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North-South Business Cycles

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Abstract

A central feature of the North-South debate in the professional and popular press concerns the extent to which the South is dependent on the North. Despite the age of this debate, there is little research that tries to evaluate the extent to which economic fluctuations in the Southern economies are caused by shocks originating in the North, this paper attempts to fill this gap. Toward this end, I develop a quantitative general equilibrium model of North-South trade that allows me to determine the extent to which economic fluctuations in the North cause sympathetic fluctuations in the South, as well as identifying the important channels of business cycle transmission between the North and South. I find that the model contains a strong mechanism for the transmission of business cycles from one region to the other. In fact, model simulations suggest that fluctuations in Northern aggregate output account for about 70 percent of the variation in Southern consumption.

Key words: North-South trade; Terms of trade; Business cycles, Comovement.

JEL classification: E32; F41.

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1 Introduction

Trade between the industrialized North and developing South is well known to be asymmetric: the North imports labor-intensive primary products from the South in exchange for exports of capital-intensive manufactured goods. A central feature of the North-South debate in the professional and popular press concerns the extent to which the South is *dependent* on the North, as well as the extent to which the North exploits the poorer South. These notions of dependence and exploitation arise from many sources–one is the theory of *unequal exchange*. Since Southern exports are assumed to use more labor than Southern imports, the doctrine of unequal exchange suggests that the South gains less from trade than does the North.

Another, more mainstream view argues that short-run or business cycle fluctuations in Southern economies are caused by the North, for two reasons. First, since the North uses Southern products as inputs to the North's manufacturing process, fluctuations in the Northern manufacturing produce sympathetic fluctuations in the derived demand for Southern inputs, which directly leads to large movements in Southern export prices and Southern income. Second, since the South uses Northern capital as an input in their own production process, fluctuations in the output of Northern manufactures cause fluctuations Southern import price and hence lead to fluctuations in Southern imports and Southern production more generally.

Despite the prevalence of these views, there is little research that tries to evaluate the extent to which short-run economic fluctuations in the Southern economies are caused by shocks originating in the North.[1] This paper attempts to fill this gap. Toward this end,

[1] The North-South literature can easily be separated into research dealing with the short-run and long-run. An early example of long-run North-South trade research is Ricardo's analysis of the "Corn Laws." More recent examples of theoretical long-run North-South analysis can be conveniently sub-divided into Keynesian and Neoclassical approaches. For examples of the Keynesian approach see Taylor (1981) and Sakar (1989). For examples of the Neoclassical approach see Findlay's (1984) survey, along with associated work by Burgstaller and Saavedra-Rivano (1984) which extends Findlay's model to include capital mobility, and the dual model's of Chichilnisky (1981,1984) and McIntosh (1985), and Sansarricq (1991) which extends Findlay's model by allowing the South to produce capital goods. There are is also a quantitative long-run literature. See Whalley (1984) for an example of a static computable general equilibrium model of North-South trade.

The short-run North-South literature is considerably younger than the long-run literature. Unlike the long-run literature which tends to be theoretical the short-run literature is generally quantitative. Short-run analysis requires dynamic models of North-South trade. Early quantitative dynamic North-South

I develop a quantitative general equilibrium model of North-South trade that allows me to determine the extent to which economic fluctuations in the North cause sympathetic fluctuations in the South, as well as identifying the important channels of business cycle transmission between the North and South. The attractive feature of a general equilibrium approach is that prices and quantities are determined endogenously. For example, terms of trade movements are not *exogenous shocks*–they instead reflect equilibrium responses to fundamental shocks to the two regional economies.

The paper is structured as follows. Section 2 details the empirical regularities of North-South trade and business cycles. Since the theoretical literature suggests that *real commodity prices* (ratio of non-fuel commodity prices and manufactured goods prices) play a key role in the transmission of business cycles from North and South, I present statistics on price and quantity fluctuations in each region. The Northern countries are identified as large industrial countries, while the Southern economies are developing non-oil commodity exporting countries. Section 3 develops the theoretical model of North-South production and trade, which was developed to be consistent with the key features of national input-output matrices, and patterns of international trade. Model calibration and simulation issues are discussed in section 4.

Section 5 reports the model's predictions concerning the character of North-South business cycles. The model is broadly consistent with the stylized facts of Northern and Southern business cycles. In particular, the model replicates the data along three important dimensions. First, the model captures the positive correlation between Northern manufacturing output and real commodity prices. Second, the model generates positive comovement across the Northern and Southern regions in terms of output, consumption and investment. While matching patterns of international comovement was not a primary goal of this investigation, this finding is an important outcome of this investigation. Prior equilibrium models of interacting economies have not been able to simultaneously generate international comovement of all the major macroeconomic aggregate in the presence of international trade in capital goods.[2] The present paper, with its stress on strong intersec-

trade research is documented in the survey by Currie and Vines (1988), Moutos and Vines (1989), and Mustcatelli and Vines (1989). See also McKibbin and Sundberg (1993) for an interesting application–these authors study international policy coordination in the context of a quantitative North-South trade model.

[2]See, for examples, the international business cycle literature surveys by Backus et al. (1995) and Baxter

toral linkages and important intermediate sector, has been able to overcome the limitations of prior analyses. Third and finally, the model is capable of generating realistic volatility in real commodity prices and terms of trade. This also represents an advance over existing equilibrium trade models which have been unable to generate realistic volatility in relative prices (see, for example, Backus et al. 1995).

I find that the model contains a strong mechanism for the transmission of business cycles from one region to the other. Using impulse responses, I show that fluctuations in Northern manufacturing cause large sympathetic fluctuations in Southern manufacturing, consumption and investment. Model simulations suggest that fluctuations in Northern aggregate output account for about 20 percent of the variation in Southern aggregate output, roughly 70 percent of the variation in Southern consumption, and 60 percent of the variation in Southern investment. My findings are also consistent with those of Borensztein and Reinhart (1994) who find, using regression analysis that over 50 percent of the fluctuations in real commodity prices over the 1971-1992 period are due to fluctuations in demand factors (i.e., fluctuations in Northern manufacturing output). Section 6 presents a sensitivity analysis of the model's results to key parameter values, and section 7 contains a brief summary and directions for future research.

2 North-South business cycles

Almost all of our knowledge of international business cycles has come from analyzing industrial country data; this literature has revealed that Northern economies share a number of business cycle regularities (see, for example, Backus and Kehoe 1992). In contrast, Southern economies defined as developing-commodity-exporting countries, tend to have diverse industrial structures which makes it difficult to characterize a typical Southern business cycle. In his survey of traditional North-South trade research Findlay (1984) cautioned that in theoretical North-South trade models the South is not necessarily representative of individual Southern economies, but should be viewed as a description of the behavior of the entire Southern region. In a similar vein, I describe the cyclic behavior of the South through an aggregate of non-oil, commodity-exporting countries. Data for developing countries tend

(1995).

to be less reliable than that of industrial countries. I limit the data set to the *market-based* economies that have the best data coverage. My country classifications are consistent with World Bank (1992), Table 1. A summary of this table is reported in appendix C.

Tables 1–4 describe the cyclic behavior of major North and South macroeconomic time series. These statistics are based on annual data covering 1969 to 1988.[3] I follow the international business cycle literature by using a Hodrick and Prescott (1980) filter with a smoothing parameter of 10 to approximately isolate the, so called, business cycle frequencies of 6 to 32 quarters (see, Baxter and King 1995, for details). In the following discussion, cyclical *comovement* is described by various correlations of the filtered data and cyclical *volatility* is described by the percentage standard deviation from the Hodrick-Prescott trend.

North-South trade differs significantly from North-North trade. North-North trade to a large extent involves trade in the same types of goods, while North-South trade involves trade in different goods. Specifically, the North exports manufactured goods in exchange for imports of Southern primary goods. In light of this, I break up the price and quantity data into primary and non-primary components. Primary activity includes agriculture and mining, while non-primary activity includes manufacturing and services. Note, for the remainder of the discussion I follow the North-South convention of referring to the non-primary sector as the manufacturing sector.

A central stylized fact of international data is that when one country's output is above its trend, the output of many other countries tend to be above their trend. This is the basic definition of an *international business cycle.* Figure 1 and the correlations reported in Table 1 suggests there is a *North-South business cycle.* In particular, they indicate that when Northern gross domestic product (GDP) is above its trend Southern GDP tends to be above its trend. The second column of Table 1 reveals a contemporaneous correlation between Northern and Southern GDP of 0.44. Underlying this statistic is a strong correlation between Northern and Southern manufacturing value-added of 0.52. In contrast to manufacturing, the contemporaneous correlations of other North-South variables are not significantly different from zero. However, Figure 1 and the third column of Table 1 reveal that lagged Northern and current Southern data yield a completely different outcome.

[3] Data sources and definitions are described in appendix A.

In particular, this lead/lag relationship generates strong positive correlations between all Northern and Southern variables. The only exception is primary activity which appears to be uncorrelated across regions at all leads and lags.

Traditional theoretical North-South trade studies have long emphasized the role that real commodity price (ratio of non-oil commodity price to manufactured goods prices) fluctuations play in transmitting supply and demand shocks from North to South, and vice versa. On the one hand, it is argued that fluctuations in Northern manufacturing activity generate sympathetic fluctuations in the derived demand for primary inputs, but primary goods tend to be in fixed supply in the short run, so changes in primary goods demand produce large fluctuations in real commodity prices and Southern real income. On the other hand, it is argued that fluctuations in Southern primary activity produce large fluctuations in real commodity prices that lead to sympathetic fluctuations in Northern manufacturing output. Figure 1 reveals a positive correlation between world manufacturing output and world real commodity prices of 0.49. In contrast, the data indicates a weaker, although statistically significant, correlation between world primary production and world real commodity prices of -0.29. Table 2 breaks up these price/quantity correlations across regions. Here I find that there is a positive correlation between Northern activity and real commodity prices. The Southern price-quantity correlations tend to be weaker than in the North. In Kouparitsas (1997a) I argue that virtually all of the fluctuations in the North-South terms of trade (ratio of export prices to import prices) are due to movements in the real commodity prices, so it is not surprising that correlations between the North-South terms of trade and production are similar to those involving real commodity prices.

Table 3 shows that real commodity prices are considerably more volatile than Northern or Southern aggregate gross domestic product (GDP). In fact, with a percentage standard deviation of 6.98 real commodity prices are roughly five times as volatile as Southern GDP. Table 3 shows that the North-South terms of trade is less volatile than the real commodity price but also considerably more volatile than Northern and Southern GDP.

The remaining features of the data refer to within-region characteristics. The North and South share many cyclical properties: consumption is less volatile than aggregate output; investment is more volatile than aggregate output; sectoral value-added is more volatile than aggregate output. The similarities between the two region economies are also revealed in Table 4. Within region business cycles are characterized by the fact that fluctuations in aggregate activity are largely driven by movements in manufacturing activity, while primary activity has low coherence with aggregate activity. Another feature of the within-region business cycle shared by the North and South is the positive comovement of aggregate consumption, investment, and manufacturing activity.

3 A model of North-South trade

Traditional theoretical North-South trade models are highly stylized and typically assume the North is completely specialized in the production of manufactured goods and the South is completely specialized in the production of primary goods (see, for example, Findlay 1984). In general, countries produce and trade both types of good. Recent contributions to the theoretical North-South trade literature, such as Sansarricq (1991), have extended traditional models by allowing the South to produce manufactured goods. However, these models still make a range of empirically implausible assumptions for analytical tractability, such as perfectly elastic labor supplies and fixed savings rates. An alternative approach is provided by the quantitative North-South trade literature that uses static computable general equilibrium models (see, for example, Whalley 1984). These models are solved using numerical techniques and generally embody realistic North-South features, such as regional production and interregional trade of both types of goods. There are, however, three weaknesses inherent in static computable general equilibrium studies. First, they rule out capital accumulation. Second, they rule-out trade in financial assets by restrict the current account to be zero. Third, like traditional theoretical models they are long-run analyses. I overcome these weaknesses by developing a dynamic model that allows for realistic capital accumulation, trade in financial assets, and provides information on the short-run and long-run impact of regional shocks.

There is a young, but growing literature that deals with quantitative dynamic models of North-South trade. The most recent and fully developed example is McKibbin and Sundberg (1993). McKibbin and Sundberg do not evaluate the extent to which economic fluctuations in the Southern economies are caused by shocks originating in the North, as in the current paper. They instead study the implications for the South of coordinated

Northern monetary and fiscal policies. The current paper is closer in spirit to a series of papers by Currie and Vines (1988), Muscatelli and Vines (1989), and Moutos and Vines (1989). In fact, the current paper takes up the challenge presented by these papers by developing an empirically plausible quantitative model of North-South trade.

The Northern economy is modeled to reflect the industrial and trade structure of major industrial economies, while the Southern specification is flexible enough to allow for the wide range of developing non-fuel exporting economies. Northern variables are denoted by $(j = n)$ and Southern variables are denoted by $(j = s)$.

3.1 Preferences

Each region j has a single infinitely lived representative household who maximizes his expected lifetime utility from consuming a consumption good (c_{jt}) and leisure (L_{jt}):

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \frac{\left(c_{jt}^{\theta_c} L_{jt}^{1-\theta_c}\right)^{1-\sigma}}{1-\sigma}, \tag{3.1}$$

for $1 > \beta > 0$, $1 > \theta_c > 0$, and $j = n, s$.

3.2 Production technology

Each region produces two goods: primary raw materials $(i = 1)$ and manufactured goods $(i = 2)$. Primary production requires no materials inputs, so the gross value of primary output (y_{1jt}) is the same as primary value-added (y_{v1jt}). In contrast, manufacturing output (y_{2jt}) is a gross output concept because manufacturing production requires capital, labor and raw material inputs from the primary sector.

Primary Primary output is essentially value-added–that part of production attributable to non-materials inputs. Primary production (y_{1jt}) uses capital (k_{1jt}), labor (N_{1jt}^s) and land (T_{1jt}) as inputs. I assume value-added production is described by Cobb-Douglas technology:

$$y_{1jt} = y_{v1jt} = A_{1jt} N_{1jt}^{s\theta_1} k_{1jt}^{\alpha_1} T_{1jt}^{1-\theta_1-\alpha_1}, \tag{3.2}$$

for $\alpha_1, \theta_1 \geq 0, 1 \geq \theta_1 + \alpha_1 \geq 0$, and $j = n, s$. A_{1jt} is an exogenous productivity shift parameter.

Manufactures Primary goods are typically consumed as intermediate goods. The model responds to this by requiring manufacturing production to use primary goods as intermediate goods inputs, in addition to capital and labor. I make the standard assumption that manufacturing gross production (y_{2jt}) is described by a two-level constant elasticity of substitution (CES) function:

$$y_{2jt} = \left\{ \omega_y y_{v2jt}^{1-1/\sigma_\varepsilon} + (1-\omega_y) m_{jt}^{1-1/\sigma_\varepsilon} \right\}^{\frac{1}{1-1/\sigma_\varepsilon}}, \tag{3.3}$$

for $1 \geq \omega_y \geq 0$, $\sigma_\varepsilon > 0$ and $j = n, s$. The first level of production involves a value-added component and an aggregate intermediate goods component. Again I assume that the value-added production component (y_{v2jt}) is modeled as Cobb-Douglas technology which requires capital (k_{2jt}) and labor (N_{2jt}^s):

$$y_{v2jt} = A_{2jt} N_{2jt}^{s\theta_2} k_{2jt}^{1-\theta_2}, \tag{3.4}$$

for $1 \geq \theta_2 \geq 0$ and $j = n, s$. A_{2jt} is the manufacturing productivity shift term. The other factor of production is the aggregate intermediate input (m_{jt}). The elasticity of substitution between value-added and the intermediate input is σ_ε.

3.3 Investment behavior

There are two types of investment goods. The first type are durable capital goods which depreciate at rate $0 < \delta_k \leq 1$. All capital goods are used as inputs in the production of other goods, and are only produced in the manufacturing. The second type are intermediate goods which are held as inventories and completely consumed in the production of next period's manufactured goods (i.e., the current stock of inventories is next period's intermediate good inputs).

Capital goods I assume there are costs of adjusting capital stocks (k_{ijt}) in both regions. Following Baxter and Crucini (1993) I employ a cost of adjustment function $\phi_{ki}(x)$ which has the following properties: $\phi_{ki}(x) > 0, \phi'_{ki}(x) > 0$, and $\phi''_{ki}(x) < 0$. By allowing i_{ijt} to denote investment in sector i region j capital and δ_k the capital depreciation rate I can describe accumulation in the region j, sector i, capital good in the following manner:

$$k_{ijt+1} = k_{ijt}\left(1-\delta_k\right) + \phi_{ki}\left(\frac{i_{ijt}}{k_{ijt}}\right)k_{ijt}, \tag{3.5}$$

for $i = 1, 2$ and $j = n, s$.

Intermediate goods I assume that intermediate goods require one period to put in place, so that period $t+1$ inputs are produced in period t. I summarize region j's intermediate investment (i_{mjt}) behavior in the following way:

$$m_{jt+1} = i_{mjt}, \tag{3.6}$$

for $j = n, s$.

3.4 Trade flows

The North and South export both manufactured and primary goods, albeit in different proportions. To allow for incomplete specialization in production and trade I assume traded goods are differentiated by production location.[4] In particular, home produced (h_{1jt}) and imported (f_{1jt}) primary goods are aggregated according to the following CES function:

$$i_{mjt} = \left(\omega_{1j} h_{1jt}^{1-1/\sigma_{\mu1}} + \left(1-\omega_{1j}\right) f_{1jt}^{1-1/\sigma_{\mu1}}\right)^{\frac{1}{1-1/\sigma_{\mu1}}}, \tag{3.7}$$

for $1 > \omega_{1j} > 0, \sigma_{\mu1} > 0$, and $j = n, s$. The elasticity of substitution between home produced and imported primary goods is $\sigma_{\mu1}$ and ω_{1j} is the weight reflecting home good bias.

The aggregation function for manufactured goods is also a CES function given by the following:

$$c_{jt} + i_{1jt} + i_{2jt} = \left(\omega_{2j} h_{2jt}^{1-1/\sigma_{\mu2}} + \left(1-\omega_{2j}\right) f_{2jt}^{1-1/\sigma_{\mu2}}\right)^{\frac{1}{1-1/\sigma_{\mu2}}}, \tag{3.8}$$

for $1 > \omega_{2j} > 0$, $\sigma_{\mu2} > 0$ and $j = n, s$. h_{2jt} denotes home produced manufactured goods and f_{2jt} denotes imported manufactured goods. The elasticity of substitution between home

[4] See Baxter 1992 for a discussion of how complete specialization, along the lines of Ricardian comparative advantage, emerges in a dynamic Heckscher-Ohlin-Samuelson model where goods are not differentiated by production location.

produced and imported manufactures is $\sigma_{\mu 2}$ and ω_{2j} is the weight reflecting home good bias.

3.5 Resource constraints

The model contains two non-reproducible factors labor and land. Labor is mobile between sectors, subject to adjustment costs. In particular, labor services (N_{ijt}^s) are described by the following dynamic relationship:

$$N_{ijt+1}^s = \phi_{Ni}\left(\frac{N_{ijt+1}}{N_{ijt}^s}\right)N_{ijt}^s, \tag{3.9}$$

for $i = 1, 2$ and $j = n, s$. I assume ϕ_{Ni} has properties similar to the capital adjustment cost functions (i.e. $\phi_{Ni}(x) > 0, \phi'_{Ni}(x) > 0$, and $\phi''_{Ni}(x) < 0$) although the actual cost of adjusting labor and capital will be different. Note, that like capital I assume that there are costs associated with bringing new workers *on-line.* Total hours are normalized to unity so that the agents face the following regional labor constraints:

$$1 - L_{jt} - \sum_{i=1,2} N_{ijt} = 0, \tag{3.10}$$

for $j = n, s$.

Land has a minor share in the value-added of the non-primary industries. The model reflects this by modeling manufacturing value-added as a Cobb-Douglas function of capital and labor. The supply of land is a assumed to be fixed throughout the analysis.

The only financial assets available to the Northern and Southern households are non-contingent one-period bonds b_{jt}.[5] The price of these assets in terms of the numeraire is p_{bt}. By allowing p_{ijt} to denote the price of region j's good i in terms of the numeraire good I can describe region j's representative household's intertemporal budget constraint as:

$$\sum_{i=1,2} p_{ijt}y_{ijt} + b_{jt} = p_{1jt}h_{1jt} + p_{2jt}h_{2jt} + p_{1kt}f_{1jt} + p_{2kt}f_{2jt} + p_{bt}b_{jt+1}, \tag{3.11}$$

[5] A companion paper, Kouparitsas 1997b shows that the model's behavior is sensitive to the North-South asset market assumption. In particular, cross-region activity correlations and North-South terms of trade volatility are lower when North-South agents have access to a complete contingent-claims market.

for $j, k = n, s$ and $j \neq k$. Note, I allow Northern manufactured goods to be the numeraire, so $p_{2nt} = 1$.

Each regional economy is also subject to the following sectoral resource constraints:

$$\begin{aligned} \text{Primary:} \quad & y_{1jt} = h_{1jt} + f_{1kt}, \\ \text{Manufacturing:} \quad & y_{2jt} = h_{2jt} + f_{2kt} \end{aligned} \tag{3.12}$$

for $j, k = n, s$ and $j \neq k$.

3.6 Driving processes

The model is driven by shocks to sectoral productivity. Following the real business cycle literature, I assume that the log of the sectoral productivity shock variables follows a multivariate autoregressive process described by the following:

$$\ln A_{t+1} = \rho \ln A_t + \xi_{t+1}, \tag{3.13}$$

where $A_t = [A_{1nt}\ A_{2nt}\ A_{1st}\ A_{2st}]'$, and ξ_t is an identically, independently distributed (*iid*) normal with mean zero and covariance matrix Ω.

3.7 Equilibrium and model solution

I follow Baxter and Crucini's (1995) approach to solving dynamic trade models in which assets are restricted to one period bonds. In each region, the representative household owns all productive inputs. Each period the household rents these productive inputs to the various firms in the same regional economy. Firms produce both goods and sell the output to households in both regions. In each region the representative household's dynamic optimization problem is to maximize the expected lifetime utility described by (3.1) subject to the constraints given by equations (3.2) to (3.11). The competitive equilibrium is described by the stochastic processes for capital, labor, consumption, investment and their associated prices that satisfy the regional representative households optimization problems and satisfy the resource constraints given by (3.12). I use numerical techniques to solve for the models dynamic equilibria. Specifically, the log-linear approximation technique advanced in the real business cycle literature by King, Plosser and Rebelo (1988,1990). A detailed description of the model solution algorithm is given in appendix B.

4 Calibration

If I had a large enough data set I could use cointegration or generalized method of moment techniques and the model's first order necessary conditions to estimate all the preference and production parameters in the model. Unfortunately, this requires more data than is currently at my disposal. Researchers working with multisector multicountry static computable general equilibrium models, such as Shoven and Whalley (1992) have adopted an approach know as *calibration.* More recently this approach has been extended to dynamic models of international trade.[6] There are two stages in calibrating a model. First, the model builder draws on published estimates of the models parameters. Second, not all model parameters are available in the published econometric literature, so in these cases the researcher uses the model's first order necessary conditions or identities to determine the size of the remaining parameters.

Comprehensive North-South expenditure and output data is only available at the annual frequency. The model adopts a quarterly time interval for three reasons. First, an important feature of the model is trade in intermediate goods. Empirical evidence suggests that it takes some time to put these factors in place, but that this interval is less than one year. Second, by adopting a quarterly time interval I bring the model closer to existing international real business cycle models, which allows me to compare features of the model with earlier studies. Third, I can draw on the parameter set used in the earlier studies. Note, to compare the simulated model data with actual North-South data, which are at the annual frequency, I aggregate the quarterly model data to produce annual model data.

4.1 Preferences

Following King, Plosser and Rebelo (1988) I have a fairly general preference specification for aggregate consumption and leisure. First, I set the curvature parameter σ to 2. Second, θ_c is consistent with 20 percent of the agent's total time being devoted to market activity

[6] See Backus et al. 1995 and Baxter 1995 for examples of calibrated international business cycle models.

in the steady state. Finally, the average quarterly real interest rate is about 1.5 percent, which implies a Northern and Southern discount factor β of 0.9852.

4.2 Production

In general, capital share estimates tend to be much higher in the South data. Estimates on labor's share of value-added based on more reliable Northern data imply the following production parameters $\theta_1 = 0.25$ and $\theta_2 = 0.65$. Similarly, estimates based on the first-order condition for primary sector capital, and Northern data on sectoral value-added suggest land's share is roughly 35 percent of primary value-added, which suggests the following primary production parameter: $\alpha_1 = 0.35$.[7]

The manufacturing production function described by (3.3) is motivated by the manufacturing cost function estimates in Ramey (1989). Ramey estimates production functions for durable manufacturing industries using quarterly US data. Her production function includes capital, labor and inventories of raw materials, goods-in-progress and finished goods. Combining her results with the theoretical results in Sato (1969) I find that the constant elasticity of substitution between intermediate inputs and the value-added component (σ_ε) is close to zero, which suggests manufacturing production is close to Leontief at the quarterly frequency. With an elasticity of 0.20 the production process is close to Leontief and well *in-line* with Ramey's quarterly estimates. The benchmark model's manufacturing costs shares are consistent with the values reported in the Northern and Southern input-output tables.

The quarterly capital depreciation rate is set at 3 percent, which is consistent with most quarterly real business cycle studies. Following Baxter and Crucini (1993) I set the capital adjustment cost function ϕ_{ki} so that: its steady value is equal to the steady state ratio of investment to capital ($\phi_{ki}(i/k) = i/k = \delta_k$); in steady state *Tobin's* q is unity ($1/\phi'_{ki}(i/k) = 1$); and the elasticity of the sectoral investment-capital ratios with respect to their sectoral Tobin's q ($((\phi'_{ki}/\phi''_{ki})/(i/k))$ are consistent with relative sectoral and aggregate investment volatility levels (I use US sectoral capital data to estimate relative investment volatilities). The sectoral labor adjustment cost functions are calibrated in a similar fashion.

[7] Capital's share is derived from: $\alpha_1 = s_{i1}\{1-\beta(1-\delta)\}/\beta\delta$, where s_{i1} is the ratio of primary investment to primary value-added.

The primary sector has the highest capital and labor adjustment costs, which is consistent with the view that primary capital and labor inputs tend to be industry specific.

4.3 Trade

Roughly 85 percent of Northern trade is with other Northern economies, while 85 percent of Southern trade is with Northern economies. Therefore, elasticity estimates based on Southern data will be indicative of North-South substitution. I base the model's elasticities between home and foreign primary and manufactured goods on Dornbusch and Werner's (1994) estimates of these parameters from quarterly Mexican data. In particular, I assume that the North-Southern primary goods elasticity of substitution $\sigma_{\mu 1}$ is 1 and manufactured goods elasticity of substitution $\sigma_{\mu 2}$ is 0.50. I set the Southern home bias weights ω_{1s} and ω_{2s} so that they are consistent with estimates of the share of imports in total Southern primary and manufactured expenditure. The Northern home bias weights ω_{1n} and ω_{2n} are set so that the South's share of world primary and manufacturing are consistent with estimated shares.

4.4 Driving processes

The model is driven by shocks to Northern and Southern sectoral productivity. With appropriate data on sectoral value-added, capital stocks, labor hours, intermediate inputs and estimates of $(\theta_{ij}, \alpha_{ij}, \omega_{ikj}\text{'}s)$ I can measure total factor productivity directly using the production functions described in section 3. There are three problems I face in taking this route. First, data on sectoral gross output and intermediate usage is not readily available across the group of countries under study. Second, sectoral capital stocks and labor hours are not readily available for developing non-fuel exporting countries. Third, when data are available they are at the annual frequency but not the quarterly frequency.

I overcome each of these problems in the following way. First, I solve the model using a log-linear technique. In the log-linear version of the model total factor productivity can be measured directly from value-added data A_{2jt},

$$\ln A_{2jt} = \ln y_{v2jt} - \theta_2 \ln N^s_{2jt} - (1 - \theta_2) \ln k_{2jt} \tag{4.14}$$

Second, annual sectoral capital stock and hours data are available for the United States. I make the strong assumption that estimates from US data will be indicative of the productivity structure in both the Northern and Southern regions. Using annual US data from 1948-85 the estimated within region multivariate driving process is given by the following:[8]

$$\rho_n^{US} = \begin{bmatrix} \begin{matrix} 0.87 \\ (0.09) \end{matrix} & 0 \\ 0 & \begin{matrix} 0.69 \\ (0.09) \end{matrix} \end{bmatrix} \text{ and } \Omega_n^{US} = \begin{bmatrix} 0.030^2 & \mathbf{0.130} \\ . & 0.015^2 \end{bmatrix}$$

where the values in parentheses are White robust t-statistics and the bold values in Ω_n^{US} indicate the correlation between innovations. I calibrate the Southern innovations so that the standard deviation of Southern primary and manufacturing value-added in the theoretical model are close to their data analogues.

My estimates of within region sectoral innovation correlations suggest that primary sector innovations are not correlated with the non-primary innovations. I assume that it is also the case that cross-region primary innovations are not correlated. Estimates of the correlation between US and a subset of Southern countries' manufactured good productivity innovations range from 0 to 0.70. I set the cross-region correlation of non-primary sector innovations to the mean of these estimates, 0.30.

Third, the estimated process describes the annual multivariate driving process, but the model has a quarterly frequency. I circumvent this problem by retaining the innovation correlation structure of the estimated annual process Ω^{US}, and assume the quarterly sectoral innovations are more persistent. In particular, I draw on estimates from quarterly data found in the real business cycle literature which suggest the autoregressive parameter of total factor productivity is 0.95. Using this approach the implied annual North-South productivity process from 100 simulations of length 80 quarters or 20 years is:

$$\rho^{sim} = \begin{bmatrix} 0.72 & . & \dots & 0 \\ . & 0.72 & & \vdots \\ \vdots & & 0.70 & . \\ 0 & \dots & . & 0.73 \end{bmatrix} \text{ and } \Omega^{sim} = \begin{bmatrix} 0.026^2 & \mathbf{0.006} & \mathbf{0.015} & \mathbf{0.001} \\ . & 0.013^2 & \mathbf{0.005} & \mathbf{0.300} \\ . & . & 0.014^2 & \mathbf{0.013} \\ . & . & . & 0.011^2 \end{bmatrix}$$

where bold values in indicate within and across region innovation correlations.

[8] The off diagonal terms of ρ were not significantly different from zero in our initial regressions. Therefore, to rule-out spurious effects from poorly specified spillover terms we set the off-diagonal terms to be zero.

The model's benchmark parameters are summarized in Table 5. I use the model's first order conditions to calculate all remaining parameters and steady state shares. Actual aggregate expenditure and output shares are reported in Table 6 along with their model analogues.

5 Results

This section presents the major findings from simulations of the theoretical North-South economy. First, I establish the model's coherence with actual data through standard real business cycle moment comparisons. Second, I study the economic mechanisms that underlie these statistics by describing the model's impulse response function. Finally, I isolate the elements of the model that are responsible for generating the high level of relative price volatility and North-South comovement through sensitivity analysis.

5.1 Model evaluation

I establish the model's coherence with observed time-series through its ability to replicate second moments found in actual North-South data. In Tables 1–4 I summarize the model's second moment statistics by their sample averages from a series of 100 simulations of length of 80 quarters (or 20 years). For comparability with actual data all model data are Hodrick-Prescott filtered with a smoothing parameter of 10.

These tables show that the model is successful in capturing three central features of the North-South data. First, Table 1 reveals that the model generates a North-South business cycle. In particular, the model captures the strong positive comovement between Northern and Southern manufacturing output, aggregate output, consumption, and investment. While matching patterns of international comovement was not a primary goal of this investigation, this finding is an important outcome of this investigation. Prior equilibrium models of interacting economies have not been able to simultaneously generate international comovement of all the major macroeconomic aggregate in the presence of international trade in capital goods. The present paper, with its stress on strong international intersectoral linkages and an important intermediate sector, has been able to overcome the limitations of prior analyses. Second, Table 2 highlights the model's ability to replicate the strong positive correlation between real commodity prices and Northern manufacturing output, and the weak negative correlation of primary production and real commodity prices. Third and finally, Table 3 shows that the model is capable of producing the high volatility of real commodity prices and the North-South terms of trade observed in the data. This also represents an advance over existing equilibrium trade models which have been unable to generate realistic volatility in relative prices.

Table 4 reveals that the model is also successful at generating many within country business cycle statistics. For example, the model reproduces the weak correlation between primary and manufacturing sectors, and the strong positive correlation between manufacturing activity, consumption, and investment.

5.2 Variance decomposition

The main objective of this paper is to evaluate the extent to which business cycle fluctuations in the Southern economies are caused by shocks originating in the North. This question can be answered using the quantitative North-South model developed in this paper. My approach is to simulate the model under all possible recursive ordering of the innovations in (3.13) and isolate the share of the variance in Southern and Northern variables explained by the innovation of interest. Table 7 reports the upper and lower bounds from these variance decomposition exercises. The first two columns isolate the influence of productivity shocks to the primary sector. They show that primary innovations account for 97 percent of primary output volatility and a only a small share of non-primary activity (for instance, primary shocks explain only 8 percent of Northern manufacturing fluctuations). The third and fourth columns isolate the influence of productivity shocks to manufacturing output. These columns show that, in contrast to primary shocks, manufacturing shocks have a large impact on the non-primary activity. In particular, manufacturing shocks explain 86 percent of the variation in Northern GDP and 75 percent of the variation in Southern GDP.

The remaining columns of Table 7 isolate the variance explained by productivity shocks which originate in the North. Northern primary shocks have a negligible impact on Southern activity. For example, Northern primary innovations explain only 1 percent of the variation in Southern GDP. In contrast, innovations to Northern manufacturing have a large impact on all aspects of Southern activity. In fact, up to 20 percent of the variation in Southern GDP is explained by shocks originating in the North. The North has its strongest influence on Southern activity through expenditure. Innovations to Northern manufacturing explain up to 69 percent of the variation in Southern consumption and 61 percent of the movements in Southern investment. The lower bounds reported in column seven establish the strength of the model's endogenous North-South business cycle transmission mechanism. The decomposition experiments suggest that at least 5 percent of the variation in Southern GDP results from Northern innovations (note, the results are stronger for consumption and investment expenditure).

In their econometric study of commodity prices Borensztein and Reinhart 1994 found that during the period 1971-1988 supply factors (i.e. primary productivity innovations) accounted for roughly 50 percent of the volatility of commodity prices. Similarly, demand factors (manufacturing output fluctuations) explained 50 percent of the variation of commodity prices. Columns 3 and 4 of Table 7 establish further coherence between the model and the data by reporting that the model generated relative price data is consistent with Borensztein and Reinhart finding.

5.3 Transmission mechanisms

I can develop some intuition for these model properties by studying two classic North-South experiments. The first looks at the model's response to an unanticipated shock to Northern manufacturing productivity. The second studies the model's response to an unanticipated shock to Southern primary productivity.

Shock to Northern manufacturing productivity In Figure 2 I plot the model's response to an unanticipated 1 percent increase in Northern manufacturing productivity. The increase in Northern manufacturing productivity increases the demand for intermediate inputs–primary goods. Capital and labor adjustment costs combined with an important fixed factor (land) limit the ability of the primary sector activity to adjust in the short-run, so primary output prices rise in response to increased demand. The lower panel shows that real commodity prices rise by almost 4 percent. The South is a net exporter of primary goods, so higher real commodity prices lead to an improvement in the South's terms of trade and real income. Northern and Southern households respond to their higher level of income by increasing their consumption.

Northern producers respond to increased consumption and intermediate good demand by expanding production of primary goods. The expansion of Northern production is also reflected by greater capital investment. Northern agents substitute consumption and leisure in response to higher real wages. Northern and Southern manufactured goods are complements, so the increased demand for consumption in the South is satisfied by direct imports of Northern manufactures and by expanding Southern non-primary activity.

Shock to Southern primary productivity In Figure 3 I plot the model's response to an unanticipated 1 percent increase in Southern primary activity. The increase in Southern primary good supply causes the real commodity price to fall by roughly 1.5 percent. Northern manufacturing expands in response to lower primary intermediate goods price. Northern primary activity contracts in response to lower primary goods prices. Higher manufacturing production raises the demand for capital and labor inputs in the North. This is reflected in greater labor hours, capital investment and a higher real wage. Northern agents substitute consumption and leisure in response to higher real wages.

The expansion Southern activity is more than offset by the fall in real commodity prices, so Southern primary sector revenue and real income falls following the primary productivity shock. In other words, growth in the primary sector is *immiserising*. Southern manufacturing responds to the fall in primary input prices by expanding production. Southern agents respond to the loss of real income by increasing labor effort and lowering there level of consumption. The fall in real commodity prices is offset by the expansion of exports to the North, so Southern net exports deteriorate slightly.

5.4 Sensitivity analysis

I now look at the mechanics of the model and isolate those parts that yield the high terms of trade and relative price volatility, and strong positive comovement between Northern and Southern output.

Relative price volatility The South is essentially specialized in the import of manufactured goods in the North-South model. In Kouparitsas (1997a) I show that the log of the North-South terms of trade can be decomposed into two distinct parts when the region or country in question is specialized in the import of a good:

$$\ln(p_{xst}/p_{mst}) = \alpha_{xs1}\ln(p_{1st}/p_{2nt}) + \alpha_{xs2}\ln(p_{2st}/p_{2nt}) \tag{5.15}$$

where p_{xst} is the South's aggregate export price, p_{mst} is the South's aggregate import price, and α_{xsi} is the share of Southern exports devoted to good i. The first part is the Southern real commodity price, $\ln(p_{1st}/p_{2nt})$, while the second part contains the relative price of the same types goods in the North and South $\ln(p_{2st}/p_{2nt})$. In the earlier paper I show that movements in real commodity prices account for virtually all of the fluctuations in the South's terms of trade. Note that the terms of trade are less volatile than the real commodity price because α_{xs1} is less than 1. Therefore the key to generating terms of trade volatility is generating highly volatile real commodity prices.

Real commodity price volatility emerges in the North-South model from two features of the model. First, the model assumes that manufacturing production is close to Leontief in value-added and primary inputs. In other words, the model generates high terms of trade volatility because of the low elasticity of substitution between value-added and primary inputs in manufacturing production. To see how this is comes about assume that there is a single country that has *endowments* of value-added (y_{v2t}) and primary goods (y_{1t}). Just as in the model agents do not consume these goods directly rather they use them to produce manufactured goods (y_{2t}):

$$y_{2t} = \left\{\omega_y y_{v2t}^{1-1/\sigma_\varepsilon} + (1-\omega_y) y_{1t}^{1-1/\sigma_\varepsilon}\right\}^{\frac{1}{1-1/\sigma_\varepsilon}} \tag{5.16}$$

In this setting the first order necessary condition for primary intermediate goods yields the following relationship between real commodity prices and output volatility:

$$var(\ln p_{1t}/p_{2t}) = 1/\sigma_\varepsilon^2 s_{va}^2 \left\{var(\ln y_{v2t}) + var(\ln y_{1t}) - 2cov(\ln y_{1t}, \ln y_{v2t})\right\} \tag{5.17}$$

where s_{va} is the value-added share of gross output, $var(.)$ denotes variance, and $cov(.)$ denotes covariance. It follows immediately from (5.17) that lower elasticities of substitution (smaller σ_ε) produce higher real commodity price volatility. Figure 4 plots the model's point estimate of the standard deviation of real commodity prices against alternative values of σ_ε. This figure shows that the level of real commodity price volatility is indeed inversely related to the level of the manufacturing elasticity of substitution. The benchmark elasticity of 0.20 generates real commodity price volatility that matches the observed volatility in the data.

The second feature that helps in generating real commodity price volatility is the model's ability to generate the observed correlation between primary and manufactured output. Using (5.17) it follows that holding everything else constant $var(\ln p_{1t}/p_{2t})$ rises as $cov(\ln y_{1t}, \ln y_{v2t})$ approaches zero. The low correlation between primary and manufactured output emerges from important role for land, and labor and capital adjustment. These elements of the model keep primary goods supply fixed in the short-run, which causes demand fluctuations coming from movements in manufacturing output to flow to price fluctuations. Figure 7 supports this claim by showing that higher primary sector labor adjustment costs raises the volatility of the terms of trade and real commodity price.

The other relative price term in the terms of trade is relative price of Northern and Southern manufactured goods. Using the first order necessary conditions for home and imported manufactured goods it follows that:

$$var(\ln p_{2nt}/p_{2st}) = 1/\sigma_{\mu 2}^2 var(\ln f_{2st}/h_{2st}) \tag{5.18}$$

which implies the volatility of the relative price of Northern and Southern manufactured goods is sensitive to the elasticity of substitution between home produced and imported goods ($\sigma_{\mu 2}^2$). I plot the model's point estimate of the standard deviation of the terms of trade against alternative values of $\sigma_{\mu 2}$ in Figure 5. This figure suggests that the relative price of manufactured goods, and to a far lesser extent the terms of trade, is sensitive to $\sigma_{\mu 2}$.

Relative price and output comovement The signs and the size of the correlations between real commodity prices and manufacturing and primary output also emerge from the production setup. Utilizing the first order condition for primary intermediate goods and imposing a zero correlation between primary and manufactured output I find that:

$$cor(\ln p_{1t}/p_{2t}, \ln y_{va2t}) \simeq 1/\sigma_{\varepsilon} s_{va} std(\ln y_{v2t})/std(\ln p_{1t}/p_{2t}) > 0 \quad (5.19)$$

$$cor(\ln p_{1t}/p_{2t}, \ln y_{1t}) \simeq -1/\sigma_{\varepsilon} s_{va} std(\ln y_{1t})/std(\ln p_{1t}/p_{2t}) < 0 \quad (5.20)$$

where $cor(.)$ refers to correlation and $std(.)$ to standard deviation. Note, world manufacturing value-added is more volatile than primary output in the model (and the data), so it follows that the first correlation is always larger than the second in absolute terms.

International comovement A large part of the research on international business cycles is interested in whether or not the observed international comovement is due to highly correlated productivity innovations or an endogenous transmission mechanism. In Figure 6 I plot the level of the North-South manufacturing sector innovation correlation against various North-South quantity correlations. In contrast to North-North studies (see, for example, Backus et al. 1995, Figure 11.3) I find that the cross region correlation of GDP lies above the productivity shock correlation . This result reveals the model's strong endogenous transmission mechanism. To get some insight into the source of this transmission mechanism I look at the model's sensitivity the $\sigma_{\mu 2}$, but now focus on its relationship with cross-region correlations. Figure 5 suggests that $\sigma_{\mu 2}$ is an important factor in determining the size of North-South output comovement. In fact this figure suggests that the North-South output correlation is inversely related to the substitutability of Northern and Southern goods. For low values of $\sigma_{\mu 2}$ Northern and Southern goods are complements–like ice cream cones and ice cream, so the greater consumption of the Northern good generates greater consumption of the Southern good. In contrast, for higher values of $\sigma_{\mu 2}$ Northern and Southern goods are substitutes–like chocolate and strawberry ice cream, so greater consumption of the Northern good generates less consumption of the Southern good.

6 Conclusion

The traditional North-South literature has long argued that fluctuations in Southern activity are largely caused by shocks originating in the North. The basis of this argument is that the South is specialized in the production of primary goods and therefore relies on the North for its supply of manufactured goods and demand for its primary output. This paper builds a quantitative North-South trade model to examine the strength of this argument. Through simulations I am able to evaluate the extent to which fluctuations in the Southern economy are caused shocks originating in the North and identify the important channels of business cycle transmission between the North and South. My results lend support to the traditional North-South view of business cycle transmission. However, the results are weaker than those impled by theoretical models of North-South trade. Specifically, I find that shocks originating in the North explain up to 20 percent of the variation in Southern output. The model suggests that Northern productivity shocks have a greater impact on Southern expenditure, with Northern shocks explaining 70 percent of the movements in Southern consumption and 60 percent of the fluctuations in Southern investment. Using the model's impulse response function I trace through two classic North-South experiments. Again, my quantitative model fits the traditional view of North-South business cycle transmission. First, since the North uses Southern products as inputs to the North's manufacturing process, fluctuations in the Northern manufacturing produce sympathetic fluctuations in the derived demand for Southern inputs, which directly leads to large movements in Southern export prices and Southern income. Second, since the South uses Northern capital as an input in their own production process, fluctuations in the output of Northern manufactures cause fluctuations Southern import price and hence lead to fluctuations in Southern imports and Southern production more generally. Third and finally, shocks to Southern primary activity have a small impact on Northern manufacturing activity and growth in Southern primary activity is immiserising.

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A Data sources and definitions

This appendix describes the sources and definitions of the data underlying: Figure 1; Tables 1–6; and the US sectoral productivity estimates of section 4.

A.1 Sources

The main data source is World Bank (1991). This data set provides timeseries on price levels, values and volumes of production, expenditure and trade for 178 countries covering the years from 1969 to 1988. I limit the data set to the *market-based* economies that have the best data coverage. These 90 countries are listed in appendix C. The analysis focuses on trade between Northern and Southern non-fuel exporters. Non-fuel goods include non-fuel primary commodities and manufactured goods. The division of countries into fuel and non-fuel groups is based on World Bank (1992), World Tables, Table 2. The distinction between a Northern and Southern economy is based on income levels. The North includes high income countries, while the South comprises low and middle income countries. The countries are classified by income according to World Bank (1992), World Tables, Table 1.

Detailed trade and industry data used in calibrating the model comes from the following United Nations publications: National Accounts: Main Aggregates and Detailed Tables

(1990a); National Accounts: Study of Input-Output Tables (1987); the Handbook of International Trade and Development Statistics (1992) (UNCTAD); Yearbook of International Trade Statistics (1990b); and US Department of Commerce (1984).

A.2 Aggregation

A country's weight in a regional and world aggregate is based on the US$ value of their output, consumption, investment, exports and imports. The World Bank uses the Atlas method to construct comparable US$ series across countries. Specifically, let x_{jt} represent country j's real output, p_{jt} the US$ price of that output then country j's share of regional output at time t (α_{jt}) is given by the following:

$$\alpha_{jt} = \frac{p_{jt} x_{jt}}{\sum_j p_{jt} x_{jt}} \tag{A.1}$$

World Tables volume data is constructed by a Laspeyres index. Therefore, base year weights are sufficient for aggregation of volume data. I set the country weights to their sample average over 1969-1988. The regional and world quantity aggregate is given by:

$$x_t = \sum_j p_{jo} x_{jt} \tag{A.2}$$

where p_{jo} denotes base year prices and x_t is the regional aggregate at time t. Note that using the country weights explicitly and a log-linear approximation it follows that the log of the regional and world aggregates are given the following:

$$\ln x_t = \sum_j \alpha_{jo} \ln x_{jt} \tag{A.3}$$

where α_{jo} denotes the base year weight and $\ln x_t$ is the natural logarithm of regional aggregate at time t. The Hodrick and Prescott (1980) filtered log data in Tables 1–4 are constructed using the latter method (A.3).

By virtue of the fact that quantities are constructed by Laspeyres index the World Tables price series are constructed by Paasche index. The regional and world prices indices are also based on Paasche indices:

$$p_t = \frac{\sum_j p_{jt} x_{jt}}{\sum_j p_{jo} x_{jt}} \tag{A.4}$$

where p_t is the regional price index.

This paper is concerned with trade between the North and South. Roughly 85 percent of Southern trade involves trade with Northern economies, which suggests Southern trade data are indicative of North-South trade volumes and prices. Therefore, I describe the North-South terms of trade by the ratio of the aggregate Southern non-fuel exports price to aggregate Southern non-fuel import price. World non-fuel primary prices and manufactured goods prices are constructed from World Tables non-fuel primary and manufactured exports values and price indices. Individual country prices are weighted by their share of world exports.

Northern net non-fuel exports to gross domestic product is defined as the ratio of value of Northern non-fuel exports in US$ minus the value of Northern non-fuel imports in US$ divided by the US$ value of Northern gross domestic product. Southern net non-fuel exports to gross domestic product is constructed in a similar fashion.

A.3 Sectoral, expenditure and trade classifications

World Bank World Tables sectoral classifications are based on International Standard Industry Classifications (ISIC). The sectoral World Tables data contain timeseries on agriculture, industrial, manufacturing and services value-added. Industrial production includes manufacturing, mining and construction. I measure total gross domestic product as total gross domestic product at factor cost. Primary sector output is measured by agriculture value-added. Manufacturing output is measured by the sum of manufacturing and service value-added. Sectoral shares are based on World Tables sectoral data and Table 6.3 of UNCTAD. For these calculations the primary sector includes (ISIC) agriculture and mining, while manufacturing combines (ISIC) manufacturing and construction. North-South input-output shares are derived from the 1977 input-output tables of the United States and Chile. The input-output table for Chile is from United Nations (1987). The US input-output table is from US Department of Commerce (1984).

World Tables expenditure data includes private final consumption, public expenditure, fixed investment, changes in inventories, exports and imports. Consumption is measured as private final consumption. Investment is defined as private fixed investment plus change in inventories. Expenditure shares are based on World Tables expenditure data and Table 6.3 of UNCTAD. World Bank World Tables trade classifications are based on Standard International Trade Classifications (SITC). Primary non-fuels = 0+1+2+4+68, and manufactured goods = 5+6+7+8-68. All other trade data is based on ISIC classifications.

A.4 US sectoral productivity data

United States sectoral data used in the construction of US sectoral productivity shocks is from Shapiro (1987a,b). These data include labor hours, capital stocks, total labor compensation (wages), and value-added for thirteen ISIC one-digit industries for the period 1948–1985. Primary, manufacturing and service sector labor hours, capital stocks, labor income and value-added are consistent with the World Bank World Table and model definitions of the previous subsection (see Shapiro (1987a,b) for further details).

B Model solution and linearization procedures

This appendix provides details of the model solution procedures used in this paper.

B.1 Model solution

The equilibrium of the economy described by (3.1)-(3.13) consists of a set of functions describing the behavior of endogenous variables such as consumption, investment, production, etc., as functions of the exogenous shocks to the model and the stocks of capital in place in each country. I follow Baxter and Crucini's (1995) approach to solving two-country models with restricted asset trade. First, I assume that the countries are small open economies that optimize in the face of an exogenous process for the world interest rate and commodity prices. Second, I describe the general equilibrium solution by bringing together the solutions of the two small open economy problems and imposing market clearing conditions for the asset and goods markets. In the general equilibrium interest rates and commodity prices are determined endogenously.

Partial small open economy problem A straight forward way to compute the solution for the small open economy is to solve the following Lagrangian problem:

$$
\begin{aligned}
\mathcal{L}_j = E_0 \textstyle\sum_{t=0}^{\infty} \quad & \beta^t \left\{ \tfrac{1}{1-\sigma} \left(c_{jt}^{\theta_c} L_{jt}^{1-\theta_c} \right)^{1-\sigma} \right. \\
& + \omega_{jt} \left[1 - L_t - \textstyle\sum_{i=1}^{2} N_{ijt} \right] \\
& + \textstyle\sum_{i=1}^{2} \zeta_{Nijt} \left[LN_{ijt+1}^{s} - N_{ijt}^{s} \right] \\
& + \textstyle\sum_{i=1}^{2} \lambda_{Nijt} \left[\phi_{Ni} \left(N_{ijt}/LN_{ijt}^{s} \right) LN_{ijt}^{s} - LN_{ijt+1}^{s} \right] \\
& + \textstyle\sum_{i=1}^{2} \zeta_{kijt} \left[k_{ijt} - k_{ijt}^{s} \right] \\
& + \textstyle\sum_{i=1}^{2} \lambda_{kijt} \left[(1-\delta_k) k_{ijt} + \phi_{ki} \left(i_{ijt}/k_{ijt} \right) k_{ijt} - k_{ijt+1} \right] \\
& + \zeta_{mjt} \left[m_{jt} - m_{jt}^{s} \right] \\
& + \lambda_{mjt} \left[i_{mjt} - m_{jt+1} \right] \\
& + \psi_{e1jt} \left[\left(\omega_{1j} h_{1jt}^{1-1/\sigma_{\mu 1}} + (1-\omega_{1j}) f_{1jt}^{1-1/\sigma_{\mu 1}} \right)^{\frac{1}{1-1/\sigma_{\mu 1}}} - i_{mjt} \right] \\
& + \psi_{e2jt} \left[\left(\omega_{2j} h_{2jt}^{1-1/\sigma_{\mu 2}} + (1-\omega_{2j}) f_{2jt}^{1-1/\sigma_{\mu 2}} \right)^{\frac{1}{1-1/\sigma_{\mu 2}}} - c_{jt} - i_{1jt} - i_{2jt} \right] \\
& + \zeta_{v2t} \left[A_{2jt} N_{2jt}^{s\theta_2} k_{2jt}^{s\alpha_2} - y_{v2jt} \right] \\
& \left. + \lambda_{bjt} \left[\begin{array}{l} p_{1jt} A_{1jt} N_{1jt}^{s\theta_1} k_{1jt}^{s\alpha_1} + p_{2jt} \left\{ \omega_y y_{v2jt}^{1-1/\sigma_\varepsilon} + (1-\omega_y) m_{jt}^{s 1-1/\sigma_\varepsilon} \right\}^{\frac{1}{1-1/\sigma_\varepsilon}} \\ + b_{jt} - p_{1jt} h_{1jt} - p_{2jt} h_{2jt} - p_{1kt} f_{1jt} - p_{2kt} f_{2jt} - p_{bt} b_{jt+1} \end{array} \right] \right\}
\end{aligned} \tag{B.1}
$$

for $j = n, s$ and $k \neq j$. In programming this model, I found it convenient to introduce additional variables. In particular, I include capital services (k_{ijt}^{s}), intermediate good services (m_{2jt}^{s}), and lagged labor services (LN_{ijt}^{s}). The multipliers on the constraints in (B.1) have natural interpretations as utility denominated shadow prices. Specifically, ω_{jt} wage rate, ζ_{Nijt} value of marginal product of labor, λ_{Nijt} sector i value marginal product of existing labor, ζ_{kijt} sector i value marginal product of capital, λ_{kijt} sector i price of existing capital

ζ_{v2jt} value marginal product of intermediate inputs, ζ_{v2t} value marginal product of value-added index, ψ_{e1jt} price of primary inputs, ψ_{e2jt} price of non-primary good expenditure, λ_{bjt} price of Northern manufactured goods.

The first order necessary conditions for this Lagrangian problem are:

$$(c_{jt}) : \theta_c c_{jt}^{\theta_c(1-\sigma)-1} L_{jt}^{(1-\theta_c)(1-\sigma)} - \psi_{e2jt} = 0 \tag{B.2}$$

$$(L_{jt}) : (1-\theta_c) c_{jt}^{\theta_c(1-\sigma)} L_{jt}^{(1-\theta_c)(1-\sigma)-1} - \omega_{jt} = 0 \tag{B.3}$$

$$(N_{ijt}) : \lambda_{Nij} \phi'_{Ni}(N_{ijt}/LN_{ijt}^s) - \omega_{jt} = 0 \tag{B.4}$$

$$(N_{1jt}^s) : \theta_1 \lambda_{bjt} p_{1jt} A_{1jt} N_{1jt}^{s\theta_1-1} k_{1jt}^{s\alpha} - \zeta_{N1jt} = 0 \tag{B.5}$$

$$(N_{2jt}^s) : \theta_2 \zeta_{v2jt} A_{2jt} N_{2jt}^{s\theta_2-1} k_{2jt}^{s1-\theta_2} - \zeta_{N2jt} = 0 \tag{B.6}$$

$$(k_{1jt}^s) : \alpha_1 \lambda_{bjt} p_{1jt} A_{1jt} N_{1jt}^{s\theta_1} k_{1jt}^{s\alpha_1-1} - \zeta_{k1jt} = 0 \tag{B.7}$$

$$(k_{2jt}^s) : (1-\theta_2) \zeta_{v2jt} A_{2jt} N_{2jt}^{s\theta_2} k_{2jt}^{s-\theta_2} - \zeta_{k2jt} = 0 \tag{B.8}$$

$$(y_{v2jt}) : \lambda_{bjt} p_{2jt} \left(\omega_y y_{v2jt}^{1-1/\sigma_\varepsilon} + (1-\omega_y) m_{jt}^{s1-1/\sigma_\varepsilon} \right)^{\frac{1}{1-1/\sigma_\varepsilon}-1} \omega_y y_{v2jt}^{-1/\sigma_\varepsilon} - \zeta_{v2jt} = 0 \tag{B.9}$$

$$(m_{jt}^s) : \lambda_{bjt} p_{2jt} \left(\omega_y y_{v2jt}^{1-1/\sigma_\varepsilon} + (1-\omega_y) m_{jt}^{s1-1/\sigma_\varepsilon} \right)^{\frac{1}{1-1/\sigma_\varepsilon}-1} (1-\omega_y) m_{jt}^{s-1/\sigma_\varepsilon} - \zeta_{mjt} = 0 \tag{B.10}$$

$$(i_{ijt}) : \lambda_{kij} \phi'_{ki}(i_{ijt}/k_{ijt}^s) - \psi_{e2jt} = 0 \tag{B.11}$$

$$(i_{mjt}) : \lambda_{mj} - \psi_{e1jt} = 0 \tag{B.12}$$

$$(h_{1jt}) : \psi_{e1jt} \left(\omega_{1j} h_{1jt}^{1-1/\sigma_{\mu 1}} + (1-\omega_{1j}) f_{1jt}^{1-1/\sigma_{\mu 1}}\right)^{\frac{1}{1-1/\sigma_{\mu 1}}-1} \omega_{1j} h_{1jt}^{-1/\sigma_{\mu 1}} - \lambda_{bjt} p_{1jt} = 0 \quad \text{(B.13)}$$

$$(f_{1jt}) : \psi_{e1jt} \left(\omega_{1j} h_{1jt}^{1-1/\sigma_{\mu 1}} + (1-\omega_{1j}) f_{1jt}^{1-1/\sigma_{\mu 1}}\right)^{\frac{1}{1-1/\sigma_{\mu 1}}-1} (1-\omega_{1j}) f_{1jt}^{-1/\sigma_{\mu 1}} - \lambda_{bjt} p_{1kt} = 0 \quad \text{(B.14)}$$

$$(h_{2jt}) : \psi_{e2jt} \left(\omega_{2j} h_{2jt}^{1-1/\sigma_{\mu 2}} + (1-\omega_{2j}) f_{2jt}^{1-1/\sigma_{\mu 2}}\right)^{\frac{1}{1-1/\sigma_{\mu 2}}-1} \omega_{2j} h_{2jt}^{-1/\sigma_{\mu 2}} - \lambda_{bjt} p_{2jt} = 0 \quad \text{(B.15)}$$

$$(f_{2jt}) : \psi_{e2jt} \left(\omega_{2j} h_{2jt}^{1-1/\sigma_{\mu 2}} + (1-\omega_{2j}) f_{2jt}^{1-1/\sigma_{\mu 2}}\right)^{\frac{1}{1-1/\sigma_{\mu 2}}-1} (1-\omega_{2j}) f_{2jt}^{-1/\sigma_{\mu 2}} - \lambda_{bjt} p_{2kt} = 0 \quad \text{(B.16)}$$

$$(\omega_{jt}) : 1 - L_t - \sum_{i=1}^{2} N_{ijt} = 0 \quad \text{(B.17)}$$

$$(\zeta_{Nijt}) : L N_{ijt+1}^{s} - N_{ijt}^{s} = 0 \quad \text{(B.18)}$$

$$(\zeta_{kijt}) : k_{ijt} - k_{ijt}^{s} = 0 \quad \text{(B.19)}$$

$$(\zeta_{mjt}) : m_{jt} - m_{jt}^{s} = 0 \quad \text{(B.20)}$$

$$(\psi_{e1jt}) : \left(\omega_{1j} h_{1jt}^{1-1/\sigma_{\mu 1}} + (1-\omega_{1j})\, f_{1jt}^{1-1/\sigma_{\mu 1}}\right)^{\frac{1}{1-1/\sigma_{\mu 1}}} - i_{mjt} = 0 \quad \text{(B.21)}$$

$$(\psi_{e2jt}) : \left(\omega_{2j} h_{2jt}^{1-1/\sigma_{\mu 2}} + (1-\omega_{2j})\, f_{2jt}^{1-1/\sigma_{\mu 2}}\right)^{\frac{1}{1-1/\sigma_{\mu 2}}} - c_{2jt} - i_{1jt} - i_{2jt} = 0 \quad \text{(B.22)}$$

$$(\zeta_{v2t}) : A_{2jt} N_{2jt}^{s\theta_2} k_{2jt}^{s\alpha_2} - y_{v2jt} = 0 \quad \text{(B.23)}$$

$$(LN^s_{ijt+1}) : E_t\gamma_{Nij}(N_{ijt+1}/LN^s_{ijt+1})\beta\lambda_{Nijt+1} + \zeta_{Nijt} - \lambda_{Nijt} = 0 \tag{B.24}$$

$$(k_{ijt+1}) : E_t\gamma_{ij}(i_{ijt+1}/k_{ijt+1})\beta\lambda_{kijt+1} + \beta E_t\zeta_{kijt+1} - \lambda_{kijt} = 0 \tag{B.25}$$

$$(m_{jt+1}) : \beta E_t\zeta_{mjt+1} - \lambda_{mjt} = 0 \tag{B.26}$$

$$(b_{jt+1}) : \beta E_t\lambda_{bt+1-}\lambda_{bt}p_{bt} = 0 \tag{B.27}$$

$$(\lambda_{Nijt}) : \phi_{Ni}\left(N_{ijt}/LN^s_{ijt}\right) LN^s_{ijt} - LN^s_{ijt+1} = 0 \tag{B.28}$$

$$(\lambda_{kijt}) : (1-\delta_k)k_{ijt} + \phi_{ki}\left(i_{ijt}/k_{ijt}\right) k_{ijt} - k_{ijt+1} = 0 \tag{B.29}$$

$$(\lambda_{mjt}) : i_{mjt} - m_{jt+1} = 0 \tag{B.30}$$

$$(\lambda_{bjt}) : \begin{array}{l} p_{1jt}A_{1jt}N^{s\theta_1}_{1jt}k^{s\alpha_1}_{1jt} + p_{2jt}\left\{\omega_y y^{1-1/\sigma_\varepsilon}_{v2jt} + (1-\omega_y)m^{s1-1/\sigma_\varepsilon}_{jt}\right\}^{\frac{1}{1-1/\sigma_\varepsilon}} + b_{jt} \\ -p_{1jt}h_{1jt} - p_{2jt}h_{2jt} - p_{1kt}f_{1jt} - p_{2kt}f_{2jt} - p_{bt}b_{jt+1} = 0 \end{array} \tag{B.31}$$

$$E_0 \lim_{t\to\infty} \lambda_{kijt}k_{ijt+1} = 0 \tag{B.32}$$

$$E_0 \lim_{t\to\infty} \lambda_{bjt}b_{jt+1} = 0 \tag{B.33}$$

for $i = 1, 2$, $j = n, s$ and $k \neq j$, where $\gamma_{Nij}(z) \equiv [\phi_{Ni}(z) - z\phi'_{Ni}(z)]$ and $\gamma_{kij}(z) \equiv [\phi_{ki}(z) - z\phi'_{ki}(z) + (1-\delta_k)]$.

World general equilibrium In world general equilibrium, each of the regions faces the problem described above, but in general equilibrium the bond price (p_{bt}) and commodity prices (p_{ijt}'s) are endogenously determined. The the following constraints are imposed on the world general equilibrium. First, bond market clearing requires that:

$$(p_{bt}) : b_{nt} + b_{st} = 0 \tag{B.34}$$

since the bonds are in zero net supply in the world economy, while the efficiency conditions for b_{jt+1} yield the following condition:

$$(b_{nt+1}, b_{st+1}) : \beta E_t(\lambda_{bnt+1}/\lambda_{bnt}) = \beta E_t(\lambda_{bst+1}/\lambda_{bst}) = p_{bt} \tag{B.35}$$

Second, goods market clearing requires that:

$$(p_{1jt}) : y_{1jt} - h_{1jt} - f_{1kt} = 0 \tag{B.36}$$

$$(p_{2jt}) : y_{2jt} - h_{2jt} - f_{2kt} = 0 \tag{B.37}$$

for $j, k = n, s$ and $j \neq k$. I follow Baxter and Crucini's (1995) approach to computing the world general equilibrium. First, I drop one of the asset accumulation equations (B.31) since in a two region world only one of the asset stocks is independent. I drop the Northern region's asset accumulation equation. Second, I treat the Northern region's shadow price of Northern manufactured goods (λ_{bnt}) as an additional control variable. Third, I impose the equilibrium condition (B.35) by replacing p_{bt} with the expression $\beta E_t(\lambda_{bnt+1}/\lambda_{bnt})$ in the Southern accumulation equation for b_{st+1}:

$$(\lambda_{bst}) : \begin{array}{c} p_{1st} A_{1st} N_{1st}^{s\theta_1} k_{1st}^{s\alpha_1} + p_{2st} \left\{ \omega_y y_{v2st}^{1-1/\sigma_\varepsilon} + (1-\omega_y) m_{st}^{s1-1/\sigma_\varepsilon} \right\}^{\frac{1}{1-1/\sigma_\varepsilon}} + b_{st} \\ -p_{1st} h_{1st} - p_{2st} h_{2st} - p_{1nt} f_{1st} - p_{2nt} f_{2st} - \beta E_t(\lambda_{bnt+1}/\lambda_{bnt}) b_{st+1} = 0 \end{array} \tag{B.38}$$

The world general equilibrium is described by the following system of equations: Northern {(B.2)-(B.26), (B.28)-(B.30), (B.36)-(B.37)}(note, $p_{2nt} = 1$, so (B.37) is the system's equation for ψ_{2nt}); and Southern {(B.2)-(B.26), (B.28)-(B.30), (B.35)-(B.38)}.

B.2 Log-linearization and state space solution

The procedure described above yields a dynamic system of equations that can be linearized and solved using the method advanced in the real business cycle literature by King, Plosser and Rebelo (1988, 1990). I briefly summarize their methodology. First, linearization of the non-linear system is achieved by a first-order Taylor series approximation at the model's steady state. This yields a linear system where the arguments are percentage deviations from steady state, $\hat{x}_t = (x_t - \bar{x})/\bar{x}$ where $\bar{x}$ is the steady state value of x. For small percentage deviations $\hat{x}_t \simeq \ln(x_t) - \ln(\bar{x})$, which conveniently allows the model data to be compared to logged actual data. Second, the resulting linear system is solved using standard linear systems theory (see King, et al. for details).

C. Country lists

C.1 Northern and Southern regions

C.1.1 Southern countries

Low-income countries

Benin
Burkina Faso
Central African Republic
Egypt
Ethiopia
Gambia, The
Ghana
Guyana
Haiti
Honduras
India
Kenya
Lesotho
Madagascar
Malawi
Mali
Mauritania
Nepal
Niger
Pakistan
Rwanda
Sierra Leone
Somalia
Sudan
Tanzania
Togo
Uganda
Zaire
Zambia

Middle-income countries

Argentina
Barbados
Bolivia
Botswana
Brazil
Cameroon
Chile
Colombia
Costa Rica
Dominican Republic
Ecuador
El Salvador
Fiji
Greece
Guatemala
Jamaica
Jordan
Korea, Republic of
Malaysia
Malta
Mauritius
Mexico
Morocco
Nicaragua
Panama
Papua New Guinea
Paraguay
Peru
Philippines
Portugal
Senegal
South Africa
Syrian Arab Republic
Thailand
Tunisia
Turkey
Uruguay
Zimbabwe

C.1.2. Northern Countries

Australia
Austria
Canada
Cyprus
Denmark
Finland
France
Germany
Hong Kong
Iceland
Ireland
Israel
Italy
Japan
Netherlands
New Zealand
Norway
Singapore
Spain
Sweden
Switzerland
United Kingdom
United States

Table 1: Regional business cycle correlations

Variable	Correlation with same variable in South at t+j: j= -1	j= 0	j= +1
Northern variable at t		**Data (1969-1988)**	
Gross Domestic Product (GDP)	-0.27	0.44	0.68
	(0.21)	(0.14)	(0.13)
Primary Output	0.18	-0.07	-0.17
	(0.23)	(0.21)	(0.22)
Manufacturing Output	-0.38	0.52	0.58
	(0.19)	(0.12)	(0.17)
Consumption	-0.25	0.09	0.74
	(0.25)	(0.20)	(0.12)
Investment	-0.27	0.18	0.49
	(0.17)	(0.17)	(0.19)
		North-South model	
Gross Domestic Product (GDP)	0.22	0.52	0.05
Primary Output	-0.05	-0.68	0.03
Manufacturing Output	0.19	0.52	0.03
Consumption	0.24	0.75	0.11
Investment	0.21	0.74	0.09
Labor Hours	-0.07	0.52	0.21

Notes: Items in the data rows report the author's calculations based on data from World Bank 1991. Values in parentheses are GMM standard errors using a QS kernel. The model rows report averages over 100 simulations of 80 quarters (20 years) for the North-South model. Actual and model data are Hodrick and Prescott 1980 filtered with a smoothing parameter of 10. Quantity data are logged prior to filtering. See appendix A for a detailed description of the data and appendix C for a listing of countries by region.

Table 2: International correlations

Correlation with:	Northern NX/GDP	Northern Terms of Trade	Real Commodity Price
		Data (1969-1988)	
Northern			
GDP	-0.65	-0.23	0.50
	(0.20)	(0.20)	(0.20)
Primary	0.14	0.20	-0.20
	(0.21)	(0.15)	(0.17)
Manufacturing	-0.61	-0.40	0.49
	(0.17)	(0.16)	(0.15)
NX / GDP		0.10	-0.31
		(0.24)	(0.23)
		North-South Model	
Northern			
GDP	-0.47	-0.55	0.36
Primary	0.47	0.31	-0.56
Manufacturing	-0.55	-0.61	0.45
NX / GDP		0.96	-0.96

Correlation with:	Southern NX/GDP	Southern Terms of Trade	Real Commodity Price
		Data (1969-1988)	
Southern			
GDP	-0.37	0.11	0.07
	(0.24)	(0.18)	(0.22)
Primary	-0.39	0.02	-0.32
	(0.21)	(0.21)	(0.25)
Manufacturing	-0.29	0.27	0.19
	(0.27)	(0.21)	(0.27)
NX / GDP		0.28	0.40
		(0.23)	(0.22)
		North-South Model	
Southern			
GDP	0.04	0.05	0.12
Primary	-0.12	-0.26	-0.18
Manufacturing	0.10	0.18	0.22
NX / GDP		0.96	0.96

Notes: Items in the shaded rows report the author's calculations based on data from World Bank 1991. Values in parentheses are GMM standard errors using a QS kernel. The unshaded rows report averages over 100 simulations of 80 quarters (20 years) for the North-South model. Actual and model data are Hodrick and Prescott 1980 filtered with a smoothing parameter of 10. Quantity and price ratios are logged prior to filtering. Real Commodity Price = ratio of world primary goods price to world manufactured goods price. Terms of trade = ratio of non-fuel export prices to non-fuel import prices. See appendix A for a detailed description of the data and appendix C for a listing of countries by region.

Table 3: North-South business cycle volatility

	Percentage Standard Deviation from Trend			
	North		South	
Variable	**Data (1969-1988)**	**Model**	**Data (1969-1988)**	**Model**
Gross Domestic Product (GDP)	1.38 (0.25)	1.41	0.78 (0.18)	1.00
Primary Output	2.62 (0.51)	2.59	1.46 (0.21)	1.49
Manufacturing Output	1.43 (0.22)	1.44	1.10 (0.16)	1.16
Consumption	1.02 (0.17)	0.77	0.71 (0.11)	0.86
Investment	3.38 (0.65)	3.46	2.53 (0.54)	2.94
Labor Hours		0.54		0.46
Non-Fuel Net Exports / GDP	0.22 (0.05)	0.18	0.67 (0.12)	0.91
Non-Fuel Terms of Trade (px/pm)			4.74 (0.60)	4.63
Real Commodity Price (p1/p2)			6.98 (1.08)	6.74

Notes: Items in the data columns report the author's calculations based on data from World Bank 1991. Values in parentheses are GMM standard errors using a QS kernel. The remaining columns report averages over 100 simulations of 80 quarters (20 years) for the North-South model. Actual and model data are Hodrick and Prescott 1980 filtered with a smoothing parameter of 10. Quantity and price ratios are logged prior to filtering. Real commodity price=ratio of world primary goods price to world manufactred goods price. Non-fuel terms of trade = ratio of non-fuel export prices to non-fuel import prices. See appendix A for a detailed description of the data and appendix C for a listing of countries by region.

Table 4: Within-region business cycle correlations

Correlation with:	Pri	Man	Con	Inv
		Data (1969-1988)		
Northern				
GDP	0.04	0.92	0.84	0.95
	(0.31)	(0.02)	(0.10)	(0.02)
Primary		-0.03	-0.13	-0.00
		(0.26)	(0.25)	(0.29)
Manufacturing			0.80	0.89
			(0.14)	(0.06)
Consumption				0.82
				(0.10)
		North-South Model		
Northern				
GDP	0.42	0.99	0.99	0.98
Primary		0.32	0.40	0.48
Manufacturing			0.98	0.97
Consumption				0.96

Correlation with:	Pri	Man	Con	Inv
		Data (1969-1988)		
Southern				
GDP	0.11	0.90	0.76	0.89
	(0.26)	(0.12)	(0.19)	(0.20)
Primary		-0.22	0.07	0.25
		(0.21)	(0.18)	(0.29)
Manufacturing			0.75	0.72
			(0.20)	(0.25)
Consumption				0.57
				(0.21)
		North-South Model		
Southern				
GDP	0.54	0.91	0.77	0.84
Primary		0.17	0.16	0.22
Manufacturing			0.84	0.89
Consumption				0.95

Notes: Items in the data rows report the author's calculations based on data from World Bank 1991. Values in parentheses are GMM standard errors using a QS kernel. The model rows report averages over 100 simulations of 80 quarters (20 years) for the North-South model. Actual and model data are Hodrick and Prescott 1980 filtered with a smoothing parameter of 10. Quantity are logged prior to filtering. See appendix A for a detailed description of the data and appendix C for a listing of countries by region.

Table 5: Benchmark parameters

Parameter	North	South	Global
Preferences			
β			0.98
σ			2.00
N			0.20
Production			
δ			0.025
Primary sector			
θ_1			0.25
α_1			0.35
$(i/k)/(\phi_k' / \phi_k'')$			-0.70
$(N/N^s)/(\phi_N' / \phi_N'')$			-50.00
Manufacturing sector			
σ_ε			0.20
θ_2			0.65
ω_y consistent with value-added cost share:			0.90
$(i/k)/(\phi_k' / \phi_k'')$			-0.10
$(N/N^s)/(\phi_N' / \phi_N'')$			-0.0001
Trade			
Primary			
$\sigma_{\mu 1}$			1.00
ω_1 consistent with imports/(total domestic usage) share:	0.40	0.11	
Manufacturing			
$\sigma_{\mu 2}$			0.50
ω_2 consistent with imports/(total domestic usage) share:	0.03	0.34	

Table 6: Actual and model steady state shares

Variable	North Data	North Model	South Data	South Model
Production-Domestic share				
Output gross domestic product	1.00	1.00	1.00	1.00
Primary value-added	0.08	0.07	0.26	0.27
Manufacturing value-added	0.92	0.93	0.74	0.73
Production-World share				
Output gross domestic product	0.84	0.85	0.16	0.15
Primary value-added	0.48	0.53	0.52	0.47
Manufacturing value-added	0.87	0.86	0.13	0.14
Labor-Sectoral share				
Primary		0.03		0.13
Manufacturing		0.97		0.87
Investment-Sectoral share				
Primary		0.06		0.25
Manufacturing		0.94		0.75
Expenditure-Share of GDP				
Consumption	0.75	0.78	0.77	0.80
Investment	0.25	0.22	0.24	0.20
Exports	0.04	0.07	0.15	0.34
Imports	0.04	0.07	0.17	0.34
Trade-Export shares				
Primary	0.20	0.03	0.58	0.58
Manufacturing	0.80	0.97	0.42	0.42

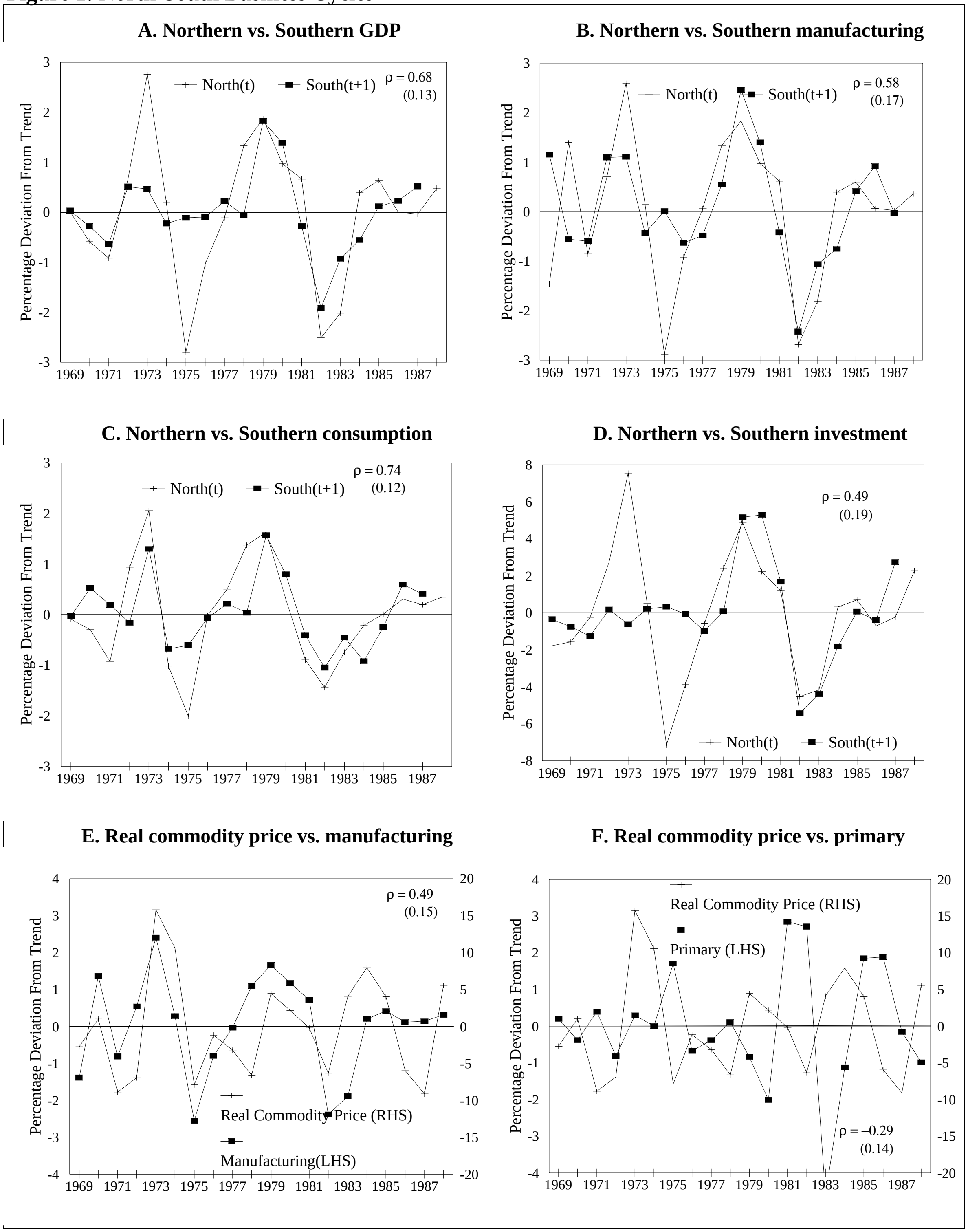
Notes: Author's calculations based on data from World Bank (1991) and United Nations (1992), Tables 6.3 and 6.4.

Table 7: Variance Decomposition Bounds

Variable	Source of Innovation: A. Both regions productivity shocks — Primary	A. Manufacturing	B. Northern Productivity Shocks — Primary	B. Manufacturing
Northern				
Gross Domestic Product (GDP)	(14 , 14)	(86 , 86)	(11 , 11)	(77 , 86)
Primary Output	(97 , 97)	(3 , 3)	(96 , 96)	(2 , 3)
Manufacturing Output	(8 , 8)	(92 , 92)	(6 , 6)	(82 , 92)
Consumption	(15 , 15)	(85 , 85)	(11 , 11)	(76 , 85)
Capital Investment	(24 , 24)	(76 , 76)	(18 , 18)	(68 , 76)
Southern				
Gross Domestic Product (GDP)	(25 , 25)	(75 , 75)	(1 , 1)	(5 , 20)
Primary Output	(97 , 97)	(3 , 3)	(2 , 2)	(1 , 2)
Manufacturing Output	(5 , 5)	(95 , 95)	(2 , 2)	(4 , 22)
Consumption	(1 , 1)	(99 , 99)	(1 , 1)	(42 , 69)
Capital Investment	(3 , 3)	(97 , 97)	(1 , 1)	(33 , 61)
Non-Fuel Net Exports / GDP	(33 , 33)	(67 , 67)	(31 , 31)	(64 , 65)
Non-Fuel Terms of Trade (px/pm)	(29 , 29)	(71 , 71)	(18 , 18)	(67 , 69)
Real Commodity Price (p1/p2)	(49 , 49)	(51 , 51)	(44 , 44)	(42 , 50)

Notes: Each cell indicates the share the variable's variance explained by the selected productivity shock(s). The first value indicates the lower bound of these variance decomposition exercises, while the second value indictaes the upper bound. Note, that primary sector innovations are orthogonal to the manufacturing innovations.

Figure 1: North-South Business Cycles



Notes: Author's calculations based on data from World Bank 1991. Unbracketed values reported in the chart are correlation coefficients. Values in parentheses are GMM standard errors using a QS kernel. Data are Hodrick and Prescott 1980 filtered with a smoothing parameter of 10. Quantity and price ratios are logged prior to filtering. Real commodity price = ratio of world primary goods price to world manufactured goods price. See appendix A for a detailed description of the data and appendix C for a listing of countries by region.

Figure 2: The effects of a 1% shock to Northern manufacturing productivity

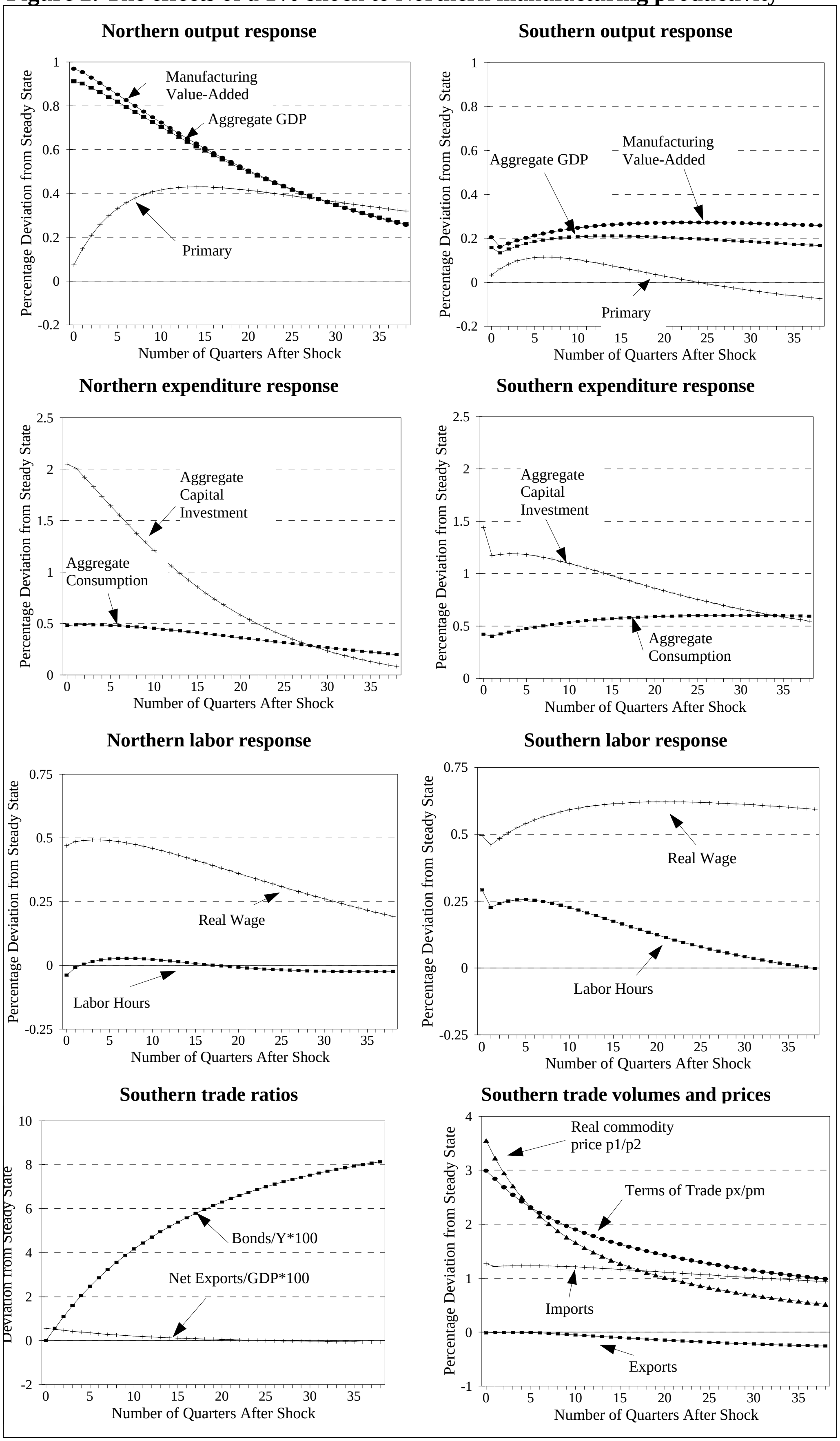


Figure 3: The effects of a 1% shock to Southern primary productivity

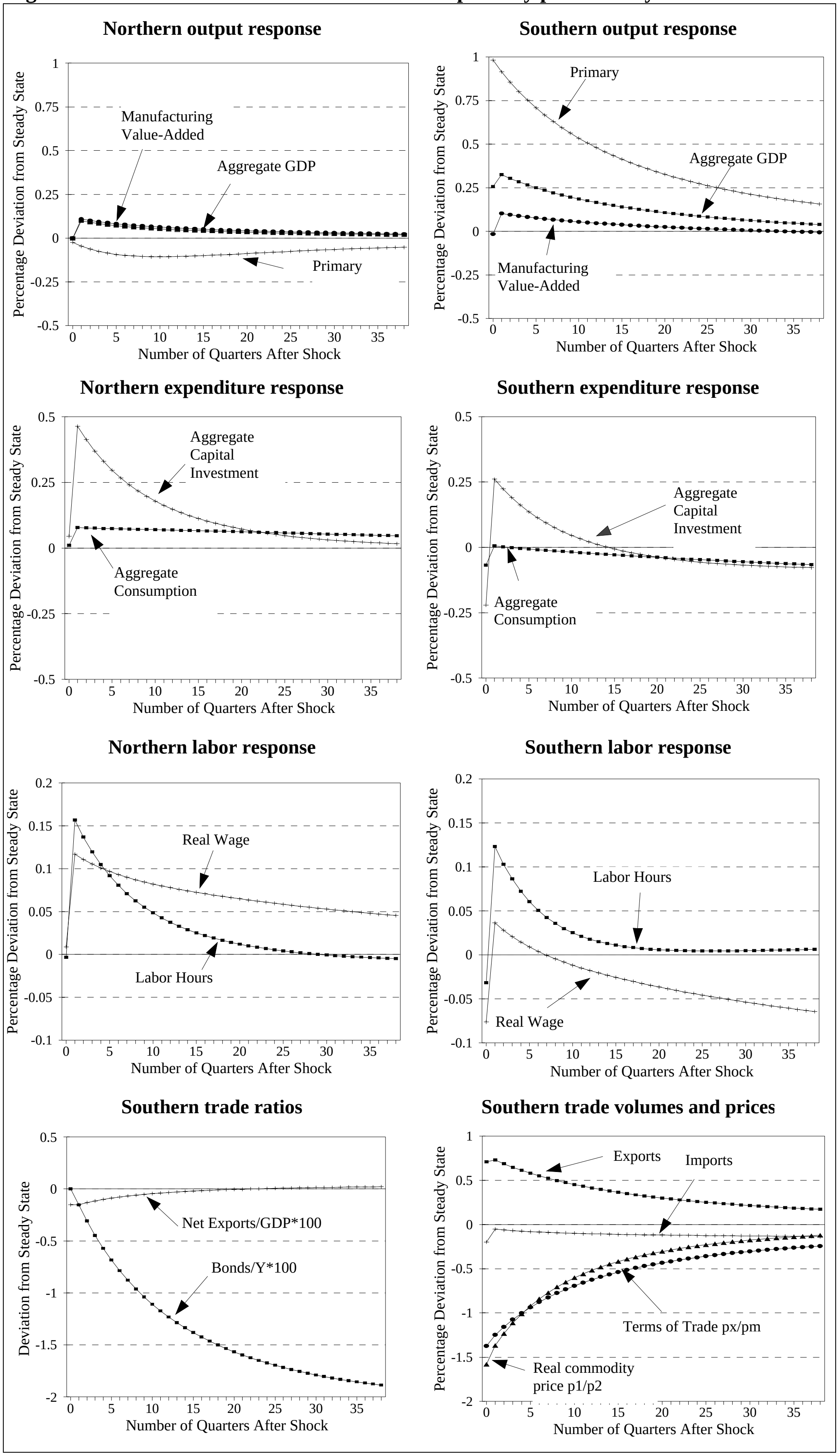


Figure 4: The effects of varying the elasticity of substitution between manufacturing inputs

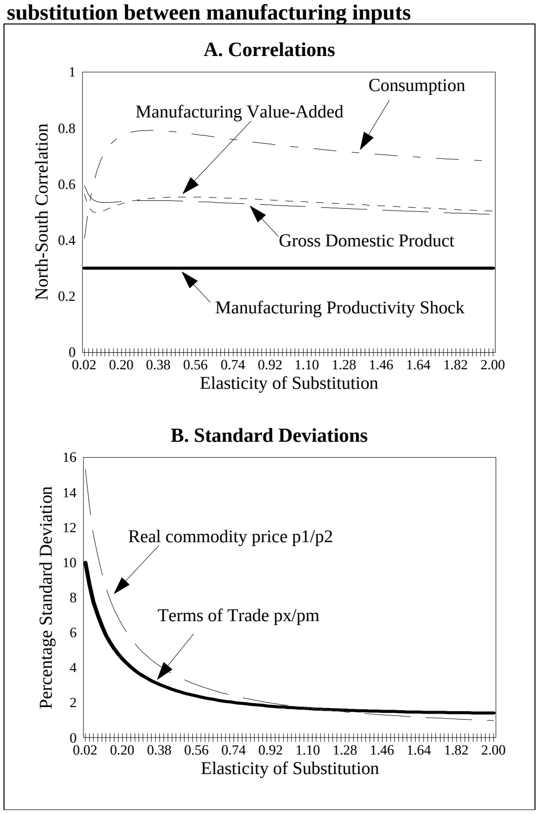


Figure 5: The effects of varying the elasticity of substitution between Northern and Southern manufactured goods

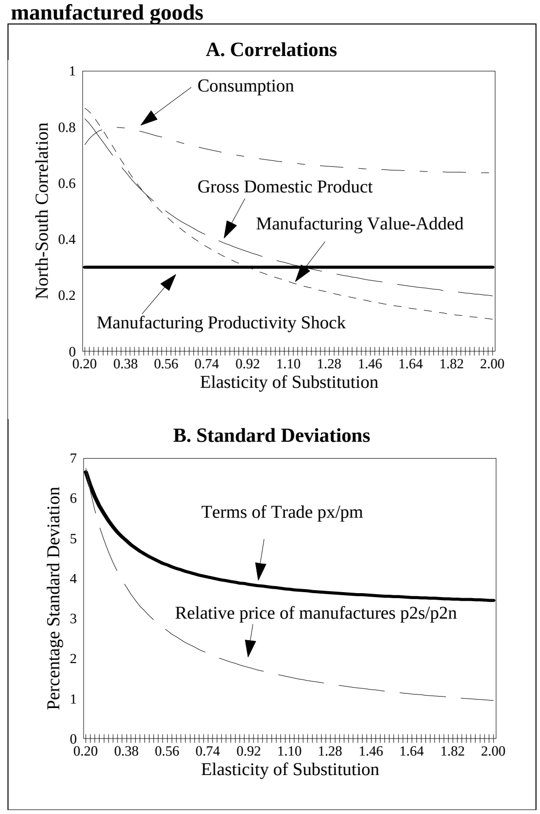


Figure 6: The effects of varying the cross-region correlation of non-primary innovations

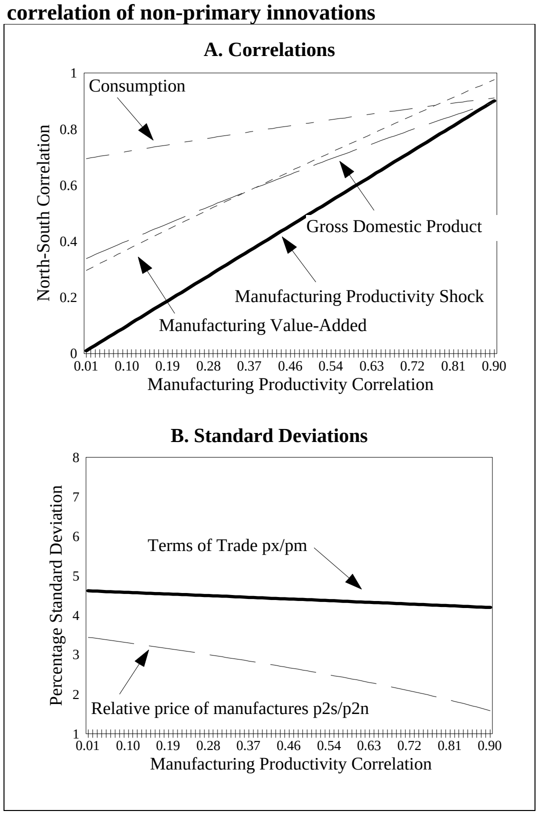


Figure 7: The effects of varying the primary sector labor adjustment elasticity