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Abstract

This paper investigates the effects of globalization on aggregate productivity, output growth, and inflation. I present a simple two-country, two-good, flexible exchange rate model using Fisher Ideal aggregators to examine changes in the mapping from *micro*economic to *macro*economic productivity growth as nations globalize. Advances in industry-specific labor productivity are shown to have potentially a much greater pass-through to aggregate productivity, output, and prices the more open nations are to trade. Globalization raises both the level and growth rate of aggregate productivity by allowing more economywide reorganization in response to ongoing technological advances than would be optimal otherwise.

I develop a globalized version of the quantity equation of money, where inflation in the home country depends on domestic money growth and a weighted average of home and foreign GDP growth. Relative country size, consumer preferences, production technologies, and the openness of trade are the chief determinants of these weights. Calibrating the model to match certain stylized facts about the U.S. and global economies, U.S. consumer price inflation falls from roughly 3.8 percent when economies are closed to under 2 percent in the transition period, eventually settling at around 2.3 percent in free trade. Producer and consumer prices trek a common path under autarky but diverge as the world globalizes. Both home and foreign aggregate productivity growth rates increase—by 0.4 and 0.7 percentage points, respectively. Roughly 30 percent of the output weight in the determination of home inflation shifts from the home to the foreign economy—greater than might be expected from strong home bias.

JEL codes: E01, E31, F43, F47, O47
Keywords: Globalization, inflation, productivity, growth, aggregator

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This paper presents a simple model to investigate the effects of globalization on aggregate productivity, output growth, and inflation. It has long been known (Ricardo 1817) that trade has the potential to raise living standards by allowing nations to focus production on the industries of their comparative advantage. Much less acknowledged are the effects of trade on national productivity, output, and prices as measured by conventional macroeconomic aggregators. Here, I present a simple two-country, two-good model wherein Fisher Ideal Indexes are employed to examine changes in the mapping from microeconomic to macroeconomic productivity growth as globalization proceeds. Advances in industry-specific unit labor outputs are shown to have potentially a much greater pass-through to aggregate productivity, output, and prices the more open nations are to trade. In short, in the most basic way possible, globalization increases the pace of productivity and output growth and lowers inflation.

Previous studies of openness and inflation tend to fall into two camps—one focusing on globalization's effect on money growth and the other on its effect on productivity. On the monetary side, numerous theoretical and empirical studies (Romer 1993, 1998; Lane 1997; Rogoff 2003; Loungani and Razin 2005) offer reasoning and evidence for how globalization leads to lower inflation through decreasing the central bank's incentive to inflate.

On the real side, a variety of hypotheses have been put forward whereby globalization can raise productivity growth either through increased competition (Chen, Imbs, and Scott 2004; Mann 1997), through direct improvements in the production process (Grossman and Rossi-Hansberg 2006; Jones and Kierzkowski 2001), via enhanced market incentives (Helpman and Krugman 1985; Romer 1990; Grossman and Helpman 1991), from scale effects (Helpman and Krugman 1985; Rivera-Batiz and Romer 1991), or from knowledge spillovers (Grossman and Helpman 1995; Coe and Helpman 1995). These studies largely concentrate on productivity gains at the microeconomic level—increases in output per worker within the firm or industry. This paper focuses instead on macroeconomic productivity gains—improvements in the overall economy's ability to reorganize aggregate production in response to underlying shifts in unit labor productivity and relative prices.

Because the effects set out here are real in nature and do not depend on money prices, they are independent of the exchange rate regime. It is generally believed that a flexible exchange rate system insulates one country from another's monetary and real shocks.[1] While such results may hold in a one-good framework, they cannot be generalized to the multi-good framework, where macroeconomic reorganization allows nations to reorder production and trade in response to gains in microeconomic efficiencies that arise anywhere on the globe. As I show here, growth in the foreign economy affects home aggregate productivity, output, and price indexes—as conventionally calculated and reported in national income accounts—even when exchange rates are completely flexible.

[1] See Cox 1980 for a discussion of the international transmission of disturbances in a one-good setup.

There are many channels by which globalization links economies and thus has the potential to alter economic behavior. A thorough investigation of these links is beyond the scope of this paper. The goal here is to present a minimal deep structure model that yields multiple useful insights. Much can be learned from a conventional trade model of two countries and two goods with dissimilar production technologies.

In Section 1, I set out the assumptions and the basic model. Section 2 derives closed-form solutions for the variables of key interest in two tractable cases, with primary focus on the behavior of Fisher Ideal Price Indexes for aggregate consumption and production. The results of this section are useful for understanding globalization's effects, but the model does not permit general closed-form solutions, so I turn to numerical simulations in Section 3. With these two tools, it is possible to glean much insight into how globalization changes the relationship between micro- and macroeconomic productivity growth, with implications for the behavior of aggregate output growth and inflation. Section 4 summarizes the key findings.

1. THE MODEL

Here I set out a simple two-country, two-good trade model that centers on the basic tenets of comparative advantage and macroeconomic reorganization in production.

Households in the home and foreign (*) country are assumed to maximize utility from the consumption of goods X and Y according to the functions

$$U = \left[\phi c_X^{\alpha} + (1-\phi) c_Y^{\alpha}\right]^{1/\alpha}, \text{ and} \tag{1.1}$$

$$U^* = \left[(1-\phi) c_X^{*\alpha} + \phi c_Y^{*\alpha}\right]^{1/\alpha}. \tag{1.2}$$

Leisure yields no utility. I assume the production functions display constant returns to scale of the economy but diminishing returns to each industry application. Each home household has one unit of work time spent in the fractions h and $(1-h)$ working in the X and Y industries; each foreign household has one unit of work time spent in the fractions h^* and $(1-h^*)$ working in the Y^* and X^* industries. Aggregate output in the X, Y, X^*, and Y^* industries is produced with diminishing marginal returns to industry labor but constant returns to the economy as

$$X = Lxh^{\beta}, \tag{2.1}$$

$$X^* = L^*x^*(1-h^*)^{\beta}, \tag{2.2}$$

$$Y = Ly(1-h)^{\beta}, \text{ and} \tag{3.1}$$

$$Y^* = L^*y^*h^{*\beta}, \tag{3.2}$$

where L and L^* are the number of home and foreign households, and x, y, x^*, and y^* reflect per-unit labor productivities in the X, Y, X^*, and Y^* industries, respectively. By assumption, $x/y > x^*/y^*$.

Note that this setup is symmetrical both in production and consumption across countries. In production, the home country has a comparative advantage in making X and the foreign country in making Y^*. In consumption, the parameter ϕ reflects home bias—the degree to which households in each country prefer the good of their comparative advantage (their "own good") over their neighbor's.

For simplicity, I assume there is no capital stock, no investment, and no savings. Thus, households face a budget constraint that the value of consumption must equal production, which may be written

(4.1) $X + \rho Y = Lc_X + L\rho c_Y$, and

(4.2) $X^* + \rho^* Y^* = L^* c_X^* + L^* \rho^* c_Y^*$,

where ρ is the price of good Y in terms of good X in the home country and similarly for ρ^*. Following Samuelson (1954), I assume that transport costs are of the iceberg type and let τ denote the number of physical units of foreign exports that must be sent out to deliver one unit to the home country and τ^* the same cost of delivering one physical unit of home exports to the foreign country. With such transport costs, the home country must export $(X - Lc_X)/\tau^*$ to deliver $(L^* c_X^* - X^*)$ to the foreign country and similarly for foreign exports to the home country. So:

(5.1) $X - Lc_X = \tau^*(L^* c_X^* - X^*)$, and

(5.2) $Y^* - L^* c_Y^* = \tau(Lc_Y - Y)$.

Arbitrage requires that relative prices in the two countries equalize up to transportation costs, so that

(6.1) $\rho = \tau\tau^*\rho^*$.

Utility maximization yields the first-order conditions

(7.1) $c_X = c_Y(\lambda\rho)^\sigma$, and

$$(7.2) \qquad c_X^* = c_Y^* \left(\frac{\rho^*}{\lambda} \right)^{\sigma},$$

$\sigma \equiv 1/(1-\alpha)$ being the elasticity of substitution in consumption, and $\lambda \equiv \phi/(1-\phi)$.

Profit maximization yields the first-order conditions

$$(8.1) \qquad h = \frac{x^\delta}{x^\delta + (\rho y)^\delta}, \text{ and}$$

$$(8.2) \qquad h^* = \frac{(\rho^* y^*)^\delta}{(\rho^* y^*)^\delta + x^{*\delta}},$$

where $\delta \equiv 1/(1-\beta)$.

Exchange in each country is assumed to require the use of local fiat money with unitary velocity, so that monetary equilibrium attains when

$$(9.1) \qquad M = P_X X + P_Y Y, \text{ and}$$

$$(9.2) \qquad M^* = P_X^* X^* + P_Y^* Y^*,$$

where the Ms are monies and Ps are money prices. Note that

$$(10.1) \qquad \rho = P_Y / P_X, \text{ and}$$

$$(10.2) \qquad \rho^* = P_Y^* / P_X^*.$$

Of specific interest is the time-series behavior of the aggregate price indexes for production and consumption in the home country. Instead of using a true index, it is well known that Fisher Indexes give nearly perfect answers and are the type conventionally used by national accounting offices to gauge the magnitude of periodic change.[2] These are calculated as

[2] See Diewert 1998 for more on this issue.

$$(11.1)\quad \Pi_Q \equiv \left[\frac{P_X \bar{X} + P_Y \bar{Y}}{\bar{P}_X \bar{X} + \bar{P}_Y \bar{Y}} \frac{P_X X + P_Y Y}{\bar{P}_X X + \bar{P}_Y Y} \right]^{\frac{1}{2}}, \text{ and}$$

$$(11.2)\quad \Pi_C \equiv \left[\frac{P_X \bar{L}\bar{c}_X + P_Y \bar{L}\bar{c}_Y}{\bar{P}_X \bar{L}\bar{c}_X + \bar{P}_Y \bar{L}\bar{c}_Y} \frac{P_X Lc_X + P_Y Lc_Y}{\bar{P}_X Lc_X + \bar{P}_Y Lc_Y} \right]^{\frac{1}{2}},$$

where Π_Q and Π_C are the Fisher Ideal Price Indexes for production, Q, and consumption, C, in the home country in the current period relative to a previous period, and $\bar{B}$ represents the base period's values of B; $B = X$, Y, P_X, P_Y, and L. This notation avoids the laborious use of time subscripts, while also offering the flexibility to view Π_Q and Π_C as either price indexes or inflation rates indexed to unity, with $\Pi_Q = \Pi_C = 1$ signifying no inflation in either producer or consumer prices. I follow the latter convention.

2. CLOSED-FORM SOLUTIONS

The above equations may be used to solve for the values of h, h^*, X, X^*, Y, Y^*, c_X, c_X^*, c_Y, c_Y^*, P_X, P_X^*, P_Y, P_Y^*, U, U^*, ρ, and ρ^*, as well as Π_Q and Π_C. However, closed-form solutions are not generally attainable, and the system must be solved numerically. Section 3 presents these computed solutions with specific attention to the behavior of inflation. Before turning to numerical methods, however, it is instructive to investigate two simple cases in which closed-form solutions may be achieved. While not all the lessons learned from these special cases can be generalized, they provide valuable insights into the workings of the globalized system.

Simple Case I: Constant Returns to Scale $(\beta = 1)$; Cobb–Douglas Utility $(\alpha = 0)$

For $\alpha = 0$, the utility function simplifies to the Cobb–Douglas form, with consumer budget shares constant at ϕ and $1-\phi$. For $\beta = 1$, production in all industries occurs according to constant returns to scale. If transportation costs are not prohibitive to trade and each nation has adequate production capacity to satisfy world demand, each nation will specialize in producing the good of its comparative advantage.[3] Given that $x/y > x^*/y^*$, the home country will specialize in the production of X and the foreign country in Y^*. Otherwise, at least one country will be better off in autarky.

Transportation costs, unit labor productivities, the number of households, and money stocks are the exogenous variables that drive the system. To gain insight into the evolution of productivity and prices, it is convenient to write the model in growth terms using the following definitions, each indexed to unity:

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[3] Specifically, so long as $\tau^*(\phi/(1-\phi))(x^*/x) < L/L^* < (y^*/y)(\phi/(1-\phi))(1/\tau)$, the nations will trade and specialize, and each country's output will be sufficient to satisfy the demand of the other.

$m = M/\bar{M} =$ money growth in the home country;

$m^* = M^*/\bar{M}^* =$ money growth in the foreign country;

$\ell = L/\bar{L} =$ growth in the number of households in the home country;

$\ell^* = L^*/\bar{L}^* =$ growth in the number of households in the foreign country;

$\eta = \eta_x \equiv x/\bar{x} = \eta_y \equiv y/\bar{y} =$ growth in unit labor productivity in each home industry;

$\eta^* = \eta^*_x \equiv x^*/\bar{x}^* = \eta^*_y \equiv y^*/\bar{y}^* =$ growth in unit labor productivity in each foreign industry;

$g = \ell\eta =$ growth in real output (real GDP growth) in the home country;

$g^* = \ell^*\eta^* =$ growth in real output in the foreign country;

$z = \tau/\bar{\tau} =$ growth in the cost of importing goods into the home country;

$z^* = \tau^*/\bar{\tau}^* =$ growth in the cost of importing goods into the foreign country.

Note that z, $z^* < 1$ reflects the opening of trade, and z, z^*, τ, $\tau^* = 1$ is free trade.

Using the above definitions, the solutions for inflation in producer and consumer prices (each indexed to unity) can be written as

$$\text{(12.1)} \quad \Pi_Q = \frac{m}{g} \ ,$$

$$\text{(12.2)} \quad \Pi^*_Q = \frac{m^*}{g^*} \ ,$$

$$\text{(13.1)} \quad \Pi_C = \frac{m}{g}\left[\frac{\lambda + \left(\frac{gz}{g^*}\right)}{\lambda + \left(\frac{g^*}{gz}\right)}\right]^{\frac{1}{2}}, \text{ and}$$

$$\text{(13.2)} \quad \Pi^*_C = \frac{m^*}{g^*}\left[\frac{\lambda + \left(\frac{g^* z^*}{g}\right)}{\lambda + \left(\frac{g}{g^* z^*}\right)}\right]^{\frac{1}{2}}.$$

Let's now focus on the behavior of prices in the home country.

Equation 12.1 is the familiar quantity equation of money in growth form, which holds for producer prices in both closed and open economies.[4] Independent of foreign influence, producer prices grow at the rate of home money growth relative to home output (GDP) growth. Globalization does not affect this relationship. Consumer price inflation, however, is determined not only by the growth in home money and home GDP but also by foreign GDP growth. Changes in import costs matter also for consumer price inflation.

When nations trade, the path of consumer prices has the potential to diverge substantially from producer prices, as represented by the presence of the bracketed term (gz/g^*).

This can happen as a joint product of the opening of trade ($z < 1$) and foreign GDP growth or simply from strong foreign GDP growth relative to that at home ($g^* > g$). Since the utility of home consumers depends directly on home consumption, not production, the price index of chief interest is clearly Π_C , and so the discussion here focuses mainly on that index. Several observations are important.

First, consider the transition path from autarky to free trade. Before the opening of trade (i.e., when τ and τ^* are prohibitive), Π_C tracks Π_Q and the two home-prices indexes are indistinguishable. But as transportation costs fall (or productivities grow) to the point where the economies are being globalized, foreign output begins to matter for the determination of home prices and there is an added inflation-reducing effect of globalization on home consumer price inflation. Neither effect is manifest in producer prices. [5]

Next, consider the case where $\tau = 1$ and free trade is obtained (alternatively, when $\tau > 1$ but stable, so that $z = 1$). Even in this steady state, the foreign economy continues to affect home consumer price inflation so long as home consumers place utility in foreign output (so long as $\phi < 1$, so that λ is finite). If foreign GDP growth exceeds that at home, home inflation is lower in open than in closed steady-state growth. The opposite is true if $g^* < g$.[6]

Several more observations are important to consider, but it is helpful first to rewrite equation 13.1 in a more reductive form. As I show in the appendix, it is possible to rewrite the solution for home consumer price inflation as simply

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[4] The conventional quantity equation of money, $MV = PT$, is in levels but can be expressed alternatively in growth rates, as in equation 12.1, where $M/\bar{M} = m$, $V/\bar{V} = 1$, $P/\bar{P} = \Pi$, and T is the aggregate volume of transactions. One can either define PT as aggregate GDP transacted at output prices or as aggregate consumption transacted at consumer prices. In what follows, I focus largely on the latter.

[5] As I show in the next section, this result cannot be generalized and, indeed, understates the ability of globalization to reduce inflation, since when $\beta < 1$, the growth rate in aggregate home output (here, simply $g = \ell\eta$) depends on both home and foreign unit labor productivity growth.

[6] Generally (i.e., for $\beta < 1$), globalization raises GDP growth and thus has the potential to reduce inflation even when foreign output growth is less than that at home. See footnote 3 and the computations in Section 3.

$$(14.1)\quad \Pi_C = \frac{m}{g^{\theta} g^{*\,1-\theta}} z^{1-\theta},$$

where $0 \le \theta \le 1$. The solution for θ follows below.

Equation 14.1 gives a globalized version of the quantity equation of money. Consumer price inflation in the home country depends on domestic money growth and a weighted average of home and foreign GDP growth. In the transition to freer trade, the fall in home import costs matters, too, with the same magnitude of influence $(1-\theta)$ as foreign growth.

Note that $\theta = [\ln(1+\lambda gz/g^*) - \ln(1+\lambda g^*/gz)]/2\ln(gz/g^*)$, which is bound by 0 and 1, since λ, g, g^*, $z \ge 0$. Since g, g^*, and z are all likely to be in the neighborhood of unity, it is not interesting to consider the influence of these variables on the weight θ. Consumer preferences in this setup (where $\alpha = 0$ and $\beta = 1$) are largely what govern the degree to which home inflation depends on home versus foreign GDP growth. The greater the home country's preference for the foreign good, the lower are ϕ and λ and the lower, thus, is θ. We see that $\Pi_C|_{\phi=0} = m/g^*$, and $\lim_{\phi\to 1}\theta = 1$, so that ϕ defines the bounds of θ.

These results are clearly intuitive. Suppose trade is free. If the home country produces only X and wants only X (i.e., if $\phi = 1$), then $\theta = 1$ and the familiar quantity equation of money obtains, $\Pi_C = m/g$. If, however, the home country produces only X and wants only Y^*, $\theta = 1$, $\Pi_C = m/g^*$, and foreign GDP growth is the only one that matters for home consumer prices. When home citizens want both goods, the output of both nations matters for home prices $(0 < \theta < 1)$.

Finally, in the monetary dimension, only home money growth affects home inflation. This result—conventional within flexible exchange rate regimes—is preserved in the globalized environment even though the income result is not.

Simple Case II: Constant Returns to Scale ($\beta = 1$); No Home Bias ($\phi = ½$)

The above case illustrates the effect of globalization on home inflation, but the simplifying assumption of $\alpha = 0$ does not permit evaluation of the role of country size since consumer budget shares spent on X and Y^* are constant at ϕ and $1-\phi$ in this case. To investigate the influence of country size and still obtain closed-form solutions to explore, we may alternatively set $\phi = ½$ and $\tau = \tau^* = 1$. This gives a reduced-form solution for home consumer prices as

$$(15.1)\quad \Pi_C = \frac{m}{g}\left[\frac{\bar{S} + \left(\frac{g^*}{g}\right)^{\alpha}}{\bar{S} + \left(\frac{g^*}{g}\right)} \frac{\bar{S} + \left(\frac{g}{g^*}\right)^{1-\alpha}}{\bar{S}+1}\right]^{\frac{1}{2}},$$

where $\bar{S} \equiv \bar{P}_X \bar{X} \,/\, \bar{P}_Y \bar{Y}^*$ is the base period size of home GDP relative to that abroad, $\bar{S} > 0$. This expression may also be rewritten making use of GDP weights as

$$(16.1) \quad \Pi_C = \frac{m}{g^{\theta'} g^{*\,1-\theta'}},$$

where $0 \leq \theta' \leq 1$. The solution can be found in the appendix. Again, I arrive at a globalized quantity equation of money. The inflation in home consumer prices depends on home money growth and a weighted average of home and foreign GDP growth, where the weights now are shown to depend also on relative country size and the elasticity of substitution in consumption, as reflected in α.

Let's focus first on the role of country size. Note that $\lim_{\bar{S}\to\infty} \Pi_C = m/g$, so that the influence of the foreign economy on home prices wanes and the standard closed-economy result follows as the home country becomes relatively large in the world. In the opposite case (as $\bar{S} \to 0$), however, we get $\Pi_C = m/(g^{\alpha} g^{*1-\alpha})$, so that even when the home country is small, home GDP growth still matters for the determination of home inflation, so long as $\alpha \neq 0$.

Focus next on the role of α and the elasticity of substitution, $\sigma \equiv 1/(1-\alpha)$. Note that as $\alpha \to 1$, the two goods become perfect substitutes in consumption and $\Pi_C = m/g$ for any value of $\bar{S}$. In short, the globalized two-good, two-country model presented here proves that both home and foreign GDP growth generally matter for the determination of home consumer price inflation, but nested in this broad result is the standard one-good case wherein the quantity equation simplifies to just $\Pi_C \equiv m/g$.

This finding is important to state. The conventional expression of the quantity equation for consumer prices, while convenient and accurate for a closed economy, does not generalize to a globalized world so long as consumers desire more than one type of good. Globalization produces a new quantity equation of money where, in general, home *and* foreign GDP growth affect home inflation, and all factors—country size ($\bar{S}$), consumer preferences (ϕ), and the elasticity of substitution in consumption (σ)—matter for the GDP weights.

Proponents of flexible exchange rates often advocate such a system as a way to insulate the home economy from the rest of the world—from both foreign monetary and real shocks. However, in the most basic way possible—simply through trade—this independence is lost as the world globalizes. Although flexible exchange rates block the transmission of foreign *monetary* policy to home prices, the transmission of foreign *output* to home prices remains and is straightforward.

This result does not require that trade raise microeconomic productivity, as would be reflected here in the unit labor outputs x, y, x^*, and y^*. Trade raises both the level and growth rate of macroeconomic productivity by allowing more economywide reorganization in response to advances in x, y, x^*, and y^* than would otherwise be optimal.

Clearly, also, globalization's benefits for productivity and inflation do not require trade deficits or that a nation's trading partner have an absolute advantage in any industry. They hold here under balanced trade, even though the home country may trade with a nation that is less productive in every industry than itself.

3. NUMERICAL SIMULATIONS

To gain further insight into the dynamics of the system and gauge the magnitude of globalization's effects on productivity and inflation, it is useful to simulate the model numerically. The primary goal is to examine the mapping from exogenous to endogenous variables as transportation costs fall and nations transition from closed to open economies. I present two simulations, one calibrated to the case where the two nations are identical opposites and one calibrated to match certain stylized facts about the U.S. and world economies. In each case, I simulate the behavior of the system over forty periods, through three distinct phases:

- **Phase 1:** Autarky, periods 0–11. $\tau = \tau^* > \min\{y^*L^*/yL,\ xL/x^*L^*\}$, so that transportation costs are high enough to prohibit trade.

- **Phase 2:** Transition, periods 12–30. $z = z^* < 1$ and $\tau = \tau^* > 1$. Transportation costs are falling and no longer so high as to prohibit trade.[7]

- **Phase 3:** Free trade, periods 31–40. $z = z^* = \tau = \tau^* = 1$. Transportation costs are eliminated, and the economies reach steady equilibrium.[8]

For consistency throughout the two simulations, the choices of levels for the key exogenous variables—x, y, x^*, and y^*—center on the opening of trade, $t = 12$.

The Symmetric Model

It is instructive to begin with the case in which the two nations are identical opposites, with equal labor forces ($L = L^*$), no home bias ($\phi = ½$), and mirror unit labor productivities: $y = x^*$, $x = y^*$. The levels and growth rates for this case are in Table 1, along with the calibrated values of the parameters α, β, and ϕ. The two nations' labor supplies are assumed to be equal and constant. The two monies are assumed to be equal and growing at the rate of 6 percent periodically. Unit labor productivities in the X and Y^* industries are equal and four times those in X^* and Y, so that each nation has a distinct and equivalent comparative advantage in one industry.

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[7] For the system to reach equilibrium, it is not necessary that transportation costs fall to zero, only that they cease to fall. As long as $z = z^* = 1$ and $\tau = \tau^* < \min\{y^*L^*/yL,\ xL/x^*L^*\}$, the two nations will trade and reach the same long-run growth paths (albeit not the same levels) of the endogenous variables.

[8] Steady-state equilibrium is defined here as a constant growth rate of all exogenous variables, although this condition generally does not yield constant growth rates of the endogenous variables because relative prices and country sizes are constantly evolving when productivity growth rates differ across countries or industries.

Table 1: Calibration of the Symmetric Model

	Home				Foreign				Parameters	
Variable	L	x	y	M	L^*	x^*	y^*	M^*	α	.1
Level: $t = 12$	1	8	2	1	1	2	8	1	β	.7
Growth rate	0	.04	0	.06	0	0	.04	.06	ϕ	.5

For purposes of illustration, I examine only the case where x and y^* grow, treating the factors that led to the nation's comparative advantage in autarky as continuing throughout the opening of trade and beyond.[9] Specifically, unit labor productivities in the industries of national comparative advantage are assumed to grow 4 percent periodically, whereas there is no productivity growth in the nation's inferior industries.

The parameters α and β are calibrated to ranges estimated by Backus, Kehoe, and Kydland (1992) and Gollin (2002), as discussed below in the presentation of the stylized asymmetric model. The parameter ϕ is set to 0.2 in that case, to reflect conventional findings of a home bias in consumption as exhibited in U.S. import shares; here, however, I set $\phi = 0.5$ to eliminate bias and facilitate interpretation of the results.

Figure 1 shows the time path of relative prices, consumption, producer and consumer price levels and inflation, GDP growth, and the evolution of θ. As panel A shows, relative prices exhibit complete symmetry and converge to unity in the absence of transportation costs. The consumption paths of X and Y at home are identical to those of Y^* and X^*, respectively, shown in panel B. As designed—and as replicated in the behavior of the endogenous variables—the two nations are equal in size and identical opposites in every way and following balanced growth paths. Thus, we may now clearly observe globalization's implications for the behavior of aggregate prices and growth, independent of country size, consumption bias, and asymmetric productivity growth paths.

Note first from panels C and D that the paths of producer and consumer price indexes are identical in autarky but diverge as trade is opened. Prior to the opening of trade, price indexes rise along roughly a 4 percent growth path.With the decline in transport costs and the opening of trade, however, the two indexes diverge—consumer prices plotting a growth trajectory well below that of producer prices and rising slower than before. In the symmetric open case presented here, producer and consumer price inflation rates ultimately converge, but to just under 2 percent—a substantial reduction from the steady-state 4 percent rate under autarky.[10]

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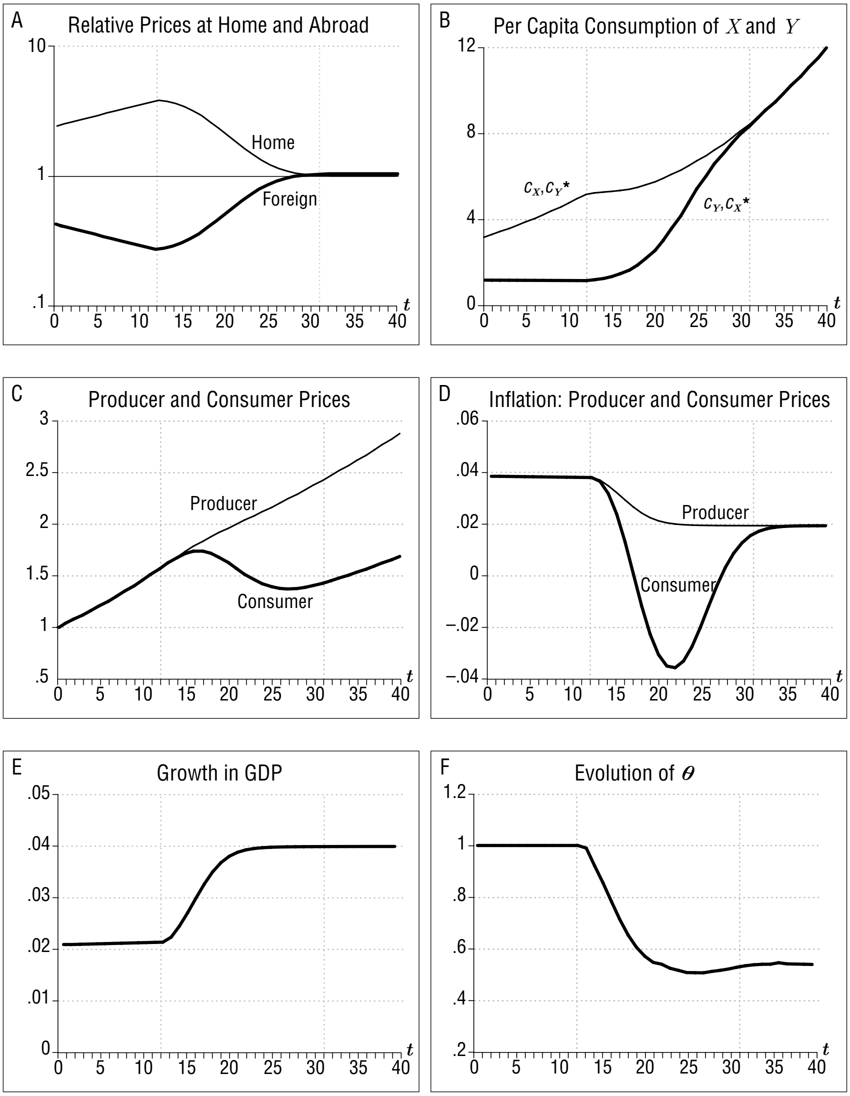
[9] More generally, the results derived here hold so long as $\eta_x > \eta_y$ and $\eta^*_y > \eta^*_x$. The case of $\eta_x < \eta_y$ and $\eta^*_y < \eta^*_x$ is uninteresting because if such a pattern were to continue indefinitely, each nation's comparative advantage would reverse and the same results derived here would obtain, but for opposite export and import industries. The case of $\eta_x = \eta_y = \eta^*_y = \eta^*_x$ is too restrictive to be of general interest and yields no features related to the setup that are worth attention.

[10] As I show next, consumer and producer inflation rates do not generally converge. Consumer prices grow slower than those for producers so long as productivity grows faster in nations' industries of comparative advantage.

These reductions in inflation reflect an increase in aggregate productivity growth, as illustrated by the GDP growth path in panel E.[11]

Figure 1, Panels A–F: Symmetric and Equal



In short, aggregate productivity and output grow faster in a globalized world, even with no increase in the microeconomic forces driving unit labor productivities in each industry. The mapping from η_x and η_y^* to g and g^* improves owing to globalization. This is because trade facilitates a greater reorganization of production in response to microproductivity growth both at home and abroad than would be optimal otherwise. More

[11] Since the labor force is constant in this example, aggregate productivity, output, and output per capita are growing at equal rates and so they may be discussed interchangeably.

labor can be transferred to the industry experiencing productivity growth and the output from that industry traded for the other goods consumers want than when economies are closed. In the example given here, globalization raises home productivity and output growth by roughly 2 percentage points, with a concomitant reduction in inflation. Advances in foreign unit labor productivity are transmitted to home aggregate productivity via domestic reorganization toward export industries, so that foreign growth clearly matters for home inflation.

Let's look next at the evolution of θ. Recall from the closed-form solutions of Section 2 that home consumer price inflation can be shown as linked to both home and foreign GDP growth, with a weight $0 \leq \theta \leq 1$ on home GDP growth that is dependent on consumer preferences (α and ϕ), production technology (β), and relative country size. Evidence from the simulations suggests that this relationship may be generalized. As panel F shows, θ begins as 1 when the economies are closed but eventually transitions to a free trade steady state where $\theta = 0.54$ with equal symmetric economies.[12]

The Stylized Asymmetric Model

I turn next to the asymmetric model, where relative labor forces, unit labor productivities, and the parameters α, β, and ϕ are chosen to replicate certain stylized facts about the U.S. and world economies. The goal of this exercise is to investigate globalization's effects on U.S. productivity and inflation when trade is opened to a large partner that is less productive in every industry than the U.S. but is growing relatively fast in its export industry. Table 2 shows the selected values of these variables and parameters, with the U.S. as the home country.

Table 2: Calibration of the Asymmetric Model

	Home				**Foreign**				**Parameters**	
Variable	L	x	y	M	L^*	x^*	y^*	M^*	α	.1
Level: $t = 12$	1	8	2	1	19	1	1	1	β	.7
Growth rate	0	.025	0	.06	0	0	.07	.09	ϕ	.8

I set $\alpha = 0.1$, which puts the elasticity of substitution at 1.1, within the range determined by Backus, Kehoe, and Kydland (1995). Following Gollin (2002) and in concert with observations regarding the U.S. economy, I set $\beta = 0.7$ to reflect labor's share of output. Similarly, I set $\phi = 0.8$ to reflect a bias in home consumption observed by Backus, Kehoe, and Kydland (1995) and reflected in U.S. imports relative to GDP. To match other stylized facts, the U.S. labor force (L) is assumed to be 5 percent of the world level; U.S. workers are assumed to be eight times as productive as foreigners in the making

[12] One might expect a steady-state θ value of 0.50 in the equal and symmetric case presented here, rather than the observed value of 0.54. However, g is itself endogenous and responds to changes in ρ caused by η_x and η_y^* in an amount that depends on the parameters α, β, ϕ, and the variables L, L^*, x, y, x^*, and y^*, which determine relative country size.

of good X and twice as productive in the making of Y. Finally, unit labor productivity in the X industry is assumed to be growing at the rate of 2.5 percent, whereas productivity in Y^* is growing at a 7 percent rate.[13] The unit labor productivities y and x^* are assumed to be constant.

The selected values of the parameters and exogenous variables yield the following late-transition-period ($t = 24–28$) computational values, which compare favorably with observations from the data:[14]

Aggregate U.S. output as a share of the world's:	0.22
Per capita U.S. output relative to that abroad:	5.4
U.S. imports as a share of output:	0.18
Growth rate of U.S. per capita output:	0.025

To facilitate the exposition, I depart somewhat from observed norms for foreign productivity growth and assume that productivity in the foreign economy's export sector is growing at a 7 percent rate, which translates into a 5½–6½ percent overall growth path for aggregate foreign output.[15] Although this path is above the average observed outside the U.S., it is well below that observed for our rapidly growing import partners—China and India—where recent per capita real growth rates have been in the 5–9 percent range.

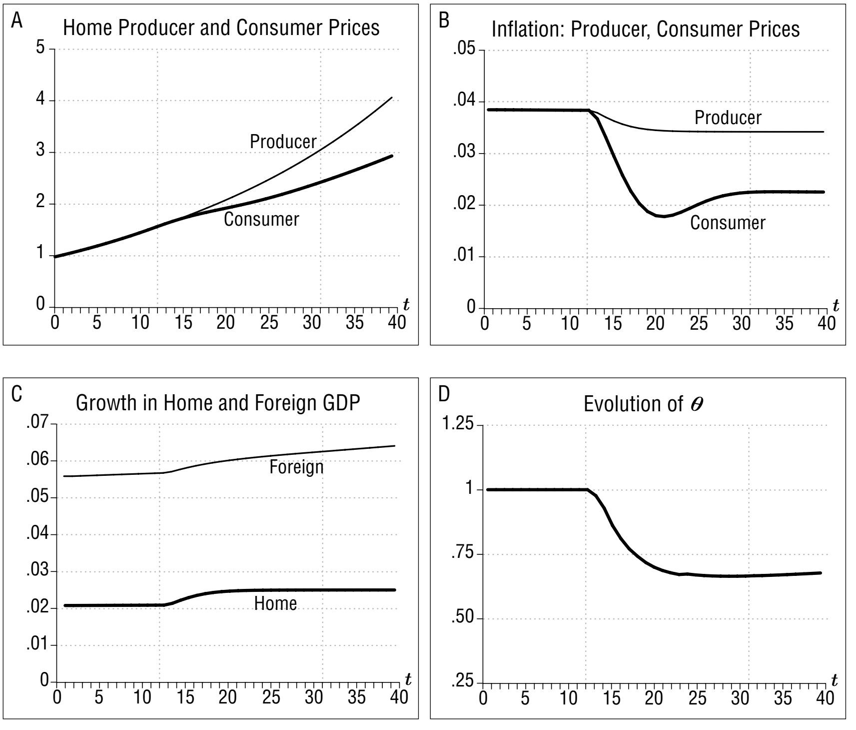
Figure 2 shows the paths of home consumer and producer prices (panel A) and inflation (B), home and foreign GDP growth (C), and the evolution of θ (D) as nations move from autarky, through the transition period to free trade.

[13] Note that for $y = 2$, $y^* = 1$, and $\eta_y^* - \eta_y = .07$, the foreign country develops an absolute advantage in the production of y^* in period 22. It can be shown that for $\eta_y^* - \eta_y \leq 0.025$, $y > y^*$ throughout the simulated forty periods, while preserving the major result that globalization increases the steady-state rate of home productivity growth. This finding supports the claim that globalization raises home productivity growth even when the home country trades with a nation that is less productive than it in every industry.

[14] Sources of the data are the World Development Indicators database and the Bureau of Economic Analysis' national income and product accounts tables. As I discuss below, aggregate home productivity growth increases from roughly 2.1 percent at the beginning of the transition period (upon leaving autarky) to 2.5 percent at the end (under free trade).

[15] It is not necessary that the foreign economy grow faster than the home economy for the latter to derive a steady-state decline in inflation from globalization. Globalization brings a reduction in inflation even when foreign growth is slower than that at home provided the foreign productivity gain occurs in the industry of foreign comparative advantage. One simple way to verify this result, not discussed above, is to note globalization's effect on the foreign economy. Although globalization introduces the foreign economy to a trading partner whose overall growth is slower than its, consumer and producer price inflation in the foreign country nonetheless fall 0.25 and 0.70 percentage points, respectively, from period 12 to period 40. These effects are much smaller than those observed in the home country, owing largely to relative country size. See also footnote 6.

Figure 2, Panels A–D: The Asymmetric Case



Again, producer and consumer prices trek a common path under autarky but diverge as the world globalizes. Most notably, inflation in U.S. consumer prices falls from roughly 3.8 percent when economies are closed to under 2 percent in the transition period, eventually settling at around 2.3 percent in free trade.[16] Home and foreign aggregate productivity growth rates each increase—by 0.4 and 0.7 percentage points, respectively. Finally, note that θ declines from 1 to 0.7, implying that roughly 30 percent of the output weight in the determination of home inflation shifts from the home to the foreign economy, greater than might be expected from the strong home bias ($\phi = 0.8$). These results clearly show that globalization can significantly affect the behavior of inflation.

Sensitivity Analysis

In this section, I conduct sensitivity analysis to examine the robustness of the results. In particular, I focus on the behavior of Π_C and θ in response to variations in α, β, ϕ , and y^*.

Figure 3 shows these results. In line with the findings from the closed-form solutions of Section 2, a decrease in α increases the impact of globalization on home inflation. This is because a lower α reflects a lower elasticity of substitution in consumption between home and foreign goods, meaning that consumers see foreign goods as unique. When this is the case, foreign

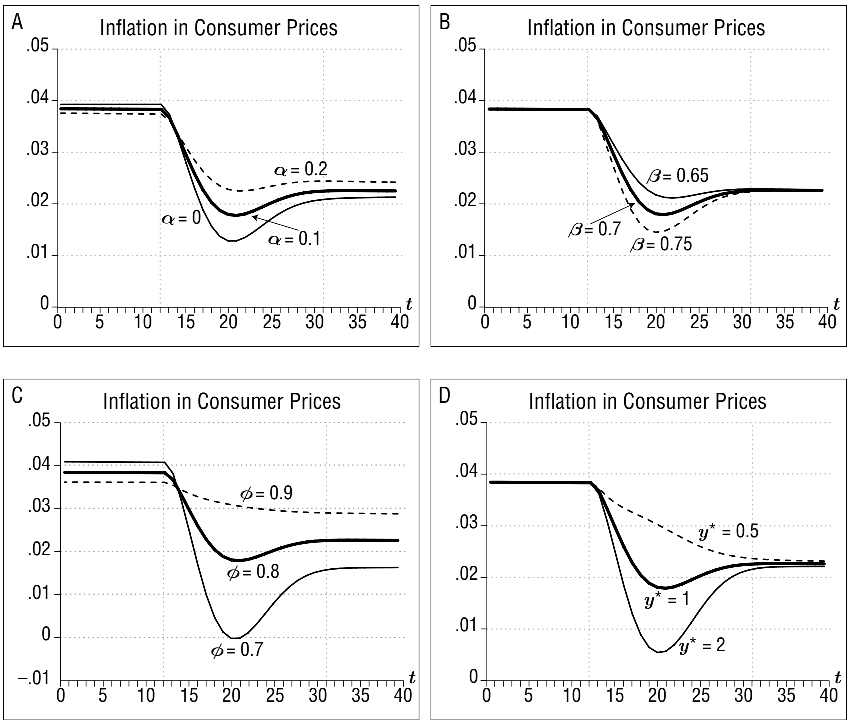
[16] Foreign consumer and producer price inflation rates fall as well—by 0.2 and 0.6 percentage points, respectively. Globalization reduces both nations' consumer and producer price inflation rates, but it lowers consumer inflation rates more than producer ones for nations whose trading partner is growing fast in its export industry, and vice versa.

growth in production of the home import good has more potential to benefit home consumers. The opposite holds for an increase in α.

The parameter β is important for the transition path of the inflation rate and for determining how fast the economy gets to the steady state, but it plays no role in determining the eventual steady-state inflation rate. This is because as long as $\eta_x > \eta_y$ and $\eta^*_y > \eta^*_x$, each nation will eventually specialize in the good of its comparative advantage.

As could be expected, the path of Π_C is highly sensitive to ϕ—the size of the home bias. A decrease in ϕ from 0.8 to 0.7 lowers the transition path of home consumer price inflation by nearly 2 percentage points and the steady-state path by roughly 0.6 percentage point. The more consumers like foreign goods (i.e., the lower ϕ is), the more globalization lowers home inflation, especially when growth in those favored foreign industries is strong.

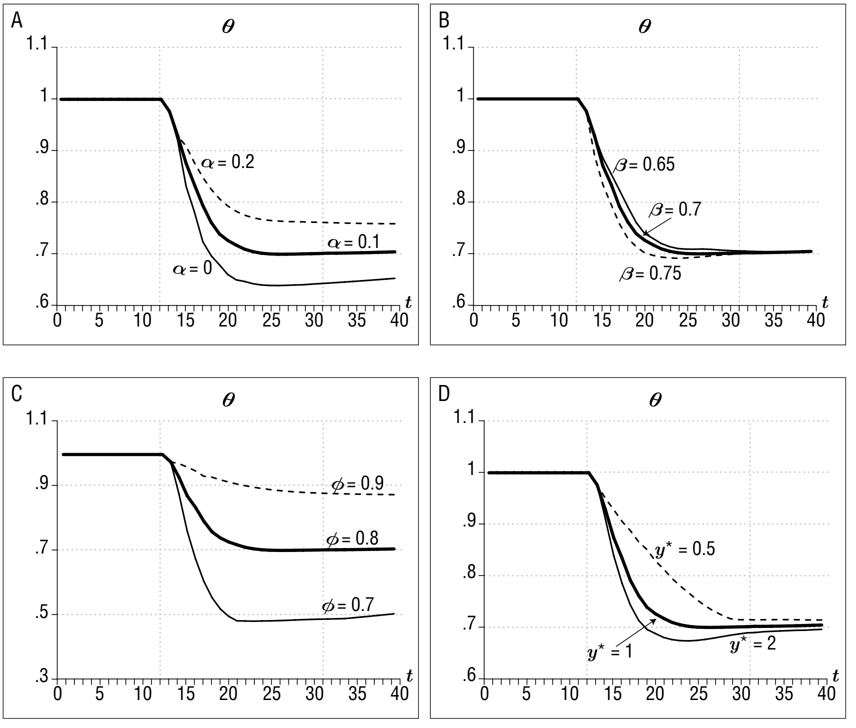
Figure 3, Panels A–D: Sensitivity Analysis on Π_C



Finally, note that the level of productivity in the foreign export industry upon the opening of trade (y^*) substantially affects the transition path of inflation from autarky to free trade but has no effect on the eventual steady state. The greater y^* is upon the opening of trade, the more home consumers can benefit from trade in terms of lower prices. But the steady-state path of Π_C, though lower in a globalized world, is unaffected by y^* since the steady-state growth *rates* of productivity are unaffected by level changes.

Figure 4 shows the effect on θ of varying α, β, ϕ, and y^*. As with Π_C, the sensitivity of θ to the calibrations of β and y^* are slight, affecting only the transition path and not the steady state, whereas α and ϕ have relatively large effects on the evolution of θ both in transition and the steady state.

Figure 4, Panels A–D: Sensitivity Analysis on θ



In view of the sensitivity of the model outcomes to variation in α and ϕ—and to a lesser extent, β and y^*—it is useful to examine the effects of calibration on the computed benchmark values shown in Table 2. Table 3 shows how varying α, ϕ, β, and y^* affects the computed model values of imports relative to GDP, the share of world output the home country produces, and home relative to foreign GDP per capita.[17] The parameter β has little effect on any of these values and, moreover, is confined by observations from Gollin (2002) and thus is set confidently at 0.70. Variation in the parameter ϕ—reflecting home bias—clearly has a strong effect on

Table 3: Implications of Sensitivity Analysis for Selected Model Values

Model Parameter	α			β			ϕ			y^*		
Model value	0	.1	.2	.65	.70	.75	.7	.8	.9	.5	1	2
Aggregate U.S. output as a share of the world's	.22	.22	.22	.22	.22	.23	.22	.22	.22	.34	.22	.13
Per capita U.S. output relative to that abroad	5.5	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	9.9	5.4	2.9
U.S. imports as a share of output	.20	.18	.16	.18	.18	.19	.08	.18	.28	.17	.18	.19

[17] Table 3 varies one parameter, keeping each of the others constant at its value shown in Table 2.

the model computation of imports relative to home GDP, causing those values to stray well outside bounds currently observed in the data.[18] A similar result obtains from varying α. The implied computed value of home imports falls (rises) markedly as α rises (falls) to reflect more (less) perceived substitutability between home and foreign goods by consumers. Similarly, the choice of y^* clearly has a large effect both on the computed values of aggregate U.S. output relative to the world and on U.S. per capita GDP relative to that abroad. The computed benchmark values match stylized facts from the data for $y^*=1$ but stray widely from observed bounds as foreign productivity levels deviate from that defined value.

In sum, the model calibrations presented in Table 2 appear most consistent with observations from the data and are preferred, providing confidence for the central findings stated above.

4. SUMMARY AND CONCLUSION

It is standard practice in national income accounting to measure economywide output, consumption, productivity, and prices using Fisher Ideal aggregators. Implicit in the utilization of such indexes is the observation that the supplies of individual goods and their prices tend to grow at divergent rates—through technological change, shifts in preferences, and trade. Economists have also recognized for nearly two centuries that national consumption can rise when nations open themselves to trade and reorganize aggregate production toward the good of their comparative advantage. Yet relatively little attention has been given to how trade manifests itself in the performance of aggregate indexes.

This paper focuses on how globalization affects the mapping from microeconomic to macroeconomic productivity growth. Advances in industry-specific unit labor outputs are shown to have potentially a much greater pass-through to aggregate consumption, output, productivity, and prices the more open nations are to trade. Globalization raises both the level and growth rate of aggregate productivity by allowing more economywide reorganization in response to technological advances than would be optimal otherwise.

The model presented here shows that when countries are open to trade, the standard quantity equation of money does not hold and must be replaced with a globalized version where home country inflation depends on domestic money growth and a weighted average of home and foreign GDP growth. Relative country size, consumer preferences, production technologies, and the openness of trade are the chief determinants of these weights.

Proponents of flexible exchange rates often advocate it as a way to insulate the home economy from foreign monetary and real shocks. However, in the most basic way possible—through trade—this independence is lost as the world globalizes. Although a flexible exchange rate regime blocks the transmission of foreign *monetary* policy to home prices, the transmission of foreign *output* to home prices remains and is straightforward. Nested in the general setup presented here is, indeed, the standard one-good model

[18] U.S. imports relative to GDP are currently at 17 percent and rising.

where the quantity equation simplifies to its conventional form and the home economy is independent of foreign influence. Advocates of flexible exchange rates will welcome this familiar result—but find their comfort confined to the narrow space of one-good models. So long as consumers view home and foreign goods as imperfect substitutes (i.e., when there are two or more distinct goods), both home and foreign outputs matter for the determination of home prices.

Producer and consumer prices trek a common path under autarky but diverge as the world globalizes. The smaller the home country, the more consumers view each good uniquely, and the smaller the bias in home consumption, the more producer and consumer price indexes will diverge when nations trade. Policymakers will find it problematic to use one price index to infer movements in the other.

Calibrating the model to match certain stylized facts about the U.S. and global economies, U.S. consumer price inflation falls from roughly 3.8 percent when economies are closed to under 2 percent in the transition period, eventually settling at around 2.3 percent in free trade. Home and foreign aggregate productivity growth rates each increase—by 0.4 and 0.7 percentage points, respectively. Roughly 30 percent of the output weight in the determination of home inflation shifts from the home to the foreign economy—greater than might be expected from the strong home bias.

By all accounts, globalization is important for the determination of aggregate productivity and inflation.

APPENDIX

In this appendix, I show that

$$\frac{m}{g}\left[\frac{\lambda+\left(\frac{gz}{g^*}\right)}{\lambda+\left(\frac{g^*}{gz}\right)}\right]^{\frac{1}{2}} = \frac{m}{g^{\theta}g^{*\,1-\theta}}z^{1-\theta},$$

where $0 \le \theta \le 1$ for $\lambda, g, g^*, z \ge 0$. The proof proceeds as follows.

Define

$$A \equiv \frac{gz}{g^*} > 0.$$

Then

$$\frac{m}{g}\left[\frac{\lambda+\left(\frac{gz}{g^*}\right)}{\lambda+\left(\frac{g^*}{gz}\right)}\right]^{\frac{1}{2}}$$

can be rewritten as

$$\frac{m}{g}\left[\frac{\lambda+A}{\lambda+A^{-1}}\right]^{\frac{1}{2}}, \text{ and}$$

$$\frac{m}{g^{\theta}g^{*\,1-\theta}}z^{1-\theta}$$

can be rewritten as

$$\frac{m}{g}A^{1-\theta}.$$

Thus I need only show that

$$\left[\frac{\lambda+A}{\lambda+A^{-1}}\right]^{\frac{1}{2}} = A^{1-\theta},$$

with $0 \le \theta \le 1$. Now

$$\left[\frac{\lambda+A}{\lambda+A^{-1}}\right]^{\frac{1}{2}} = A^{1-\theta}$$

can be rewritten as

$$\theta = \left[\frac{\ln(1+\lambda A) - \ln(1+\lambda A^{-1})}{2\ln A} \right],$$

applying repeated operations. Clearly, for $A = 1$ (i.e., when $g^* = gz$), θ is both indeterminate and irrelevant, and so we need not consider this case. To show that

$$0 \leq \frac{\ln(1+\lambda A) - \ln(1+\lambda A^{-1})}{2\ln A} \leq 1,$$

for $A \neq 1$ we must consider two cases.

Case I: $\mathbf{0 < A < 1}$

$0 < A < 1$ implies $\ln A < 0$, so that $0 \leq \theta \leq 1$ iff $0 \geq \ln(1+\lambda A) - \ln(1+\lambda A^{-1}) \geq 2\ln A$. Because ln is a monotonic transformation, and because $0 < A < 1$ and

$$\lambda \equiv \frac{\phi}{1-\phi} \geq 0,$$

given that $\phi \geq 0$, we see that $\ln(1+\lambda A^{-1}) \geq \ln(1+\lambda A)$, and thus the left-hand side of the $0 \leq \theta \leq 1$ inequality is satisfied. The term $\ln(1+\lambda A) - \ln(1+\lambda A^{-1})$ can be easily transformed to

$$\ln\left[A(\lambda + A^{-1})\right] - \ln\left[A^{-1}(\lambda + A)\right],$$

which equals $\ln(\lambda + A^{-1}) - \ln(\lambda + A) + 2\ln A$, and thus the right-hand side of the $0 \leq \theta \leq 1$ inequality is clearly satisfied, since $\ln(\lambda + A^{-1}) \geq \ln(\lambda + A)$ for $0 < A < 1$. Thus, $0 \leq \theta \leq 1$ for $0 < A < 1$.

Case II: $\mathbf{A > 1}$

$A > 1$ implies $\ln A > 0$, so that $0 \leq \theta \leq 1$ iff $0 \leq \ln(1+\lambda A) - \ln(1+\lambda A^{-1}) \leq 2\ln A$. Now $A > 1$ implies that $\ln(1+\lambda A) \geq \ln(1+\lambda A^{-1})$, so the left-hand side of the $0 \leq \theta \leq 1$ inequality is satisfied. Again, $\ln(1+\lambda A) - \ln(1+\lambda A^{-1})$ can be transformed to $\ln(\lambda + A^{-1}) - \ln(\lambda + A) + 2\ln A$, so the right-hand side of the $0 \leq \theta \leq 1$ inequality is satisfied, since $\ln(\lambda + A^{-1}) \leq \ln(\lambda + A)$ for $A > 1$. Thus, $0 \leq \theta \leq 1$ for $A > 1$. It follows that θ is bound by 0 and 1.

A similar proof yields

$$0 \leq \theta' \equiv \left[\frac{\ln(\bar{S}+1) - \ln(\bar{S} + B^{-\alpha}) + \ln(\bar{S}B + 1) - \ln(\bar{S}B^{-1} + B^{-\alpha})}{2\ln B} \right] \leq 1,$$

where

$$B \equiv \frac{g}{g^*}.$$

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