario of a home bias, however, the country with a positive shock will obtain a higher consumption and its cross-country comovements will be inhibited. For $\theta = 1$ the economies are closed and consumption and output movements will be closely aligned. Finally, output correlations will be governed by the productivity process and the transmission of shocks across countries through relative investments.

To capture a relatively higher import intensity for investments in the data, consider now the following version of the model in which a country's output is *nontraded for consumption* but traded

for producing capital.¹⁶ Specifically,

$$c_t + x_t + x_t^* = y_t \equiv z_t f(k_t), \quad (2a)$$

$$\underbrace{k_{t+1} - (1 - \delta) k_t}_{i_t} = x_t^\theta m_t^{1-\theta}. \quad (2b)$$

An efficient allocation now requires the MRS of consumption between country 1 and 2 equal MRT between x and m goods for each country's investment, that is

$$\frac{u'(c_t)}{u'(c_t^*)} = \frac{\theta}{1 - \theta} \frac{m_t}{x_t} = \frac{1 - \theta}{\theta} \frac{m_t^*}{x_t^*}$$

Let $u \equiv \ln$ and $\theta = \frac{1}{2}$. Then the above conditions along with (2a) imply that each country's output is apportioned into domestic consumption and investment inputs in country 1 and 2 identically, i.e.,

$$\frac{c_t}{y_t} = \frac{c_t^*}{y_t^*}, \frac{x_t}{y_t} = \frac{m_t}{y_t^*}, \frac{x_t^*}{y_t} = \frac{m_t^*}{y_t^*}$$

To fix ideas, assume a bivariate AR(1) process for $\{z, z^*\}$ as estimated by Backus, Kehoe, and Kydland (1992) and, for simplicity, assume that there are no spillovers, i.e., the off-diagonal elements in the autocorrelation matrix are zero.¹⁷ Consider now a high realization of z . A rise in output will raise consumption, but expecting a high future productivity country 1 may assign a relatively higher portion of its extra output towards its investment. If the percentage rise in consumption is less than its percentage rise in output, the ratio $\frac{c_t}{y_t}$ falls. Since country 2's output has remained the same, this requires country 2's consumption to fall. This in turn is justified by a higher supply of its output for country 1's increased investment. Under this scenario, in contrast to perfect consumption sharing in the earlier two-goods version, *the cross-country consumptions comove negatively*.

The above intuition is confirmed by the following simulation results. Let $f(k) = k^{0.4}$, $u \equiv \ln$, $\beta = 0.99$, and $\delta = 0.025$. Then, Figure 1 below presents the quantity correlations for the two

¹⁶A more realistic model will have both consumption and investment as composites of exports and imports, and assume a lower share parameter for imports within the consumption aggregator. For simplicity, here it is assumed to be 0.

¹⁷The 2×2 autocorrelation matrix estimated by Backus, Kehoe, and Kydland (1992) has 0.906 at the diagonals and 0.088 off-diagonals. Positive spillovers will further strengthen the results that follow.

versions discussed above.

Figure 1

Evidently for all plausible values of $\theta \in [0.5, 1]$ cross-country output correlations always fall below the consumption correlations in the first version. The consumption correlation is unity for $\theta = \frac{1}{2}$ and converges closer to output correlation as $\theta \rightarrow 1$. In the second version, the situation is reversed. Indeed, the cross-country consumption correlation remains negative for θ as high as 0.8. While the results assume logarithmic utilities, the relative shapes survive for $\sigma \in [0.5, 2]$ as has been verified numerically.

The basic intuition behind the above two contrasting results is that in the first version consumption and investment are identical goods and both can be adjusted through exchange of intermediate goods. A windfall in one country can then be shared in another. However, in the second version, while the capital goods can be adjusted by exchange of traded goods, the consumption is nontraded. Here, the planner does not want to increase foreign consumption in response to a positive domestic shock, and the cross-country consumption correlation is reduced.

The next section develops the paper's benchmark model that explicitly includes a nontraded sector.

4 The model

Motivated by empirical evidence, this section extends the two-country, three-good, complete market model of Stockman and Tesar (1995) in two dimensions. First, capital goods are produced with specific technologies that combine both traded and nontraded goods as inputs. Second, as in Burstein, Neves, and Rebelo (2003), traded goods can be consumed only after using distribution services. As capital goods, these services are also produced by combining both traded and nontraded goods as inputs.

The model retains the environment and notations described in Section 3. In addition to x -good and m -good produced by countries 1 and 2, respectively, both countries now also produce a

nontraded good denoted as the n -good (n^*) for country 1 (2).

The representative household is endowed with a unit of time and it maximizes its expected lifetime utility over consumption, c_t , and leisure, $1 - h_t$, given by

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \frac{c_t^\gamma (1 - h_t)^\eta}{\gamma}, \quad (4)$$

where $\beta \in (0, 1)$ is the discount factor; $(1 - \gamma)^{-1}$ is the intertemporal elasticity of consumption substitution; and η is the share parameter of leisure in utility. Consumption represents a composite of three goods:

$$c_t = \left[\omega (c_{xt}^\nu c_{mt}^{1-\nu})^{-\rho} + (1 - \omega) (c_{nt})^{-\rho} \right]^{-\frac{1}{\rho}}, \quad (5)$$

where c_x , c_m , and c_n denote the consumption of exportables, importables, and nontraded goods; ω and $1 - \omega$ are the weights in agents' preferences of traded and nontraded goods, and $(1 + \rho)^{-1}$ is the elasticity of consumption substitution between them. The traded-good composite is a Cobb-Douglas aggregator in which ν denotes the share of exportables. The specifications of the functional forms of the utility index in (4) and the consumption composite (5) follow Stockman and Tesar (1995).

Traded and nontraded goods are produced with sector-specific, Cobb-Douglas technologies that combine sector-specific capital and labor, namely k_x and h_x , to produce the exportable good while k_n and h_n produce the nontraded good. The labor allocations $h_x \geq 0$ and $h_n \geq 0$ are constrained to satisfy the following:

$$h_{xt} + h_{nt} \leq h_t \leq 1. \quad (6)$$

The output of traded goods is allocated between gross exports, e_x , domestic consumption, c_x , and as inputs for producing distribution services and capital goods. The output of nontraded goods, similarly, is allocated between domestic consumption, c_n , and as inputs. Let x_d , x_x , and x_n (respectively, n_d , n_x , and n_n) denote the amount of traded (respectively, nontraded) goods used as inputs in the production of distribution services, investment goods for the exportable sector, and investment goods for the nontraded sector. The resource constraints on the use of exportable and

nontraded goods are:

$$c_{xt} + \sum_{i=d,x,n} x_{it} + e_{xt} \leq \lambda_{xt} (k_{xt})^{\theta_x} (h_{xt})^{1-\theta_x} \quad (7a)$$

and

$$c_{nt} + \sum_{i=d,x,n} n_{it} \leq \lambda_{nt} (k_{nt})^{\theta_n} (h_{nt})^{1-\theta_n}, \quad (7b)$$

where λ_x and λ_n are sectoral productivity shocks and $\theta_x \in (0, 1)$ and $\theta_n \in (0, 1)$ are the capital-share parameters in their respective Cobb-Douglas technologies.

Distribution services and investment goods are also produced with Cobb-Douglas technologies,¹⁸ as follows:

$$s_i = \mu_i (x_i)^{\alpha_i} (m_i)^{\epsilon_i} (n_i)^{1-\alpha_i-\epsilon_i}, \quad i = d, x, n. \quad (8)$$

Here s represents output, μ is a scale parameter, and m denotes inputs of importable goods; $\alpha \geq 0$ and $\epsilon \geq 0$ are input-share parameters, and $\alpha + \epsilon \leq 1$.

The investments undertaken in the two sectors mature in one period:

$$k_{it+1} = (1 - \delta_i) k_{it} + s_{it}, \quad i = x, n, \quad (9)$$

where δ_i denotes the depreciation rate of capital in sector i .

As country 1's exports are country 2's imports and vice-versa, the following worldwide constraint on the use of importables (exportables) must hold:

$$c_{mt} + \sum_{i=d,x,n} m_{it} \leq e_{mt}^*, \quad (10)$$

where e_m^* is the export (import) of good m by country 2 (1).

Distribution services are incorporated into consumption by assuming that ψ_x (ψ_m) units of distribution services are necessary to convert a unit of exportables (importables) into a unit of *consumable* exportable (importable) goods. Thus, the production and use of distribution services satisfies the following:

$$s_{dt} \geq \psi_x c_{xt} + \psi_m c_{mt}. \quad (11)$$

¹⁸Bems (2008) reports that shares of traded and nontraded components of investment expenditures have been fairly stable over time, thus providing a rationale for using Cobb-Douglas technology for the production of capital goods.

To complete the description of the problem, the sectoral technology shocks are assumed to evolve according to the following VAR(1) process:

$$\boldsymbol{\lambda}_{t+1} = \mathbf{\Lambda} \boldsymbol{\lambda}_t + \boldsymbol{\varepsilon}_t, \quad (12)$$

where $\boldsymbol{\lambda}_t \equiv [\lambda_{xt}, \lambda_{nt}, \lambda_{mt}^*, \lambda_{nt}^*]$; $\mathbf{\Lambda}$ is a 4×4 symmetric matrix of autoregressive coefficients; and $\boldsymbol{\varepsilon}_t \equiv [\varepsilon_{xt}, \varepsilon_{nt}, \varepsilon_{mt}^*, \varepsilon_{nt}^*]$ is a vector of i.i.d. innovations with a known covariance matrix $\boldsymbol{\Sigma}$.

Since complete contingent-claims markets are assumed to exist, the allocations of the decentralized world competitive equilibrium are identical to the allocations obtained by a social planner who maximizes the country-weighted sum, $\zeta U + (1 - \zeta) U^*$, where $\zeta \in (0, 1)$ is the weight in total welfare the planner gives to country 1. The constraints of the planner's maximization problem are equations (5) to (11) for country 1, a similar set of equations for country 2, and the process for the productivity shocks (12).

The above *benchmark* model nests the Stockman and Tesar's model by (a) assuming that each sector's capital goods be produced by using exclusively its own final good, which amounts to setting $\alpha_x = \epsilon_n = 1$ in (8); (b) eliminating the distribution services by setting $s_{dt} = \psi_x = \psi_m = 0$ in (11); and (c) adding an exogenous, constant growth rate of labor-augmenting productivity, which requires re-expressing the model to induce stationarity. Note that (a) and (b) also imply setting $x_i = n_i = 0$, $i = d, x, n$, in equations (7).

5 Model calibration

For sectoral traded and nontraded GDP value-added aggregation, 60-industry data provided by GGDC is utilized. The traded sector of GDP includes Agriculture, Forestry, Fishing, Mining and quarrying, and Manufacturing; the rest are in the nontraded sector (see the data appendix for further details). Retail and wholesale services, transportation services, and services of restaurants and hotels are included in the nontraded sector, whereas Stockman and Tesar (1995) bundle them in the traded sector due to data constraints.¹⁹ Over 1979-2004, these services account for about

¹⁹See footnote 11 in Stockman and Tesar (1995).

15% of GDP, not only in the US but also in the European aggregate EU15, and this share has remained fairly stable over time. With these services included, the size of nontraded output on an average is 2.25 times its traded counterpart, whereas in Stockman and Tesar (1995) the GDP is evenly split between the two components.

The two subsections below calibrate parameters for the model of the previous section. The first presents an estimate, via an input-output accounting exercise, of input shares of the US production of capital goods and distribution services. The second completes the calibration of the remaining parameters of the model.

5.1 Investment goods and distribution services: input shares

The goal here is to calibrate the shares of exportables, importables, and nontraded goods used in the production of capital goods used in the traded and the nontraded sector, and distribution services. The estimates are shown in Tables 5 and 6, respectively.

The construction of these estimates starts with the industrywise investment data reported by the Bureau of Economic Analysis (BEA). For the period 1947-2004, these data identify two types of investment, namely Equipment & Software (E&S) and Structures.²⁰ According to the BEA data, on average, for traded sector of the US economy the share of investment expenditure on E&S is 69% and the remaining 31% is on Structures. For nontraded sector the shares are 39% on E&S and 61% on Structures.

In E&S, the BEA includes “machinery, equipment, furniture, vehicles, and computer software” all of which are traded goods according to the GDP value-added classification of this paper. On the other hand, the BEA defines Structures as the “products that are usually *constructed* at the location where they will be used and that typically have long economic lives.” Following the sectoral classification of construction industry, Structures are henceforth treated as nontraded goods.

The next step is to decompose traded inputs, E&S, into exportables and importables, as has

²⁰The corresponding tables in the BEA database are Table 3.7E, Historical-Cost Investment in Private Equipment and Software by Industry; and Table 3.7S, Historical-Cost Investment in Private Structures by Industry.

been reported in the two central columns of Table 5. To ascertain this, a reference is made to 1967-2004 BEA table of Exports and Imports of Goods and Services by Type of Product, which identifies three items as investment goods: durable goods for industrial use, capital goods, and automotive vehicles, engine, and parts. The last category, however, includes consumers' purchases of vehicles. The BEA's benchmark 1997 import matrix, which indicates that about 32.4% of automotive imports are allocated to private fixed investment, helps to apportion the investment component of automotive imports.

The BEA export-import data can be combined with the BEA industrywise investment data to obtain total annual import expenditure series (1967-2004) for private fixed investment. For example, in 1997, the import expenditures on durable goods for industrial use, capital goods, and automotive vehicles, engines and parts were equal to 69.2, 253.4, and 139.5 (current) billion dollars, respectively. By excluding consumer imports of automotive products, the total import expenditure for private fixed investment in that year turns out to be 367.8 billion dollars ($= 69.2 + 253.4 + 139.5 \times 0.324$).

The question now is how to impute these imports to the E&S investments made by the traded and nontraded final goods sectors. This is resolved by following the methodology the BEA uses to compute its commodity import matrix. The BEA imputes imports of commodities to industries by using the proportions in which these industries demand domestically supplied goods. Adhering to this convention requires that the imports of capital goods be imputed to the traded and nontraded sectors with the same ratios as the ones observed for their total investment on these capital goods. For the year 1997 example discussed above, 28% of the economywide investment on E&S goes to the traded sector and the remaining 72% to the nontraded sector. Then the imputed traded and nontraded sector's import expenditure on investment goods becomes 103 ($= 367.8 \times 0.28$) and 264.8 ($= 367.8 \times 0.72$), respectively. Similar calculations obtain a time series (1967-2004) for total import expenditures on investment goods by the two sectors.

Recall that each sector's total investment on traded inputs was obtained right at the beginning of this exercise. A simple division of the import series by the total traded input series obtains an average imports to total traded input ratio of 0.37 for the traded sector, whereas for the nontraded

sector the ratio equals 0.36. Applying these ratios to the expenditure shares of traded inputs, 0.69 and 0.39 in the traded and nontraded sectoral investments, respectively, obtains the expenditure shares on domestically produced traded goods (exportables) and on importables, as reported in Table 5.

In regard to the empirical aspects of distribution services, studies by Burstein, Neves, and Rebelo (2003) and Campa and Goldberg (2006) have quantified the role these services play in the delivery of traded goods to consumers. These studies measure the “distribution margin” as the value of the wholesale and retail trade component (both considered as nontraded goods) incorporated into the value of the private final consumption of traded goods.

As in Burstein, Neves, and Rebelo (2003), it is assumed below that only the following GDP sectors utilize wholesale and retail services: Agriculture, Forestry, Fishing & Hunting, Mining, and Manufacturing. The remaining sectors mainly consist of services in which the distribution margin is assumed to be zero. These assumptions, along with yearly BEA input-output tables, allow one to obtain the estimates of the US distribution margins reported in Table 6. The table also presents distribution margins for the US and the nations that represent the second country in the model. The average distribution margin for these countries equals 41.6% according to estimates obtained by Burstein, Neves, and Rebelo (2003).

As for the input shares of intermediate goods utilized in producing distribution services, Table 5 shows the estimates following a strategy similar to the one used for deriving the input shares for capital goods, and it is based on the 1997 BEA’s benchmark input-output table and the 1997 BEA’s import matrix.

5.2 Other model parameters

The benchmark model is calibrated to the US data, which in the case of value-added across sectors, are roughly consistent with the data of the European aggregates EU15 and EU5 (France, Germany, Italy, Netherlands, and UK) and of a group of five countries (Canada, France, Germany, Italy, and U.K.). The data sources are BEA, BLS, OECD, and GGDC statistics. All parameter values are

summarized in Table 7.

The average ratio of value-added in the nontraded sector to that in the traded sector turns out to be 2.25 (BEA, 1947:2005, GDP value-added by sector). Labor compensation in the US equals 64% (62%) of the value added in the traded (nontraded) sector (GGDC, 1979-2003); thus, $\theta_x = 0.36$ and $\theta_n = 0.38$. As in previous studies, β is set equal to 0.96. It is assumed that households allocate 30% of their time to market activities, and that labor is perfectly mobile across sectors. Then, given the values of the sectoral outputs, those of θ_x and θ_n , the labor constraint $h = h_x + h_n$, and the equality of wages across sectors, the steady-state values of the following can be obtained: sectoral labors, h_x and h_n , sectoral capital stocks, k_x and k_n , and the steady state values of final goods technology parameters, λ_x and λ_n .

The BLS reports an average depreciation rate of 12% for Equipment & Software and 5% for Structures. It also reports that the capital stock is equally divided between E&S and Structures in the farm and manufacturing sectors (traded sectors), while the respective fractions in the non-farm, non-manufacturing sectors (nontraded sectors) are 30% and 70%. Accordingly, the depreciation rates in the traded and nontraded sectors are set to $\delta_x = 0.5 \times (0.12 + 0.05) = 0.085$ and $\delta_n = 0.30 \times 0.12 + 0.7 \times 0.05 = 0.071$, respectively.

The values of δ_x , δ_n , k_x and k_n determine the output of the industries that produce capital goods, s_x and s_n . The share parameters of the respective Cobb-Douglas technologies are set to the ones in Table 5. The values of the input shares, along with those of the inputs and outputs of the capital goods industries obtain the values of the scale parameters μ_x and μ_n .

Following the evidence presented earlier, the distribution margin is set to 41.6% and, consistent with the US data, the GDP share of exports of goods is 12% (BEA 1951: 2004). Then, given the value of the distribution margin, the share of input usage in the distribution sector from Table 5, and the goods-markets clearing conditions for the three final goods, the value of the scale parameter of the distribution technology and the value of consumption allocations for the three goods are obtained.

Although the sectoral GDP value-added definition of this paper differs from that in Stockman

and Tesar (1995), the definition of sectoral consumptions are identical in the two studies.²¹ Therefore, as estimated by Stockman and Tesar (1995), the elasticity of substitution between traded (composite) and nontraded consumption is set to 0.44. Then, the planner’s first order conditions for labor, consumption of nontraded goods, and consumption of imported goods obtain the labor share in the utility function, η ; the share of nontraded consumption within the consumption aggregate, ω ; and the share of imports within the traded composite, $1 - \nu$.

An estimation of the VAR(1) process for $\boldsymbol{\lambda}_t \equiv [\lambda_{xt}, \lambda_{nt}, \lambda_{mt}^*, \lambda_{nt}^*]$ is obtained by applying seemingly unrelated OLS, with cross-country symmetry restrictions, to a pairwise time-series of sectoral Solow residuals for the following countries: Canada, France, Germany, Italy, UK, and US, for which capital stock data is available. An average of the above pairwise estimates is presented in Table 8.

The parameters calibrated above define the benchmark model. To highlight the role of multi-sectoral inputs in investment and the role of distribution services, we recalibrate two variations of the model. In the first, $\alpha_x = \alpha_n = 1$; $\epsilon_x = \epsilon_n = 0$, i.e., the two sectors utilize their own output for investment. Here, the model is recalibrated to match the remaining data ratios. The key changes occur in the share parameter for traded consumption aggregate and that of exportable consumption within that traded aggregate (see Table 7). Readjustment of investment inputs leaves excess traded inputs that are now reallocated towards consumption. Moreover, as investments no longer demand imports, excess imports are allocated towards imported component of traded consumption. As a result, the traded consumption scale parameter ω increases from 0.065 to 0.12 while the share of exportable consumption within the traded aggregate, ν , reduces from 0.56 to 0.45.

In the second variation, $\psi_x = \psi_m = 0$; i.e., the distribution services are assumed away. For expositional convenience, further discussion of this recalibration exercise is postponed to Section 6.2.

²¹As in the present work, Stockman and Tesar (1995, footnote 6) define consumption of nondurable goods and consumption of services as traded and nontraded components of consumption, respectively. An alternative definition that bundles consumption by activity is also similar to the one used in the present work (see data Appendix).

6 Quantitative results

This section compares the moments generated by the benchmark model with the data moments discussed in Section 2. The results are first compared with the Stockman and Tesar (1995) (S&T henceforth) results and a variation of the benchmark model in which, as in S&T, sectors use their own as capital instead of multisectoral inputs in investments (*MII* henceforth). The results from the benchmark model's version that abstracts from distribution services are also compared with. The intuition behind the key differences between the benchmark results and its alternatives are discussed in subsequent subsections.

The solution technique used throughout is linear-quadratic approximation and all business-cycle statistics are computed from 300 simulations of 300 periods each, after disregarding the first 200 periods of each simulation. The model generated data is HP-filtered exactly as in Section 2. All aggregate quantities in the data, discussed in Section 2, are at constant (base) prices, which implies that intersectoral relative prices too are constant across time at the base year level. Since results can be sensitive to the method of aggregation,²² all economywide aggregates in the model, to ensure consistency with the data, are constructed by using constant intersectoral relative prices.

Table 9 reports volatilities of (aggregate as well as sectoral) output, consumption, investment, employment, and volatilities of trade balance, terms of trade, relative price of nontraded goods, and real exchange rates. Domestic correlations are reported in the last part of the table. Table 10 reports cross-country correlations of aggregate as well as sectoral quantities. In both the tables, the first column (a) presents data moments discussed in Section 2. Results obtained from the benchmark model are presented in column (c), preceded by S&T results in column (b) for a convenient contrast.²³ The next two columns (d) and (e) present results from the benchmark model's two variations (i) without MII and (ii) without distribution services, respectively.

In all columns of Table 9, volatilities of output, investment, and employment in the traded

²²Kehoe and Ruhl (2008), for example, show that the comovement of terms of trade with GDP crucially depends on how the latter is constructed.

²³The differences in S&T results reported here and in their paper arise because (a) the shocks are different, (b) their simulation results are not filtered, and (c) all aggregates in S&T paper are computed at current prices.

sector are higher than their nontraded counterparts, as in the data. Column (c) indicates that the benchmark model replicates the volatilities of output and investment reasonably well. The volatilities of employment are close to the lower bound of the data range as is the case with other models. Consumption volatilities fall much below the data, but all other versions fare equally badly. The model without MII reports (column (d)) a higher traded sector volatility of output, employment, and investment. While the first two are relative improvements, its traded sector investment volatility turns out to be too high. On the other hand, while S&T volatilities of output, consumption and employment (column (b)) are similar to the benchmark, its investment volatilities are low; the benchmark model is closer to the data.

The volatilities of trade balance and relative prices are remarkably improved under the benchmark model. Relative to the S&T and the model without MII, the benchmark volatility of trade balance is about three times, its volatility of terms of trade and relative price of nontraded goods is about two to three times, and that of its real exchange rate is about twice. Once again, benchmark volatilities are much closer to the data. Yet, the real exchange rate volatility in the benchmark model falls below the data.

The benchmark model substantially outperforms its version without MII as well as S&T model in replicating within country correlations. Specifically, its correlation of trade balance with output, as in the data, is significantly negative (-0.37) compared to the model without MII (-0.14) and S&T (0.20). Similarly, its consumption correlation with output (0.87) is closest to the data compared with the other two (0.95). In S&T and the benchmark's version without MII investment is perfectly correlated with output; the benchmark model lowers it, although only slightly (to 0.98). Finally, within country correlations of sectoral outputs, consumptions, investments, and employments are all improved in the benchmark model relative to the model without MII and the S&T model.

What distinguishes the benchmark model most against its version without MII and S&T is its relative ordering of cross-country correlation of output and consumption (see Table 10). Although cross-country correlation of aggregate output remains about the same across various versions (0.41 – 0.46), that of aggregate consumption is much reduced in the benchmark model (0.27) relative

to its version without MII (0.41) and S&T (0.70); sectoral consumption correlations are also lower than the other two. Investment correlations in the benchmark model are close to the data targets, whereas it is slightly higher in the model without MII and the S&T model. The only relative shortcoming of the benchmark model is its cross-country correlation of traded sector's output and employment; in particular the latter exceeds the data upper bound. All models, however, underpredict nontraded output and employment correlations.

To summarize, the benchmark model markedly outperforms its own version without MII and the S&T model in matching data volatilities of investments, trade balance, terms of trade, and real exchange rates. It comes closest to the data in replicating all within country correlations, and as in the data its cross-country consumption correlation falls much below that of output.

A comparison of the improvements by benchmark over its version without MII *vis-à-vis* improvements by benchmark over S&T indicates that these are qualitatively similar. Below we first attempt to understand the underlying mechanism that aligns benchmark results (in contrast to the other two) with the data due to its inclusion of multisectoral investment composition.

6.1 The role of multiple input investments

An examination of impulse responses helps understand these results. Figure 2 shows the responses of output, consumption, investment, and employment under one standard deviation shock to the traded sector (i.e., exportable) productivity of country 1. Figure 3 repeats the same for a shock to the nontraded sector. In both figures, solid (broken) lines represent the benchmark (without MII) model, whereas darker (lighter) lines represent country 1 (2).

Under a traded sector shock, the most striking differences arise in the nontraded sector of country 1. While nontraded output, investment, and employment of country 1 fall in the model without MII, they all rise in the benchmark model. The reason is simple. When the exportable sector invests solely in its own good, a high relative demand for exportables drives labor from nontraded to exportable production. Moreover as shocks are persistent, future lower relative demand for nontraded output lowers its investment as well. In contrast, in the benchmark model, exportable

sector's *investment demand* for nontraded goods raises its output, employment, and investment. A similar logic works for country 2's exportables' response, albeit quantitatively to a lesser degree; its output, investment, and employment rise on impact due to country 1's *investment demand* for imports; the responses are almost flat in the model without MII. This explains why internal correlations of sectoral outputs, employments, and investments turn to be positive (instead of close to zero or negative in model without MII), and also why traded sector's cross-country correlations of output and employment rise.

Nontraded consumption response of country 1 also provides a stark contrast. In the benchmark model, a higher exportable sector investment demands more of its nontraded goods lowering its consumption on impact. This helps reduce within country traded-nontraded consumption correlations. Also, because of a fall in its nontraded component, aggregate consumption rise is muted in the benchmark model relative to its version without MII. The consumption response in country 2, though quantitatively smaller, is qualitatively similar to that in country 1. In sum, both countries' consumption rises are inhibited in the benchmark model.²⁴

Finally, notice that the aggregate output in country 1 does not differ much. Essentially, in country 1 the rise in nontraded output in the benchmark model is offset by a fall in its traded output. In country 2 aggregate output slightly rises due to a rise in its traded component, thus helping a slight rise in cross-country correlations.

Consider now a positive productivity shock in the nontraded sector of country 1 (Figure 3). As under traded sector shock, the most striking differences now are in the production and employment in the other sector, i.e., the exportables. Both move positively with their nontraded counterparts in contrast to their negative comovement in the model without MII. In the benchmark model, a higher investment demand for exportables from the nontraded sector induces a higher output and employment in the former. This again helps align model's domestic correlations with the data. Similarly, with a higher nontraded sector's investment demand for imports, country 2's exportable

²⁴Consumption comovement across the two countries appears more aligned under the traded sector shock. It can therefore be conjectured that the explanation for a lower crosscountry consumption correlation in the benchmark model mainly lies with the nontraded shocks.

output is higher in the benchmark model. A part of the increased demand for imports is met by cutting country 2's traded consumption as well as its traded sector investment. As a result, cross-country comovements of traded consumption and investment are reversed in the benchmark model, helping reduce the correlation of their aggregates as well.

Since nontraded sector invests only partly on its own output, a larger part can be absorbed as consumption in the benchmark model relative to its version without MII. The consumption of traded goods remains almost identical under the two specifications. Therefore, unlike under traded sector shock, aggregate consumption of country 1 is higher in the benchmark model (compare Figure 2(d) with Figure 3(d)). The aggregate consumption of country 2 hardly changes. This further helps in uncoupling cross-country consumption comovements.

Once again, as under traded sector shock, the aggregate output response for both countries is almost identical under the two models. In country 1 a relatively higher exportable output is compensated by a relatively lower nontraded output. That is why cross-country output correlation rises only slightly to 0.45 in the benchmark from 0.41 in its version without MII.

6.2 The role of distribution services

It is evident that the improvements that benchmark achieves over its version without MII are further pronounced when the former is compared with the S&T results. To explore whether this is due to the inclusion of distribution services in the benchmark model, column (e) presents results from the benchmark's version without distribution services while retaining the multisectoral composition of investments. The results hardly differ from the benchmark. Comparing column (e) with (c) in Table 9 shows that the volatilities are similar except slightly higher values for aggregate output and traded consumption. Within country correlations are similar except for sectoral consumptions and investments; it underpredicts the former and overpredicts the latter and fares worse on both counts. Also, trade balance is less countercyclical. Cross-country correlations in Table 10 are hardly different from their benchmark counterparts: only the correlation of traded sector output and consumption is slightly lower, and that of nontraded employment is higher.

Why does the role of distribution services appear to be marginal? It helps to first understand the calibration exercise. In the benchmark model, traded output is only about 44% of nontraded output, whereas traded consumption is about 62% of nontraded consumption. After duly accounting for investment expenditure shares, the disproportionate traded consumption expenditure at the retail level relative to its own output is reconciled by its *embodied* nontraded distribution services. To be consistent with the observed consumption expenditures, abstracting from distribution services therefore requires a counterfactual reclassification of sectoral outputs: the nontraded component that delivers traded consumption at the retail level now counts as part of the traded output *precisely as in SET*.²⁵ A rebalancing then raises the size of exportable GDP to 72% of the nontraded GDP. This in turn requires recalibrating sectoral input shares for the two sectoral investments as well. Accordingly, the model is recalibrated to match observed investment input expenditures, export/GDP ratio, and traded to nontraded consumption (see Table 7). Bundling distribution costs with exportable consumption expenditure lowers the share of imports in traded consumption to 25% ($\omega = 0.75$) from 44% under the benchmark ($\omega = 0.56$). Another change occurs in the elasticity of substitution between traded and nontraded consumption; it drops from 0.44 in the benchmark model to 0.33.²⁶

Thus, the higher output volatility in the model without distribution is explained by its higher relative size of the traded sector and the fact that the traded sector is more volatile than the nontraded sector. A lower countercyclicality of trade balance and a lower cross-country correlation of traded consumption follow from a home bias in exportables' consumption. The rest of the results are explained below with the help of impulse responses.

Figures 4 and 5 compare impulse responses of output, consumption, investment, and employment under traded and nontraded shocks, respectively. Again, darker (lighter) line represents

²⁵It is worth reiterating that the model with distribution services is the only specification that is consistent not only with sectoral classifications (of traded and nontraded goods) but also with the relative consumption expenditure shares.

²⁶However, the results are almost identical if the elasticity is allowed to remain the same at 0.44, and instead the share parameter ω is recalibrated (from 0.065 to 0.13).

country 1 (2); solid (broken) line represents the benchmark model (without distribution).

Figure 4 shows that the traded consumption in country 1 rises relatively more in the model without distribution because fixed-proportions bundling with nontraded distribution services is no longer required, thus increasing the volatility of traded consumption (mostly exportables due to home bias). A larger traded consumption raises consumption demand for nontraded goods. In addition, the recalibrated traded sector in the model without distribution invests a larger share on nontraded goods. Lastly, traded sector is larger in the model without distribution. All three raise nontraded output and employment in country 1. The nontraded consumption still falls but less than in the benchmark model. Overall, the negative comovement of the two consumption components is more pronounced thus lowering their within country correlation. On the other hand, nontraded output and investment comovements with those of exportables are more pronounced, raising their within country correlations. A higher home-bias in the model without distribution demands less of importables. Nontraded output in country 2 rises slightly. Increases in nontraded outputs in both countries are brought about by even larger increases in their employment which helps explain their higher cross-country correlation.

Under a nontraded positive shock (see Figure 5), a higher nontraded output in the model without distribution does not command as high a rise in traded consumption as in the benchmark model. The savings in exportables can rather be used for its own investment. Under both shocks, therefore, within country cross-sectoral correlation of consumption falls while that of investment rises. In country 1, without distribution services, all non traded aggregates i.e., consumption, output, and investment rise less on impact. A lower nontraded output in country 1 requires a much smaller rise in its employment, which now comoves less negatively with country 2's nontraded employment, thus again helping raise their cross-country correlation.

The result that an explicit inclusion of distribution services in the model does not matter much is robust to an alternative calibration exercise in which the benchmark sectoral GDP definitions are retained, i.e., distribution services are measured as part of the nontraded sector and therefore the relative size of its GDP is left at 2.25. When no longer required to deliver traded consumption, dis-

tribution services have to be absorbed as nontraded consumption. The ratio of traded to nontraded expenditure falls to 0.34 from 0.62 in the benchmark model (and as in the data). A recalibration obtains a much lower share parameter ($\omega = 0.035$ relative to 0.065 under the benchmark) of traded consumption. The results once again are very similar to the benchmark.²⁷

Finally, notwithstanding the equivalence of results discussed here, it is worth reiterating that the model with distribution services is the only correct specification that is consistent not only with sectoral classifications (of traded and nontraded goods) but also with the relative consumption expenditure shares.

6.3 Benchmark *vis-à-vis* S&T

In principle, the benchmark model reduces to S&T model after dropping distribution services and multiple-input investments. Yet, while removing MII from the benchmark model raises the cross-country consumption correlation from 0.27 to 0.41, it rises to as high as 0.70 in S&T. Since an explicit incorporation of distribution costs does not seem to matter much, what explains this scale of benchmark's improvement over the S&T?

The key once again lies in the calibration exercises. While in S&T's calibration the inclusion of hospitality industry and distribution services in the traded sector makes its size equal nontraded sector's, the relative size of the latter in the benchmark model (and this paper's version without MII) is 2.25. This substantially enhances differences between *with* and *without* MII when applied to benchmark *vis-à-vis* S&T. If instead S&T definition of sectoral outputs is adopted and distribution services are subsumed within exportable consumption, the nontraded sector still remains relatively (about 1.4 times) larger. Moreover, while S&T's calibration finds equal shares of imports and exportables in the traded consumption composite, with the data used in this paper a similar calibration indicates a substantial (3 to 1) home bias. A larger size of nontraded sector and home

²⁷Indeed, the results are even closer to the benchmark results. For example the GDP - trade balance correlation is -0.34 (-0.37 in the benchmark), cross country output correlation is 0.43 (0.45 in the benchmark) and that of consumption is 0.28 (0.27 in the benchmark). See the working paper version, Oviedo and Singh (2011), for further details.

bias within traded composite, both inhibit consumption sharing across countries in this paper.

7 Concluding Remarks

This paper incorporates observed compositional shares of investment expenditures into an otherwise standard two-country complete-markets international business cycle model as in Stockman and Tesar (1995). In the model presented in this study, not only consumption but also investments comprise exportables, imports, and nontraded goods. Another departure from Stockman and Tesar (1995) is that distribution services (Retail and wholesale services; Transportation services) are defined in the nontraded sector and are explicitly incorporated into the model *à la* Burstein, Neves, and Rebelo (2003).

The model so calibrated outperforms the model in which sectoral investments utilize their own outputs. It obtains higher volatilities of trade balance, terms of trade, relative prices of nontraded goods, real exchange rates, and overall comes closer to the data. Trade balance as in the data is significantly countercyclical. Within country comovements of sectoral aggregates are remarkably closer to the data and the comovements of output with consumption, investment, and employment are also improved. Finally, cross-country consumption correlation lies sufficiently below that of output: the quantity anomaly does not arise in the model with multisectoral composition of investments.

The standard nomenclature for sectoral aggregation calls for distribution services to be in the nontraded sector and indeed the model performs the best when distribution costs are explicit in the model. However, whether distribution services are *explicitly* featured as technology or, somewhat counterfactually, *implicitly* embedded in preferences is not critical to the results as long as a careful output-absorption calibration is exercised. The main lesson that emerges is that aligning model with data primarily requires recognizing that capital goods are produced using inputs of exportable, importable, and nontraded goods, so that any changes in the production and absorption possibilities of one directly impacts those of the others.

A major shortcoming of complete markets assumption in this study is that the marginal rate of consumption substitution across countries is perfectly correlated with the real exchange rate, contrary to its low and negative correlation in the data as first noted by Backus and Smith (1993). In addition, models with perfect risk sharing generate lower price volatilities than in the data. Research has shown that the performance of relative price movements and consumption-price comovements improve under incomplete markets.²⁸ Insofar as intersectoral investment demands increase relative price volatilities as shown in this paper, and also uncouple relative price movements from their relative consumption demands, introducing multisectoral composition of investments under incomplete markets will likely help towards the resolution of Backus-Smith puzzle. A formal check of this conjecture is left for future work.

8 Data Appendix

Main aggregates: For sectoral Traded and Non-traded GDP value-added aggregation, 60-industry data provided by Groningen Growth Development Center (GGDC) is utilized. The industries are grouped according to the International Standard Industrial Classification (ISIC) revision 3, as in the detailed tables provided under National Accounts by OECD statistics. Traded aggregate includes Agriculture, Forestry, Fishing, Mining and quarrying, and Manufacturing, while Non-traded aggregate includes Electricity, Gas and Water Supply; Construction; Wholesale and Retail Trade; Restaurants and Hotels; Transport and Storage and Communications; Finance, Insurance, Real Estate and Business Services; Community Social and Personal Services. The industrywise data includes value added at current prices as well as the corresponding price deflator growth rates. *Within* sector aggregation is then obtained by using Tornqvist aggregation method. Aggregate GDP at constant base prices is obtained from OECD National Accounts.

Sectorwise Consumption data at constant prices is obtained from detailed tables provided under National Accounts of OECD Statistics. The traded aggregate of consumption includes Food and non-alcoholic beverages; Alcoholic beverages, tobacco and narcotics; Clothing and footwear; Furniture and furnishings, carpets and other floor coverings; Household textiles; Household appliances; Glassware, tableware and household utensils; Tools and equipment for house and garden; Medical products, appliances and equipment; Audio-visual, photographic and information processing equipment. The non-traded consumption aggregate includes Housing, water, electricity, gas and other fuels; Goods and services for routine household maintenance; Out-patient services; Hospital services; Operation of personal transport equipment; Transport services; Communications; Other recreational items and equipment, gardens and pets; Recreational and cultural services; Newspapers, books and stationery; Package holidays; Education; Restaurants and hotels; Miscellaneous goods and services. An alternative way to distinguish between traded and non-traded consumption is as in Stockman and Tesar (1995): traded consumption is proxied by the private final consumption of non-durable goods, while the private final consumption of services is used for non-traded consumption. The second moments of sectoral aggregates by both definitions however are very close to each other. The total consumption aggregate is the sum of the two components.

²⁸See, for example, Corsetti, Dedola, and Leduc (2008).

Sectoral investment and employment aggregates follow the GDP classification. Industrywise Total Annual Hours Worked provided by GGDC is utilized for employment aggregates. For investment aggregates, Gross Fixed Capital Formation provided by OECD STAN at current prices is used. The sectoral series are deflated by GDP deflator assuming that, as in the data, investments utilize inputs from both traded and nontraded sectors.

Solow residuals: This exercise utilizes sectoral output and employment data from GGDC and Gross Capital Stock at constant prices from OECD Structural Analysis Network (STAN); the latter is available only for a limited number of countries: within G-7 it is not available for the US and Japan; for Germany it is only partially (1991-2003) available. The GDP sectoral classification is followed for sectoral aggregation of capital stock. The data for the US is obtained from the Bureau of Labor Statistics (BLS) which decomposes assets into Farm, Manufacturing, and Non-farm Non-manufacturing sectors. While assets relating to farm and manufacturing constitute the traded sector capital, nonfarm nonmanufacturing capital stock corresponds to the non-traded sector.

References

- [1] Ambler, Steve, Emanuela Cardia, and Christian Zimmermann, “International transmission of the business cycle in a multi-sector model,” *European Economic Review* 46 (2002), 273-300
- [2] Backus, David, Patrick Kehoe, and Finn Kydland, “International real business cycles”. *Journal of Political Economy* 100 (1992), 745-775
- [3] Backus, David, Patrick Kehoe, and Finn Kydland, “Dynamics of the Trade Balance and the Terms of Trade: J-Curve?” *American Economic Review*, 84 (1994), 84-103
- [4] Backus, David and Gregor Smith, “Consumption and real exchange rates in dynamic economies with nontraded goods,” *Journal of International Economics* 35 (1993), 297-316
- [5] Baxter, Marianne and Mario Crucini, “Business cycles and the asset structure of foreign trade” *International Economic Review* 36 (1995), 821-854
- [6] Bems, Rudolfs, “Aggregate investment expenditures on tradable and nontradable goods,” *Review of Economic Dynamics* 11 (2008), 852-883
- [7] Burstein, Ariel, Joao Neves, Sergio Rebelo, “Distribution costs and real exchange rate dynamics during exchange-rate-based-stablizations” *Journal of Monetary Economics* 50 (2003), 1189-1214
- [8] Jose Manuel Campa and Linda Goldberg, “Distribution margins, imported inputs, and the sensitivity of the CPI to exchange rates,” *NBER Working Paper* 12121 (2006)
- [9] Corsetti, Giancarlo and Luca Dedola, “A macroeconomic model of international price discrimination,” *Journal of International Economics* 67 (2005), 129-155
- [10] Corsetti, Giancarlo, Luca Dedola, and Sylvain Leduc, “International Risk Sharing and the Transmission of Productivity Shocks,” *Review of Economic Studies* 75 (2008), 443–473

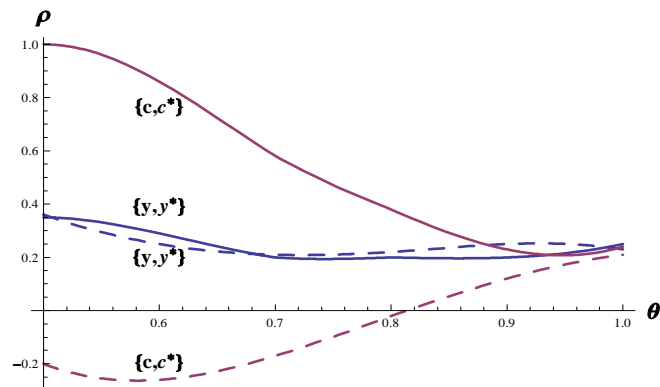
- [11] Heathcote, Jonathan and Fabrizio Perri, “Financial autarky and international business cycles,” *Journal of Monetary Economics* 49 (2002), 601-627
- [12] Heathcote, Jonathan and Fabrizio Perri, “Why Has the U.S. Economy Become Less Correlated with the Rest of the World?” *AEA Papers and Proceedings* 93 (2003), 63-69
- [13] Huang, Kevin and Zheng Liu, “Multiple stages of processing and the quantity anomaly,” *FRB of Kansas City Working Paper* 04-05 (2004)
- [14] Kehoe, Patrick and Fabrizio Perri, “International business cycles with endogenous incomplete markets,” *Econometrica* 70 (2002), 907-928
- [15] Kehoe, Timothy and Kim Ruhl, “Are shocks to the terms of trade shocks to productivity?”, *Review of Economic Dynamics* 11 (2008), 804–819
- [16] Kollman, Robert, “Incomplete asset markets and the cross-country consumption correlation puzzle” *Journal of Economic Dynamics and Control* 20 (1996), 945-961
- [17] Kouparitsas, Michael, “North-South Financial Integration and Business Cycles,” *FRB of Chicago Working Paper* 96-10 (1997)
- [18] Mendoza, Enrique, “The Terms of Trade, The Real Exchange Rates, and Economic Fluctuations,” *International Economic Review* 36 (1995), 101-137
- [19] Pakko, Michael, “International Risk Sharing and Low Cross-Country Consumption Correlations: Are They Really Inconsistent?”, *Review of International Economics* 5 (1997), 386 - 400
- [20] Stockman, Alan and Linda Tesar, “Tastes and technology in a two-country model of the business cycle: Explaining international comovements,” *American Economic Review* 85 (1995), 168-185
- [21] Yakhin, Yossi, “Risk sharing and the international consumption correlation puzzle,” *Mimeo*, UCLA (2005)

Table 1: Cross-country Correlations of Consumption and Output in the Data and in the Present and Previous Studies

| Study / Data | $\rho(c, c^*)$ | $\rho(y, y^*)$ |
|--|----------------|----------------|
| Data [§] : US - EU15 | 0.47 (0.32) | 0.61 (0.40) |
| Bakus, Kehoe, and Kyndland (1992) | 0.88 | -0.18 |
| Baxter and Crucini (1995) [†] | 0.92 | 0.06 |
| Baxter and Crucini (1995) [‡] | -0.28 | 0.54 |
| Corsetti, Dedola, and Leduc (2008) | 0.30 | 0.38 |
| Heathcote and Perri (2002) | 0.85 | 0.24 |
| Kehoe and Perri (2002) | 0.29 | 0.25 |
| Kollman (1996) | 0.38 | 0.10 |
| Stockman and Tesar (1995) | 0.68 | 0.63 |
| Present Study | 0.27 | 0.45 |

Notes: §: Annual data for Consumption and GDP at constant prices (1970-2004): OECD National Accounts. The numbers within brackets correspond to the entire available period, 1955-2005. $\rho(x, x^*)$ denotes the cross-country correlation of variable x . Figures in the table are the best predictions of the corresponding models. †: incomplete-markets model with trend-stationary shocks; ‡: incomplete-markets model with unit-root shocks without cross-country spillovers.

Figure 1: Crosscountry correlations in two-goods extensions of the BKK model



Notes: Solid lines denote crosscountry correlations for the two-goods extension of the BKK model used by Backus, Kehoe, and Kydland (1994) and Heathcote and Perri (2003). Dashed lines denote the same for the variation presented in this paper.

Table 2: Standard Deviations of Macro Aggregates

| Country | Output | Consumption | Investment | Employment |
|-----------|--------|-------------|------------|------------|
| EU15 | | | | |
| Aggregate | 1.43 | 1.40 | 3.74 | 1.58 |
| Traded | 2.22 | n.a. | n.a. | 1.99 |
| Nontraded | 1.18 | n.a. | n.a. | 1.45 |
| US | | | | |
| Aggregate | 1.99 | 1.78 | 5.84 | 1.93 |
| Traded | 4.50 | 3.25 | 9.57 | 2.79 |
| Nontraded | 1.87 | 1.25 | 6.35 | 1.83 |
| UK | | | | |
| Aggregate | 2.17 | 2.26 | 7.67 | 2.75 |
| Traded | 3.12 | 3.03 | 9.49 | 4.23 |
| Nontraded | 3.18 | 1.54 | 8.48 | 2.59 |
| Japan | | | | |
| Aggregate | 1.97 | 1.64 | 6.1 | 0.83 |
| Traded | 3.22 | 1.19 | n.a. | 1.47 |
| Nontraded | 3.13 | 1.19 | n.a. | 0.77 |
| Italy | | | | |
| Aggregate | 1.47 | 1.82 | 4.40 | 1.71 |
| Traded | 2.25 | 2.74 | 7.06 | 2.08 |
| Nontraded | 2.23 | 1.32 | 4.52 | 1.67 |
| Germany | | | | |
| Aggregate | 1.82 | 1.83 | 4.41 | 1.41 |
| Traded | 3.30 | 1.80 | 8.64 | 2.97 |
| Nontraded | 3.21 | 0.99 | 4.86 | 1.16 |
| France | | | | |
| Aggregate | 1.36 | 1.13 | 4.93 | 1.32 |
| Traded | 2.27 | 1.95 | 8.70 | 1.38 |
| Nontraded | 2.21 | 1.29 | 4.66 | 1.37 |
| Canada | | | | |
| Aggregate | 2.23 | 2.29 | 6.87 | 2.38 |
| Traded | 4.74 | 3.5 | 10.89 | 3.87 |
| Nontraded | 4.88 | 1.92 | 6.80 | 2.04 |

Source: Output and Employment (1979-2003) from GGDC 60-Industry database; Consumption (1970-2003) from OECD National Accounts; Investment (1970-2003) from OECD STAN database; Investment data for Germany is available for 1991-2003 only.

Table 3: Standard Deviations of International Variables and Domestic Cross-sectoral Correlations

| | EU15 | US | UK | Japan | Italy | Germany | France | Canada |
|--|-------|-------|-------|-------|-------|---------|--------|--------|
| Standard deviations | | | | | | | | |
| Trade Balance/GDP | 0.51 | 0.52 | 1.33 | 0.77 | 1.22 | 1.18 | 0.63 | 1.05 |
| Terms of Trade | 3.56 | 2.12 | 1.64 | 6.27 | 3.25 | 3.6 | 1.69 | 2.65 |
| Real Exchange Rate | 6.7 | 7.15 | 4.91 | 3.67 | 2.77 | 8.42 | 7.18 | 5.25 |
| Correlation with output of | | | | | | | | |
| Consumption | 0.91 | 0.88 | 0.85 | 0.85 | 0.77 | 0.81 | 0.83 | 0.85 |
| Investment | 0.93 | 0.89 | 0.82 | 0.94 | 0.92 | 0.84 | 0.91 | 0.80 |
| Employment | 0.95 | 0.91 | 0.83 | 0.48 | 0.57 | 0.85 | 0.86 | 0.93 |
| Trade balance | -0.73 | -0.45 | -0.67 | -0.59 | -0.60 | -0.56 | -0.50 | -0.28 |
| Correlation between traded and nontraded | | | | | | | | |
| Output | 0.80 | 0.74 | 0.99 | 0.99 | 0.95 | 0.99 | 0.94 | 0.99 |
| Consumption | n.a. | 0.75 | 0.75 | -0.25 | 0.71 | 0.56 | 0.80 | 0.75 |
| Investment | n.a. | 0.20 | 0.39 | n.a. | 0.38 | 0.11 | 0.62 | 0.38 |
| Employment | 0.89 | 0.81 | 0.64 | 0.48 | 0.71 | 0.40 | 0.75 | 0.88 |

Source: Trade Balance/GDP (1970-2003), Terms of Trade (1980 - 2008), and Real Effective Exchange Rates (1970-2005) from International Financial Statistics.

Table 4: International correlations: US vis-à-vis EU15 and G7

| | EU15 | UK | Japan | Italy | Germany | France | Canada |
|-------------|------|------|-------|-------|---------|--------|--------|
| Output | | | | | | | |
| Aggregate | 0.61 | 0.79 | 0.32 | 0.47 | 0.31 | 0.41 | 0.79 |
| Traded | 0.37 | 0.74 | 0.22 | -0.49 | 0.09 | 0.30 | 0.88 |
| Nontraded | 0.42 | 0.57 | 0.38 | 0.57 | 0.43 | 0.53 | 0.82 |
| Consumption | | | | | | | |
| Aggregate | 0.47 | 0.65 | 0.19 | 0.14 | 0.19 | 0.36 | 0.72 |
| Traded | n.a. | 0.53 | -0.62 | -0.01 | 0.35 | 0.16 | 0.67 |
| Nontraded | n.a. | 0.71 | 0.26 | -0.23 | 0.66 | 0.60 | 0.72 |
| Investment | | | | | | | |
| Aggregate | 0.27 | 0.49 | -0.05 | 0.10 | 0.65 | -0.01 | 0.35 |
| Traded | n.a. | 0.47 | n.a. | -0.37 | 0.08 | -0.18 | 0.66 |
| Nontraded | n.a. | 0.53 | n.a. | -0.08 | 0.71 | 0.16 | 0.26 |
| Employment | | | | | | | |
| Aggregate | 0.43 | 0.77 | 0.31 | -0.07 | 0.05 | 0.37 | 0.79 |
| Traded | 0.33 | 0.75 | 0.15 | -0.12 | -0.07 | 0.19 | 0.70 |
| Nontraded | 0.39 | 0.70 | 0.22 | -0.05 | -0.16 | 0.36 | 0.75 |

Table 5: Shares of Inputs in the Total Input Costs of Producing Capital Goods and Distribution Services (in percentages)

| Sector | Input | | |
|------------------------------|-------------|-------------|-----------|
| | Traded | | Nontraded |
| | Exportables | Importables | |
| <i>Capital Goods</i> | | | |
| Traded | 43 | 26 | 31 |
| Non-traded | 25 | 14 | 61 |
| <i>Distribution Services</i> | | | |
| | 15 | 2.4 | 82.6 |

Source: Bureau of Economic Analysis (BEA). Historical-Cost Investment in Private Equipment and Software by Industry (1947-2004); Historical-Cost Investment in Private Structures by Industry (1947-2004); Input-Output Tables 1997 and 2004; Import matrix 1997; Exports and Imports of Goods and Services by Type of Product (1967-2004).

Table 6: Distribution Margins in the Present and Previous (in percentages) Studies

| | Canada | France | Germany | Italy | U.K. | U.S. |
|----------------------------------|--------|--------|---------|-------|------|------|
| Burstein, Neves, & Rebelo (2002) | 41.2 | 35.0 | 41.5 | 43.3 | 45.4 | 43.4 |
| Campa & Goldberg (2005) | - | 33.5 | 40.3 | 42.0 | 48.7 | 42.8 |
| | 1987 | 1992 | 1997 | 2002 | 2005 | |
| Present Study for the U.S. | 39.8 | 42.0 | 45.1 | 46.0 | 46.2 | |

Source: The BEA's Input-Output Tables for 1987, 1992, 1997, 2002, and 2005 have been utilized for constructing the time series on the U.S. distribution margin. The distribution margin is the value of the wholesale and retail trade component incorporated into the value of the private final consumption of traded goods.

Table 7: Parameter Values: Benchmark model, the model without multiple input investments (w/o MII), and the model without distribution services

| Notation | Explanation | Parameter Values | | |
|----------------------------|---|------------------|----------------|--------------------------------|
| | | Benchmark | w/o MII | w/o distribution ^{§§} |
| Final goods technology | | | | |
| (θ_x, θ_n) | Capital shares in output | (0.36, 0.38) | (0.36, 0.38) | (0.36, 0.38) |
| (λ_x, λ_n) | Productivity shocks | (3.11, 2.78) | (3.11, 2.78) | (2.55, 2.29) |
| Capital goods technology | | | | |
| (δ_x, δ_n) | Depreciation rates | (0.085, 0.071) | (0.085, 0.071) | (0.085, 0.071) |
| (α_x, α_n) | Share of exportables | (0.43, 0.25) | (1, 0) | (0.43, 0.31) |
| (ϵ_x, ϵ_n) | Share of importables | (0.26, 0.14) | (0, 1) | (0.25, 0.18) |
| (μ_x, μ_n) | Scale parameters | (2.93, 2.52) | (1, 1) | (2.93, 2.75) |
| Distribution services | | | | |
| α_d | Share of exportables | 0.15 | 0.15 | — |
| ϵ_d | Share of importables | 0.024 | 0.024 | — |
| μ_d | Scale parameter | 1.71 | 1.71 | — |
| (ψ_x, ψ_m) | Requirement of distrib. services [†] | (0.67, 0.67) | (0.67, 0.67) | (—, —) |
| Preferences | | | | |
| ν | Share of exportables [‡] | 0.56 | 0.45 | 0.75 |
| ω | Weight on traded composite | 0.07 | 0.12 | 0.065 (0.13) |
| $(1 + \rho)^{-1}$ | Elasticity of substitution [§] | 0.44 | 0.44 | 0.33 (0.44) |
| η | Labor share parameter | −1.92 | −1.92 | −1.93 |
| γ | CES utility parameter | −1 | −1 | −1 |

Table 8: VAR Estimate of the Productivity Shocks

$$\hat{\Lambda} = \begin{pmatrix} 0.263 & 0.051 & -0.135 & 0.144 \\ -0.191 & 0.527 & -0.153 & 0.052 \\ -0.135 & 0.144 & 0.263 & 0.051 \\ -0.153 & 0.052 & -0.191 & 0.527 \end{pmatrix} \quad \hat{\Sigma} = 0.001 \times \begin{pmatrix} 0.502 & 0.088 & 0.16 & 0.036 \\ 0.088 & 0.14 & 0.036 & 0.015 \\ 0.16 & 0.036 & 0.502 & 0.088 \\ 0.036 & 0.015 & 0.088 & 0.14 \end{pmatrix}$$

Source: Output and Employment (1979-2003) - GGDC; Capital stock (1979-2003) for Canada, France, Germany, Italy, and UK - OECD STAN industrial database; For Germany, the capital stock data is available for 1991-2003 only. Capital Stock (1979-2003) for the US is from Bureau of Labor Statistics.

Table 9: Table of results - Standard deviations and internal correlations

| | Data [§] US [min - max] | S&T model | Present Study | | |
|----------------------------------|-------------------------------------|--------------|---------------|-------|----------|
| | | | Bench- | w/o | w/o |
| | | | mark | MII | Distrib. |
| | (a) | (b) | (c) | (d) | (e) |
| STANDARD DEVIATIONS [†] | | | | | |
| <i>Output</i> | | | | | |
| Aggregate | 1.99 [1.36 – 2.33] | 1.87 | 1.63 | 1.66 | 1.74 |
| Traded | 4.50 [2.22 – 4.74] | 2.61 | 2.57 | 3.33 | 2.47 |
| Nontraded | 1.87 [1.18 – 4.88] | 1.32 | 1.49 | 1.70 | 1.48 |
| <i>Consumption</i> | | | | | |
| Aggregate | 1.78 [1.13 – 2.29] | 0.53 | 0.52 | 0.50 | 0.51 |
| Traded | 3.25 [1.80 – 3.50] | 0.59 | 0.51 | 0.55 | 0.64 |
| Nontraded | 1.25 [0.99 – 1.92] | 0.48 | 0.62 | 0.53 | 0.57 |
| <i>Investment</i> | | | | | |
| Aggregate | 5.84 [3.74 – 7.67] | 4.94 | 5.95 | 5.48 | 6.35 |
| Traded | 9.57 [7.06 – 10.89] | 7.62 | 9.78 | 12.33 | 8.59 |
| Nontraded | 4.86 [4.52 – 8.48] | 3.25 | 6.02 | 5.86 | 5.92 |
| <i>Hours</i> | | | | | |
| Aggregate | 1.93 [0.83 – 2.75] | 0.87 | 0.79 | 0.81 | 0.84 |
| Traded | 2.79 [1.38 – 4.23] | 1.64 | 1.38 | 2.30 | 1.12 |
| Nontraded | 1.83 [0.77 – 2.59] | 0.78 | 0.64 | 0.96 | 0.81 |
| TRADE AND RELATIVE PRICES | | | | | |
| <i>TB/output</i> | 0.52 [0.52 – 1.33] | 0.13 | 0.30 | 0.09 | 0.37 |
| <i>TOT</i> | 2.11 [1.64 – 6.27] | 0.75 | 2.37 | 1.34 | 2.22 |
| <i>Price of NT goods</i> | 2.14 [1.34 – 2.14] | 0.85 | 2.09 | 1.26 | 2.20 |
| <i>RER</i> | 7.15 [2.77 – 8.42] | 0.81 | 1.76 | 0.94 | 2.06 |
| DOMESTIC CORRELATIONS | | | | | |
| (TB, y) | -0.45 [-0.28 – (-0.73)] | 0.20 | -0.37 | -0.14 | -0.23 |
| (c, y) | 0.88 [0.77 – 0.91] | 0.95 | 0.88 | 0.95 | 0.91 |
| (i, y) | 0.88 [0.80 – 0.94] | 1.00 | 0.98 | 1.00 | 0.97 |
| (h, y) | 0.91 [0.48 – 0.95] | 0.98 | 0.97 | 0.99 | 0.98 |
| (y_x, y_n) | 0.74 [0.74 – 0.99] | 0.27 | 0.60 | 0.13 | 0.69 |
| (c_T, c_n) [†] | 0.75 [0.56 – 0.80] | 0.80 | 0.59 | 0.74 | 0.43 |
| (i_x, i_n) | 0.35 [0.11 – 0.62] | 0.10 | 0.36 | -0.02 | 0.63 |
| (h_x, h_n) | 0.64 [0.40 – 0.88] | -0.16 | 0.65 | -0.30 | 0.59 |

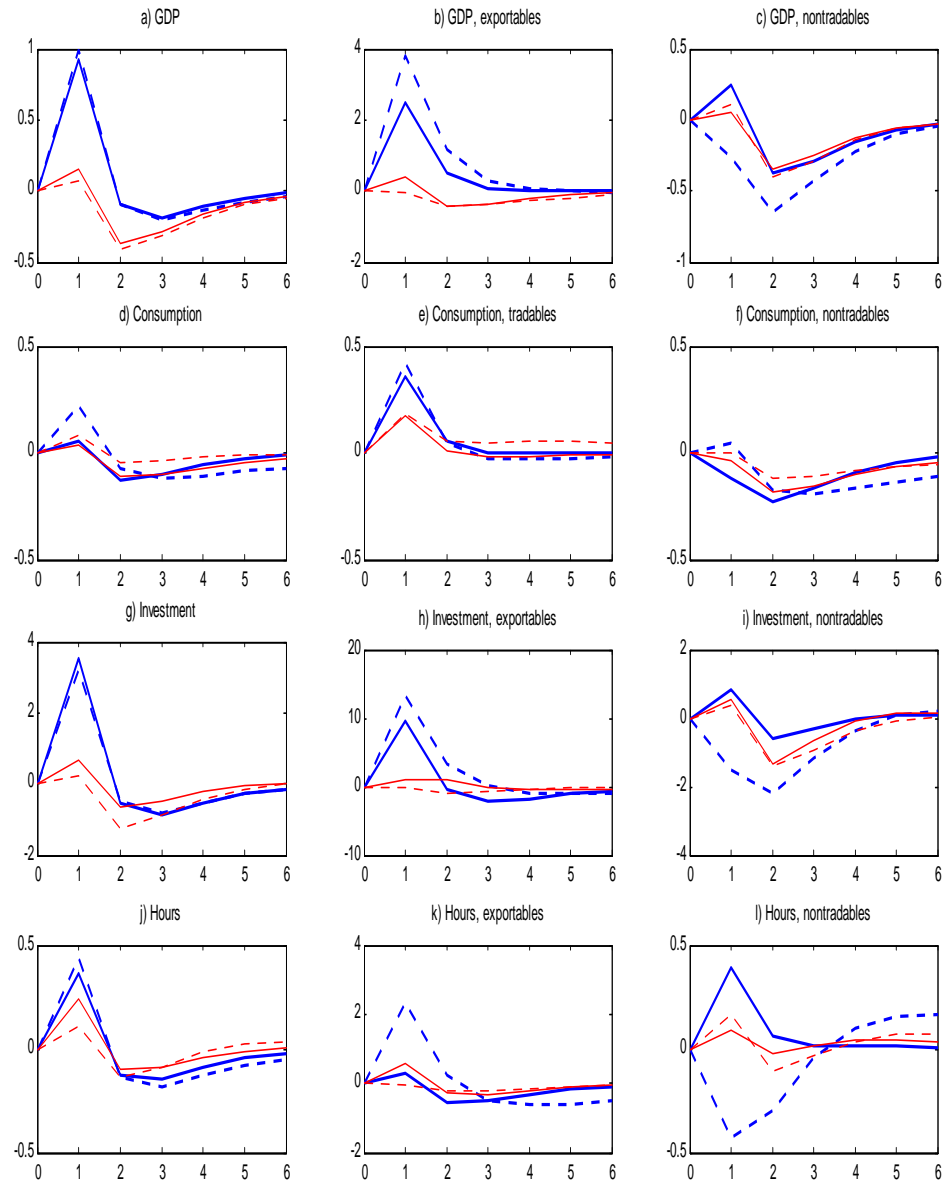
Notes: §: Data moments outside the brackets relate to the US; the numbers inside the brackets indicate the minimum and maximum for G7 and EU15 as presented in Tables 2 and 3 earlier. †: percentage deviations with respect to means. The model statistics are computed from 300 simulations of 300 periods each, after disregarding the first 200 periods of each simulation. Column (b) presents results corresponding to Stockman and Tesar (1995) model. Columns (c), (d), and (e) respectively present results from this paper's benchmark model, the model in which sectoral goods serve as their own capital, and the model without distribution services.

Table 10: Table of results - Crosscountry correlations

| | Data [§] US-EU15 [min - max] (a) | S&T model (b) | Present Study | | |
|--------------------------------|---|---------------------|-----------------------|-------------------|------------------------|
| | | | Bench- mark (c) | w/o MII (d) | w/o Distrib. (e) |
| | | | <i>Output</i> | | |
| Aggregate | 0.61 [0.31 – 0.79] [†] | 0.44 | 0.45 | 0.41 | 0.46 |
| Traded | 0.37 [0.22 – 0.89] [†] | 0.37 | 0.62 | 0.33 | 0.53 |
| Nontraded | 0.42 [0.38 – 0.82] [†] | 0.27 | 0.21 | 0.26 | 0.20 |
| <i>Consumption[‡]</i> | | | | | |
| Aggregate | 0.47 [0.14 – 0.72] [‡] | 0.70 | 0.27 | 0.41 | 0.28 |
| Traded | 0.34 [–0.01 – 0.67] [‡] | 0.79 | 0.55 | 0.60 | 0.49 |
| Nontraded | 0.49 [–0.23 – 0.72] [‡] | 0.44 | 0.27 | 0.29 | 0.25 |
| <i>Investment</i> | | | | | |
| Aggregate | 0.27 [–0.05 – 0.65] | 0.41 | 0.23 | 0.37 | 0.28 |
| Traded | 0.13 [–0.37 – 0.66] | 0.34 | 0.36 | 0.30 | 0.31 |
| Nontraded | 0.32 [–0.08 – 0.53] | 0.21 | 0.17 | 0.23 | 0.22 |
| <i>Hours</i> | | | | | |
| Aggregate | 0.43 [0.31 – 0.79] ^{§§} | 0.54 | 0.63 | 0.50 | 0.67 |
| Traded | 0.33 [0.15 – 0.75] ^{§§} | 0.36 | 0.93 | 0.32 | 0.91 |
| Nontraded | 0.39 [0.22 – 0.75] ^{§§} | 0.06 | 0.06 | 0.11 | 0.26 |

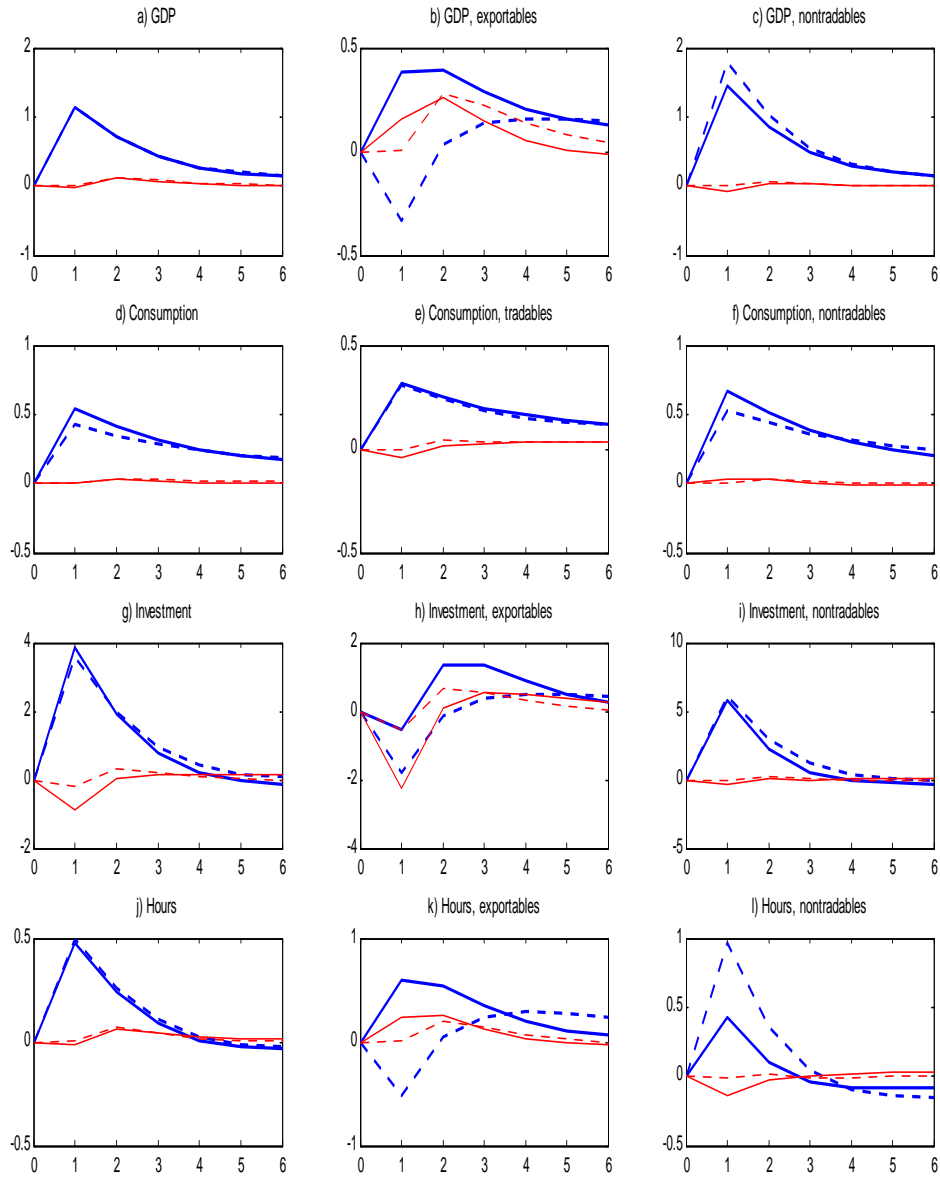
Notes: §: The correlations outside the brackets relate to US vis-à-vis EU15 whenever available; for sectoral consumptions and sectoral investments EU15 series is not available and therefore the numbers indicate averages for US vis-à-vis other countries in G7, as presented in Table 4. The numbers inside the brackets indicate the minimum and maximum correlations between US and others in G7 and EU15. †: After dropping Italy as an outlier. ‡: After dropping Japan as an outlier. §§: After dropping Italy and Germany as outliers.

Figure 2: A shock to the traded sector – Impulse response functions from the benchmark model and the model in which sectoral goods serve as their own capital



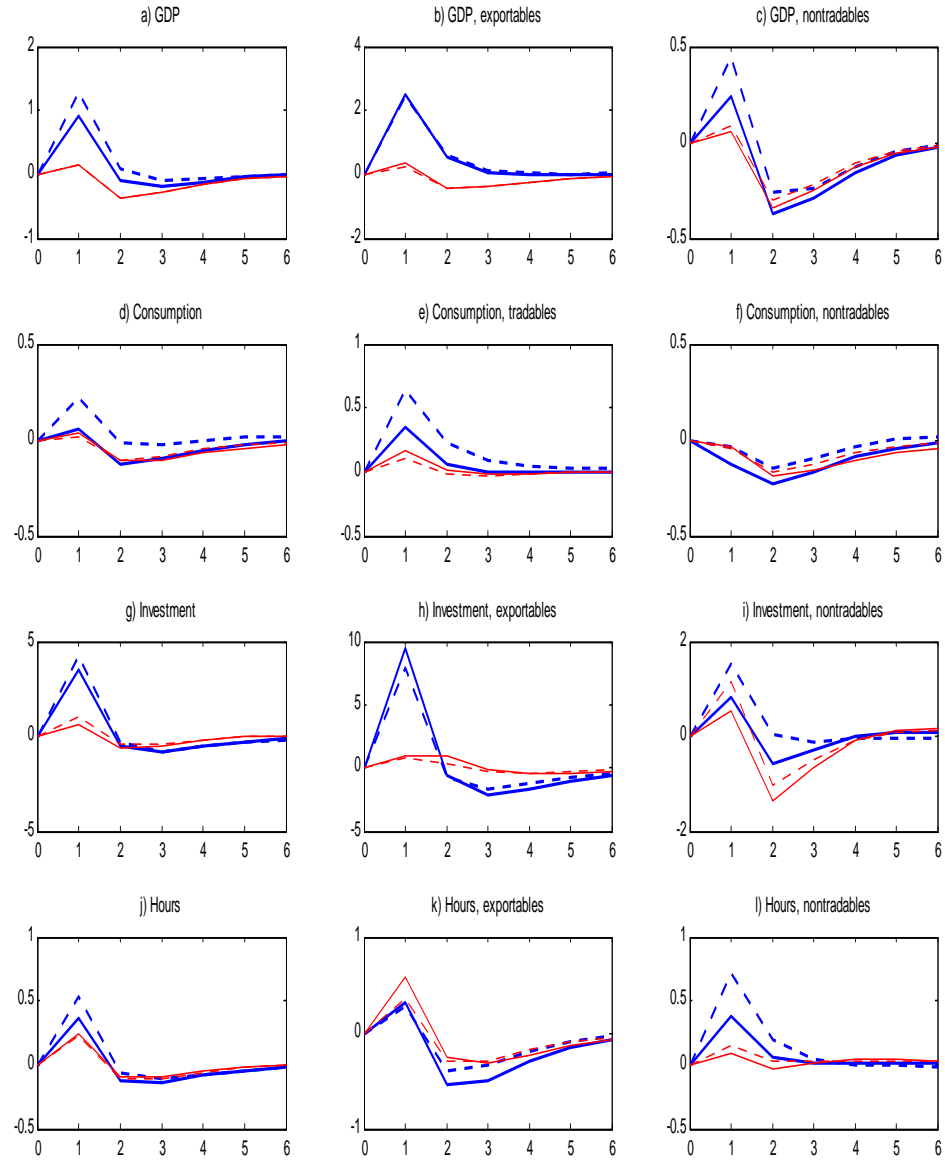
Notes: Darker (blue when colors are available) lines are used for country 1 and lighter (red) lines are used for country 2. For each country, solid (dashed) lines are used for impulse response functions of the model that includes (excludes) the multiple-input technologies in the production of capital goods.

Figure 3: A shock to the nontraded sector – Impulse response functions from the benchmark model and the model in which sectoral goods serve as their own capital



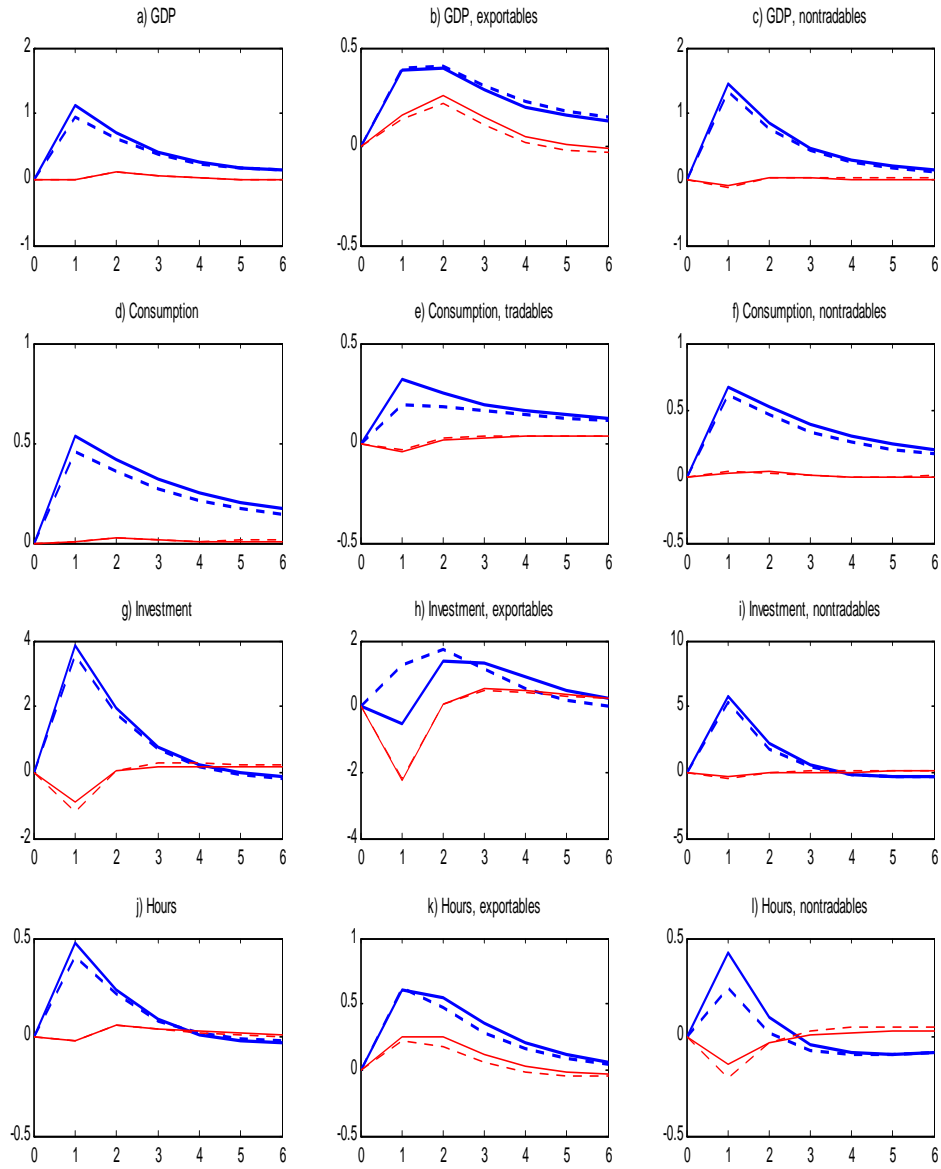
Notes: Darker (blue when colors are available) lines are used for country 1 and lighter (red) lines are used for country 2. For each country, solid (dashed) lines are used for impulse response functions of the model that includes (excludes) the multiple-input technologies in the production of capital goods.

Figure 4: A shock to the traded sector – Impulse response functions with and without distribution services



Notes: Darker (blue when colors are available) lines are used for country 1 and lighter (red) lines are used for country 2. For each country, solid (dashed) lines are used for impulse response functions of the model that includes (excludes) distribution services.

Figure 5: A shock to the nontraded sector – Impulse response functions with and without distribution services



Notes: Darker (blue when colors are available) lines are used for country 1 and lighter (red) lines are used for country 2. For each country, solid (dashed) lines are used for impulse response functions of the model that includes (excludes) distribution services.