November 2010

# Trade Liberalization, Growth, and Productivity*

[Preliminary and Incomplete]

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ABSTRACT

We investigate the theoretical relationship between trade policy and growth. We use simple versions of some of the most common international trade models to investigate a number of specific mechanisms by which trade liberalization is thought to enhance growth or productivity: improvements in the terms of trade, increases in product variety, reallocation toward more productive firms, and an increased incentive to accumulate capital. In each model, trade liberalization improves social welfare. This is to be expected, but our results on real GDP may come as a surprise. In the static models, there is no general connection between trade liberalization and increases in real GDP per capita — the relationship may even be negative. In a dynamic model with capital accumulation, some countries will have slower rates of growth under free trade than under autarky. Opening to trade improves welfare, but does not necessarily increase real GDP per capita or speed up growth. If openness does in fact lead to large increases in real GDP, these increases do not come from the standard mechanisms of international trade.

*This paper was prepared for the conference "New Directions in International Trade Theory" at the University of Nottingham. We thank the participants and the discussant, Doug Nelson, for comments. The views expressed herein are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System.

## 1. Introduction

Mexico began an ambitious program of liberalization in the late 1980s, and the 1990s was a period of exceptional trade growth; imports as a fraction of gross domestic product in Mexico almost doubled between 1990 and 2000. A decade later, China began its own program to liberalize trade, with similar results: imports doubled in China from 1998-2008. The behavior of real gross domestic product (GDP) growth in the two countries, however, has been vastly different. While Chinese GDP per capita has grown at 8.6 percent per year, Mexican GDP per capita has stagnated. This has led some pundits to champion the export led growth in China and others to wonder if NAFTA was really the right policy for Mexico. In this paper we use models to show that the link between trade liberalization and output growth is a tenuous one. In fact, for some of the models commonly used to study trade liberalization, opening to trade from autarky actually decreases real GDP! When liberalization takes the form of decreased tariffs, models predict small increases in real GDP because "real tariff revenues" are being calculated using the old—larger—tariff rates.

We investigate the theoretical relation between trade policy and growth. We do so using simple versions of some of the most common international trade models, including a Heckscher-Ohlin model, a Ricardian model with a continuum of goods, a monopolistic competition model with homogeneous firms, a monopolistic competition model with heterogeneous firms, and a dynamic Heckscher-Ohlin model. These models allow us to investigate a number of specific mechanisms by which trade liberalization is commonly thought to enhance growth or productivity: improvements in the terms of trade, increases in product variety, reallocation toward more productive firms, and an increased incentive to accumulate capital.

For each model we provide an analytic solution for the autarky equilibrium and for the free trade equilibrium. We then look at the extreme case of trade liberalization by comparing autarky and free trade. To be consistent with empirical work, we measure real GDP in each of these models as real GDP is typically measured in the data: GDP at constant prices. In each model the supply of labor is fixed, so changes in real GDP are also changes in measured labor productivity. We then contrast real GDP with a theoretical measure of real income, or social welfare.

In each model, trade liberalization improves social welfare. This is to be expected, but our results on real GDP may come as a surprise. In the static models, there is no general connection between trade liberalization and increases in real GDP per capita — the relationship may even be negative. Moreover, in a dynamic model with capital accumulation, some countries will have slower rates of growth under free trade than under autarky. Opening to trade improves welfare, but does not necessarily increase real GDP per capita or speed up growth. If openness does in fact lead to large increases in real GDP, these increases do not come from the standard mechanisms of international trade. As Rodriguez and Rodrik (2001) point out, "growth and welfare are not the same thing. Trade policies can have positive effects on welfare without affecting the rate of economic growth."

There is a vast empirical literature on the relationship between trade and growth. This literature typically studies the correlation between some measure of openness —for example, trade relative to GDP — and the growth of real GDP or real GDP per capita. Early papers in this line of research include Michaely (1977) and Balassa (1978). Lewer and Van den Berg (2003), in a survey of this literature, conclude that most studies find a positive relationship between trade volume and growth and that the size of this relationship is consistent across studies. Other studies finding a positive relationship between trade openness and growth (using different techniques and openness measures) include World Bank (1987), Dollar (1992), Sachs and Warner (1995), Frankel and Romer (1999), Hall and Jones (1999), and Dollar and Kraay (2004).

Rodriguez and Rodrik (2001) question the findings of these studies. They argue that the indicators of openness used in these studies are either bad measures of trade barriers or are highly correlated with variables that also affect the growth rate of income. In the latter case, the studies may be attributing to trade the effects on growth of those other variables. Following this argument, Rodrik, Subramanian, and Trebbi (2002) find that openness has no significant effect on growth once institution-related variables are added in the regression analysis. Several studies using tariff rates as their specific measures of openness have found the relationship between trade policy and growth to depend on a country's level of development. In particular, Yanikkaya (2003) and DeJong and Ripoll (2006) find a negative relationship between trade openness and growth for developing countries.

Wacziarg (2001) and Hall and Jones (1999) find that trade affects growth mainly through capital investment and productivity. A smaller set of papers study the relationship between openness to trade and productivity. Examples are Alcalá and Ciccone (2004) and Hall and Jones (1999), both of which find a significant positive relationship between trade and productivity.

Theoretical studies on the relationship between trade and growth do not offer a clear view on whether there should be a relationship between trade openness (measured as lower trade barriers) and growth in income. Models following the endogenous growth literature with increasing returns, learning-by-doing, or knowledge spillovers predict that opening to trade increases growth in the world as a whole, but may decrease growth in developing countries if they specialize in the production of goods with less potential for learning. Young (1991), Grossman and Helpman (1991), and Lucas (1988) are examples. By contrast, Rivera-Batiz and Romer (1991) find that trade leads to higher growth for all countries by promoting investment in research and development.

Models of trade using the Dixit-Stiglitz theory of industrial organization have typically focused on welfare. Krugman (1991) shows, for instance, that trade liberalization leads to welfare increases because of increases in product variety. Melitz (2003) incorporates heterogeneous firms into a Krugman-style model and finds that trade liberalization increases a theoretical measure of productivity. When productivity is measured in the model as in the data, Gibson (2006) shows that trade liberalization does not, in general, increase productivity—as it is measured in data—in these sorts of models. The increase is, rather, in welfare. Gibson (2006) finds that adding mechanisms to allow for technology adoption generate increases in measured productivity from trade liberalization.

Standard growth models also do not have a clear prediction for the relationship between trade and growth. In particular, in dynamic Heckscher-Ohlin models — models that integrate a neoclassical growth model with a Heckscher-Ohlin model of trade — opening to trade may increase or decrease a country's growth rate of income depending on parameter values. Trade may slow down growth in the capital-scarce country even while it raises welfare. Papers in this literature are Ventura (1997), Cuñat and Maffezzoli (2004), and Bajona and Kehoe (2006).

## 2. General approach and measurement

In this paper we consider five commonly used models of trade. In each model we choose standard functional forms and, as needed, make assumptions so as to obtain analytical solutions for both the autarky equilibrium and the free trade equilibrium. (Throughout the paper we denote autarky equilibrium objects by a superscript $A$ and free trade equilibrium objects by a superscript $T$). This allows us to examine the extreme case of trade liberalization. In most of the models, however, it is straightforward to add *ad valorem* tariffs or iceberg transportation costs.

In each model we measure real GDP as it is measured in the data. We then contrast this with a theoretical measure of real income, or social welfare. Using this approach, Gibson (2007) and Kehoe and Ruhl (2007) show that the difference between the data-based measure and the theoretical measure can be surprising. In each model there is a perfect real income index with which we measure a country's social welfare in each period (throughout the paper we denote this by $v$). For simplicity, in each of the models the period utility function takes the form $u(c) = \log f(c)$, where $f(c)$ is homogeneous of degree one in $c$. The real income index is simply given by $f(c)$.

We strive to measure statistics in our models the same way they are measured in the data. This allows us to directly compare the model with the data. The issue here is the measurement of real GDP. Empirical studies use real GDP as reported in the national income and product accounts. This is either GDP at constant prices or GDP at current prices deflated by a chain-weighted price index. To be consistent with this empirical work, we measure real GDP in each of our models as GDP at constant prices. (Throughout the paper we denote GDP at current prices by $gdp$ and GDP at constant prices by $GDP$.) For instance, in each of the static models we measure real GDP as GDP at autarky prices. In the dynamic model, we measure real GDP as GDP at period-0 prices.

Finally, in each model the supply of labor is fixed. Thus changes in real GDP are also changes in measured labor productivity, value added per worker. In what follows, the terms real GDP, real GDP per capita, and labor productivity are all equivalent.

## 3. Classical models

In classical trade models trade affects income through changes in relative prices. Improvements in the terms of trade — the price of imports relative to the price of exports — lead to a reallocation of resources towards goods in which a country has comparative advantage. In this section we use two of the most common classical models, a Heckscher-Ohlin model and a Ricardian model with a continuum of goods, to show the effects of trade liberalization on measured real GDP. We consider two definitions of trade liberalization: (i) movement from autarky to free trade and (ii) reduction in an ad valorem tariff.

**A static Heckscher-Ohlin model**

Consider a world with $n$ countries, each with a measure $L_i$ , $i = 1,...n$, of consumers. Each consumer in country $i$ is endowed with one unit of labor and $k_i$ units of capital. Consumers derive utility from the consumption of two traded goods, with preferences given by:

$$u(c_{i1}, c_{i2}) = a_1 \log c_{i1} + a_2 \log c_{i2}, \tag{1}$$

where $a_1 + a_2 = 1$. The technologies to produce the traded goods are identical across countries and are given by

$$y_j = \theta_j k_j^{\alpha_j} \ell_j^{1-\alpha_j}. \tag{2}$$

for $j = 1, 2$, where we assume that $\alpha_1 > \alpha_2$ . This assumption implies that good one is capital-intensive and good two is labor-intensive. The markets for the traded goods are perfectly competitive and producers are price takers. Assume that governments impose a symmetric ad valorem tariff $\tau \geq 0$ on the import sector and that tariff revenue is reverted to the consumer as a lump sum transfer.

Let $\gamma_i = k_i / k$, where $k$ is the capital/labor ratio in the world economy. Notice that if $\gamma_i > 1$ ($\gamma_i < 1$) country $i$ is capital (labor) abundant and, therefore, will be exporting the capital (labor) intensive good.

Given the specifications of the model and assuming that countries diversify under free trade, the autarkic prices and outputs of the goods relate to the free trade prices in the following way:

$$p_{ij}^A = \gamma_i^{A_1 - \alpha_j} p_j^T$$

where $A_1 = a_1\alpha_1 + a_2\alpha_2$. Notice that for capital (labor) abundant countries the price of the capital (labor) intensive good is higher under free trade than under autarky. Expressions for the prices in the model with tariffs are more complicated and are derived implicitly in the appendix.

Define the *revenue function* as:

$$\begin{aligned} \pi\left(p_1, p_2, k_i\right) = \max&\left[p_1 y_{i1} + p_2 y_{i2}\right] \\ \text{s.t. } & k_{i1} + k_{i2} \leq k_i \\ & \ell_{i1} + \ell_{i2} \leq 1 \\ & k_{ij} \geq 0,\ \ell_{ij} \geq 0 \end{aligned} \quad . \tag{3}$$

For any given prices and factor endowments, the revenue function specifies the highest level of income that can be achieved at those prices by optimally allocating resources in the production of the traded goods. Notice that since $\alpha_1 > \alpha_2$, this function is strictly concave. Let $\left(y_{i1}^p, y_{i2}^p\right)$ be the optimal allocation of resources at prices $p$. Then for any feasible allocation $\left(y_{i1}, y_{i2}\right) \neq \left(y_{i1}^p, y_{i2}^p\right)$, it is the case that $p_1 y_{i1} + p_2 y_{i2} < \pi(p_1, p_2, k_i)$.

Measured real GDP in country $i$ is defined as:

$$GDP_i = \overline{p}_{i1} y_{i1} + \overline{p}_{i2} y_{i2} + \overline{\tau}\, \overline{q}_{ii'}(c_{ii'} - y_{ii'})$$

where $\overline{p}_{ij}$ is the producers' price of good $j$ in country $i$, $\overline{\tau}$ is the tariff, $\overline{q}_{ii'}$ is the consumer price of good $i'$ before any tariffs are applied, and $i'$ indicates the good imported by country $i$. All prices are measured in the base year period, which is the period before the trade policy is implemented (either autarky or the high tariff period. Measured total factor productivity is, then:

$$TFP_i = \frac{GDP_i}{k_i^{A_1}}. \qquad (4)$$

Notice that since the endowments of capital per worker are fixed, changes in measured real GDP translate into changes in total factor productivity.

**Proposition.** Trade liberalization increases welfare.

**Proposition:** Trade liberalization decreases measured real GDP and measured productivity.

The intuition behind the decrease in measured real GDP for the autarky to free trade scenario is simple: given factor endowments, the base-year production pattern in country *i* is the optimal production pattern for country *i* at the base year prices among all feasible production plans. Notice that in the base year period, $\overline{GDP}_i = \pi(\overline{p}_1, \overline{p}_2, k_i)$. Any deviation from that production pattern will lower the value of production at those prices. Figures 1 and 2 illustrate this effect for moving from autarky to free trade.

**A Ricardian model with a continuum of goods**

Consider a world with two symmetric countries. In each country $i$, $i = 1, 2$, the representative consumer is endowed with $\overline{\ell}$ units of labor. Consumer preferences are represented by the following utility function:

$$u(c_i) = \int_0^1 \log c_i\left(z\right) dz \qquad (5)$$

where $z \in \left[0,1\right]$, is the set of available goods to the consumer.

Good $z$ is produced with a constant returns to scale technology that differs across countries and it is given by:

$$y_i\left(z\right) = \ell_i\left(z\right) / a_i\left(z\right), \qquad (6)$$

where $a_1\left(z\right) = e^{\alpha z}$ and $a_2\left(z\right) = e^{\alpha(1-z)}$ ($\alpha > 0$) represent the quantity of labor required to produce one unit of good $z$ in country $i$. Markets are perfectly competitive and producers are price takers. Assume that governments impose a symmetric ad valorem tariff $\tau \geq 0$ on the import sector and the tariff revenue is rebated to the consumer as a lump sum transfer. Note that, since labor is the only factor of production and it is fixed, percentage changes in real GDP translate directly into changes in total factor productivity.

We normalize $w_i = 1$. The autarkic prices for good $z \in [0,1]$ in each country are $p_i^A(z) = a_i(z)$. In a trade equilibrium, countries specialize in the production of a subset of the goods. Let $Z_{di}$ be the set of goods produced by country $i$ and $Z_{fi}$ be the set of imported goods. The equilibrium producer prices in each country are then:

$$\begin{aligned} p_1(z) &= e^{\alpha z}, \quad z \in Z_{d1} \\ p_2(z) &= e^{\alpha(1-z)}, \quad z \in Z_{d2} \end{aligned} . \qquad (7)$$

Measured real GDP in country $i$ is:

$$GDP_i = \int_{Z_{di}} \overline{p}_i(z) y_i(z) dz + \overline{\tau} \int_{Z_{fi}} \overline{q}_i(z) c_i(z) dz\ , \qquad (8)$$

where $\overline{q}_i(z)$ is the consumer price of good $z$ before any tariffs are applied.

**Proposition:** Trade liberalization increases welfare

**Proposition:** Trade liberalization does not change real GDP unless there is an ad valorem tariff on the base year period.

## 4. New trade models

It is well known that, in standard monopolistic competition models with homogeneous firms, trade liberalization leads to an increase in the number of product varieties available to the consumer. This increase in product variety leads to an increase in real income, but does it lead to an increase in real GDP? We find that this depends on the nature of competition in the product market. If there is a continuum of product varieties, then real GDP does not change. If there is a finite number of product varieties, then real GDP increases. The reason is that, with Cournot (or Bertrand) competition among firms, markups over marginal cost decrease when the number of firms supplying goods to a market increases. We make this point using a monopolistic competition model with a finite number of product varieties.

### Monopolistic Competition Models

In contrast to classical models, monopolistic competition models feature consumers with love of variety preferences and firms with increasing returns to scale. These features allow us to consider gains from trade that are not present in the classical models of section 3.

Consider a world with two symmetric countries. The representative consumer in each country is endowed with $\bar{\ell}$ units of labor. Labor is inelastically supplied at wage $w$. The consumer's utility function takes the constant-elasticity-of-substitution (CES) form

$$U = \left( \int_Z c(z)^\rho \, dz \right)^{1/\rho} . \tag{9}$$

Here $Z$ is the set of goods available to the consumer, $c(z)$ is consumption of good $z \in Z$, and $1/(1-\rho)$ is the elasticity of substitution between any two goods, where $0 < \rho < 1$. Firms engage in monopolistic competition: each firm produces a unique good in the world, takes the consumers' demand functions as given, charges the profit maximizing price for its good, and meets demand at that price.

We consider three forms of trade liberalization: (i) opening to trade from autarky, (ii) reducing an iceberg transportation cost, and (iii) reducing an *ad valorem* tariff. In addition to asking how trade liberalization affects welfare, we ask how it affects measured real GDP. By *measured real GDP*, we mean GDP calculated using prices from a base period. (There are other methods of deflation that we could use, but this is the simplest) Let $Z_d$ be the set of goods produced domestically and let $Z_f$ be the set of imported goods. Then measured real GDP in each country is

$$GDP = \int_{Z_d} \overline{p}(z) y(z) dz + \overline{\tau} \int_{Z_f} \overline{q}(z) c(z) dz \,, \tag{10}$$

where $\overline{p}(z)$ is the producer price of good $z$ in the base period, $\overline{\tau}$ is the *ad valorem* tariff in the base period, $\overline{q}(z)$ is the consumer price of good $z$ in the base period before any tariff is applied, and $y(z)$ is the quantity produced of good $z$. We are assuming that any tariff revenue is rebated to the consumer as a lump sum. Since labor is the only factor of production and is fixed, percentage changes in measured real GDP, labor productivity, and total factor productivity are all equal here.

While (9) is a theoretical index of real income, (10) is a data-based index of real income, the sort of index that a national accounts statistician would create. We will show that trade liberalization affects these two measures differently, whether firms are homogeneous or heterogeneous in their technologies.

**Homogeneous Firms**

Consider a monopolistic competition model with homogeneous firms. Every firm in the world has the same increasing-returns-to-scale technology:

$$y(z) = \max\left[ x(\ell(z) - f),\ 0 \right], \tag{11}$$

where $y(z)$ is output, $\ell(z)$ is the input of labor, $f$ is the fixed cost of production in units of labor, and $1/x$ is the unit labor requirement. Profit maximization implies that the price of each good is a constant markup over marginal cost,

$$p(z) = \frac{w}{\rho x} \,. \tag{12}$$

Firms enter until profits are zero, which implies that the measure of firms (and the measure of varieties produced) in each country is

$$n = \frac{(1-\rho)\overline{\ell}}{f} \,. \tag{13}$$

Notice that $n$ does not depend on the level of the iceberg cost or tariff, which leads us to the following result.

**Proposition.** Trade liberalization does not change the measure of varieties available to consumers unless the countries are opening to trade from autarky, in which case the measure of varieties increases.

While trade liberalization increases the theoretical measure of real income (9), it does not necessarily increase the data-based measure of real income (10).

**Proposition.** Trade liberalization (i) increases welfare and (ii) does not change measured real GDP unless there is an *ad valorem* tariff in the base period, in which case measured real GDP increases.

Trade liberalization benefits consumers, but it changes nothing about the organization of production: the measure of firms in each country, the quantity produced by each firm, and producer prices all remain the same. As a result, trade liberalization does not change value added; it only shifts demand from domestically produced goods to imported goods. As is clear from (10), this increases GDP only if there is a tariff in the base period. Next we consider a model where trade liberalization does change the organization of production.

### Heterogeneous Firms

Consider a monopolistic competition model with heterogeneous firms. The representative consumer in each country is endowed with measure $\mu$ of potential firms.[1] Each potential firm draws its technological efficiency, $x$, from a probability distribution. We follow Chaney (2008) in assuming that the probability distribution is Pareto:

$$F(x) = 1 - x^{-\gamma}, \ x \geq 1. \tag{14}$$

We require that $\gamma > \rho/(1-\rho)$. A potential firm with efficiency draw $x$ chooses among three options: (i) not to produce, (ii) to produce only for the domestic market, or (iii) to produce for both the domestic market and the export market. Each potential firm has a choice of two

[1] Alternatively, we could assume that there is a fixed cost of entry and make the measure of entrants endogenous. In this case, the measure of entrants is proportional to the labor supply and does not depend on the level of the tariff or iceberg cost. It does not change our results.

increasing-returns-to-scale technologies: a technology for producing only for the domestic market (denoted by $d$) and a technology for producing for both the domestic market and the export market (denoted by $e$). The technologies are given by

$$y_i(z) = \max\left[x(z)(\ell_i(z) - f_i),\ 0\right],\ i = d, e, \tag{15}$$

where $y_i(z)$ is output, $\ell_i(z)$ is the input of labor, and $f_i$ is the fixed cost in units of labor. The level of the fixed cost depends on the export status of the firm, with exporting requiring a higher fixed cost. Regardless of which technology is used, profit maximization implies that the price charged by a firm is a constant markup over marginal cost:

$$p(z) = \frac{w}{\rho x(z)}. \tag{16}$$

Firms' operating decisions are characterized by two cutoff rules. Let $\pi_i(x)$ be the profit from a firm with efficiency $x$ operating technology $i$. Then a potential firm with efficiency $x$ operates if $x \geq \bar{x}_d$, where $\pi_d(\bar{x}_d) = 0$, and exports if $x \geq \bar{x}_e$, where $\pi_d(\bar{x}_e) = \pi_e(\bar{x}_e)$. We assume that parameter values are such that $1 < \bar{x}_d < \bar{x}_e$ (that is, not all potential firms choose to operate and not all operating firms choose to export).

In contrast to the model with homogeneous firms, trade liberalization in this model causes a reallocation of production across firms. As is well known from Melitz (2003), trade liberalization causes the least efficient firms to exit and causes the most efficient non-exporters to become exporters (that is, $\bar{x}_d$ increases and $\bar{x}_e$ decreases). For consumers, the net result is the following.

**Proposition.** Trade liberalization decreases the measure of varieties available to consumers.

With heterogeneous firms the gains from trade liberalization come from a reorganization of production: labor is reallocated toward more efficient firms and consumers are able to consume products with lower prices.

**Proposition.** Trade liberalization (i) increases welfare and (ii) does not change measured real GDP unless there is an *ad valorem* tariff in the base period, in which case measured real GDP increases.

Though trade liberalization reallocates labor toward more efficient firms, firms that are more efficient charge lower prices for their goods. The net effect is that value added is unchanged.

## 5. Trade liberalization and growth rates

Trade liberalization may affect a county's growth rate by changing the incentives to accumulate capital. With free trade, capital scarce countries concentrate in the production of labor intensive goods and exchange them for capital intensive goods, reducing their need to accumulate capital, compared to autarky. In this section we analyze the effect of trade liberalization on measured real GDP in a dynamic Heckscher-Ohlin model with endogenous capital accumulation, as in Bajona and Kehoe (2009).

Consider a world with $n$ countries, where in each country $i$, $i=1,2,...,n$, there is measure $L_i$ of infinitely lived consumers. Each consumer in country $i$ is endowed with one unit of labor and $\bar{k}_{i0}$ units of capital. There are two tradable goods, $j=1,2$ which are produced using capital and labor. The technology to produce the two goods is the same across countries.

A consumer in country $i$ derives utility from the, and chooses consumption and investment allocations $\{c_{ijt}, x_{ijt}, k_{it}\}$, $j=1,2$, $t=0,1,...$, to maximize lifetime utility,

$$\sum_{t=0}^{\infty} \beta^t \left( a_1 \log c_{i1t} + a_2 \log c_{i2t} \right), \tag{17}$$

where $a_1 + a_2 = 1$, subject to the budget constraints

$$p_{i1t}\left(c_{i1t} + x_{i1t}\right) + p_{i2t}\left(c_{i2t} + x_{i2t}\right) = w_{it} + r_{it}k_{it}, \quad t = 0,1,\ldots \tag{18}$$

and the laws of motion of capital

$$k_{it+1} = \left(1-\delta\right)k_{it} + x_{i1t}^{a} x_{i2t}^{1-a}, \qquad t = 0,1,\ldots \tag{19}$$

given $k_{i0} = \bar{k}_{i0}$. Here $p_{ijt}$ is the price of good $j$, $w_{it}$ is the wage rate, and $r_{it}$ is the rental rate of capital. The production side of the economy is the same as in the static Heckscher-Ohlin model in section 3.1, and we do not repeat it here.

We consider two scenarios. In both scenarios all countries are in autarky in the first period (period 0) and they believe that they will continue in autarky forever. In the *autarky* scenario, the countries do continue in autarky forever. In the *free trade* scenario, at the beginning of the second period (period 1) and before any production or consumption decisions are made, all economies are allowed to trade freely with each other. This assumption ensures that period-0 prices are the same under both scenarios and, therefore, real GDP is measured using the same prices under both scenarios.

Notice that in our specification of the model, the traded goods are combined in the same way in consumption and investment. This assumption greatly simplifies the solution of the dynamic model. In particular, given $k_{it}$, the equilibrium prices and production patterns of the dynamic model for period $t$ can be solved by solving a static Heckscher-Ohlin model with initial capital per person $k_{it}$ in each country *i*. Values for consumption and investment in each period are solved by using the intertemporal consumer's problem. See Bajona and Kehoe (2009) for details.

When we assume that $\delta = 1$ and that factor prices are equalized along the equilibrium path, the model can be solved analytically. Period equilibrium prices under autarky and free trade relate in the following way:

$$p_{jt}^{T} = \frac{1}{\gamma_i} \lambda_{it}^{A_1 - \alpha_j} p_{ijt}^{A}$$

where $\lambda_{it} = k_{it} / k_{it}^{A}$, $t \geq 1$, is the period ratio between the trade and autarkic level of capital for country $i$, and $\gamma_i = k_{it} / k_t$ is the country's capital per worker relative to the world capital per worker ratio. Bajona and Kehoe (2009) show that, with Cobb-Douglas production functions, this ratio is independent of $t$. The relationship between the capital stocks under both scenarios, $\lambda_{it}$ can further be expressed, for $t \geq 1$, as:

$$\lambda_{it} = \gamma_i \left( \frac{\lambda_{it-1}}{\gamma_i} \right)^{A_1} = \gamma_i^{1-A_1^{t-1}}$$

Notice that for capital abundant countries ($\gamma_i > 1$) this ratio increases over time, indicating that they accumulate capital faster under free trade than under autarky. For capital scarce countries ($\gamma_i < 1$) the ratio decreases over time, indicating that these countries accumulate capital slower under free trade than under autarky. In both cases, the ratio converges to $\gamma_i$, which indicates that as long as $\gamma_i \neq 1$, the country's steady state capital per worker differs under both scenarios.

Measured real GDP in period $t$ is defined as

$$GDP_{it} = \bar{p}_{i10} y_{i1t} + \bar{p}_{i20} y_{i2t},$$

where $\bar{p}_{ij0}$ are the period-0 prices, which coincide in both scenarios, and measured TFP is:

$$TFP_{it} = \frac{GDP_{it}}{k_{it}^{A_1}}.$$

**Proposition:** Trade liberalization increases welfare.

**Proposition:** In each period $t \geq 1$, for the capital poor country measured real GDP in the free trade scenario is lower than in the autarky scenario. [proof in progress]

The following numerical example illustrates the effect of trade liberalization on measured real GDP. Let $n = 2$ and $L_1 = L_2 = 1$, $\beta = 0.96$, $a_1 = a_2 = 0.5$, $\theta_1 = \theta_2 = 1$, $\alpha_1 = 0.6$, $\alpha_2 = 0.4$, $\bar{k}_{10} = 0.05$, and $\bar{k}_{20} = 0.03$. Under this parameterization, country 1 is the capital abundant country whereas country 2 is the capital poor country. Figures 4 and 5 compare real GDP in each country under both regimes. We observe that measured real GDP in the capital abundant country grows faster under free trade than under autarky, whereas in the capital poor country the opposite occurs. Opening to trade slows down growth in the poor country, compared to the growth rate it would have achieved had it remained in autarky.

As traditional growth theory predicts, the capital poor country grows faster in autarky. This result changes under the free trade. In the first period, the capital poor country grows faster, but its growth rate slows down substantially after both countries unexpectedly open to trade in period 1. The growth rate of the capital-poor country remains below the growth rate of the capital abundant country in the subsequent period. We plot the real GDP growth rates with free trade in figure 6.

## 6. The gains from trade in China and Mexico

We have shown that the gains from liberalizing trade will not, generally, be evident in measures of real GDP. Accurately measuring the gains from trade for China and Mexico—or any country—is an inherently model specific exercise, and is outside the scope of this paper. We can, however, calculate some statistics that provide a rough sense of the gains from trade. In this section we consider two such measures, one based on the import penetration ratio, and one that accounts for the gains from the greater varieties available through trade. Both measures point to the same conclusion: while the behavior of GDP has differed across the two countries, the gains from trade have not. The gains from trade in China and Mexico are remarkably similar.

**Gains Measured by Trade Flows**

Arkolakis, Costinot, and Rodriguez-Clare (2009) show how the gains from trade (relative to autarky) in a broad class of models can be estimated using data on the share of imports in expenditure and the elasticity of substitution,

$$\Delta W = \left(1 - s_M\right)^{-\frac{1}{\sigma}} - 1, \qquad (20)$$

where $s_M$ is the share of imports in domestic absorption and $\sigma$ is an elasticity that, in some models, is related to the elasticity of substitution between goods. The estimator in (20) is valid for models with (i) constant elasticity of substitution preferences, (ii) one factor of production, (iii) linear cost functions, (iv) complete specialization, and (v) iceberg trade costs. In addition to these assumptions, the models must also generate a gravity equation, and the demand system (a function of both supply and demand) must be of the constant elasticity type. These restrictions define a set of models that includes the Ricardian models in section 3 and the monopolistic competition models in section 4.

Figure 1 plots the share of imports in domestic absorption for Mexico, 1990-2000, and China, 1998-2008. For both countries, the import penetration ratio grows from about 15 percent to 30 percent. Given the similarity of the growth in imports in the two countries, it is clear from (20) that—as long as the elasticity, $\sigma$, is the same across countries—the gains from trade will be similar as well. In this framework, both China and Mexico have experienced almost identical gains from their expansion of trade, even though the growth paths of GDP in these two countries differ.

**Gains from New Varieties**

Based on the seminal work of Feenstra (1994), Broda and Weinstein (2006) compute the gains from the importation of new varieties for the United States. The gain from new varieties may be difficult to capture because traditional price indices do not typically account for new varieties. In what follows, we construct a measure of the bias in import prices that exists when new varieties are ignored in price indices. This bias allows us to compute the gains from the greater varieties that can be consumed with trade.

We classify imports into goods and varieties. The set of all imported goods is $G$, and for each $g \in G$, the set of all varieties available at time $t$ is $I_{gt}$. Note that we have assumed the set of goods is constant over time, while the set of varieties can change. The sub-utility of imported good $g$ at time $t$, is an aggregation of varieties,

$$M_{gt} = \left( \sum_{i \in I_{gt}} d_{git} x_{git}^{\frac{\sigma_g - 1}{\sigma_g}} \right)^{\frac{\sigma_g}{\sigma_g - 1}}, \tag{21}$$

where $x_{git}$ is the consumption of variety $i$ of good $g$. Notice that all varieties of a good have the same elasticity of substitution, $\sigma_g > 1$, but this elasticity can differ by good. Goods are aggregated into a composite import good according to

$$M_t = \left( \sum_{g \in G} M_{gt}^{\frac{\gamma - 1}{\gamma}} \right)^{\frac{\gamma}{\gamma - 1}}, \quad \gamma > 1. \tag{22}$$

Lastly, the composite import and a composite domestic good are combined in the utility function

$$U_t = \left( D_t^{\frac{\kappa - 1}{\kappa}} + M_t^{\frac{\kappa - 1}{\kappa}} \right)^{\frac{\kappa}{\kappa - 1}}, \qquad \kappa > 1. \tag{23}$$

We would like to price the good $g$ that is defined in (21). When the set of varieties being consumed is constant, $I_{gt} = I_{gt-1}$, Sato (1976) and Vartia (1976) show that the CES exact price index is

$$P_g^M(\mathbf{p}_{gt}, \mathbf{p}_{gt-1}, \mathbf{x}_{gt}, \mathbf{x}_{gt-1}, I_{gt}) = \prod_{i \in I_g} \left( \frac{p_{git}}{p_{git-1}} \right)^{\omega_{git}}, \tag{24}$$

where $\omega_{git}$ are the ideal log change weights. How can we price $g$ if the set of varieties is changing over time? Feenstra (1994) shows that the exact price index can be computed as

$$\pi_g^M(\mathbf{p}_{gt}, \mathbf{p}_{gt-1}, \mathbf{x}_{gt}, \mathbf{x}_{gt-1}, I_g) = P_g^M(\mathbf{p}_{gt}, \mathbf{p}_{gt-1}, \mathbf{x}_{gt}, \mathbf{x}_{gt-1}, I_g) \times \left( \frac{\lambda_{gt}}{\lambda_{gt-1}} \right)^{\frac{1}{\sigma_g - 1}}$$

where $I_g = I_{gt} \cap I_{gt-1}$ is the set of goods common to both periods and $\lambda_{gt}$ is the share of these common goods as a fraction of total expenditure on good $g$,

$$\lambda_{gt} = \frac{\sum_{i \in I_g} p_{git} x_{git}}{\sum_{c \in I_{gt}} p_{git} x_{git}} . \tag{25}$$

This is an important result: it allows us to compute the change in the price index even though we do not have prices for the newly traded goods.

Since preferences over goods are CES and the set of goods, $G$, is constant, Broda and Weinstein (2006) apply (24) at the good level to create the aggregate import price index

$$\pi^M(\mathbf{p}_{gt}, \mathbf{p}_{gt-1}, \mathbf{x}_{gt}, \mathbf{x}_{gt-1}, I_g) = \prod_{g \in G} P_g^M(\mathbf{p}_{gt}, \mathbf{p}_{gt-1}, \mathbf{x}_{gt}, \mathbf{x}_{gt-1}, I_g)^{\omega_{gt}} \times \prod_{g \in G} \left( \frac{\lambda_{gt}}{\lambda_{gt-1}} \right)^{\frac{\omega_{gt}}{\sigma_g - 1}} . \tag{26}$$

The second product on the right hand side of (26) is the contribution of new varieties to the price index—what Broda and Weinstein call the *aggregate import bias*. The lambda ratio, $\lambda_{gt} / \lambda_{gt-1}$, measures the extent to which the changing varieties impact expenditure on the common set of goods. If the new varieties have small expenditure shares, the lambda ratio will be close to one, and the bias will be small. The lambda ratio is weighted by a term that involves both the good's elasticity of substitution and the good's weight in expenditure. Goods with less substitutable varieties or goods with larger weights have larger impacts on the bias.

To compute the aggregate import bias for China and Mexico, we define a good to be a 3 digit category of the Harmonized System (HS). We define a variety to be a 6 digit HS code – country pair. A good, for example, would be 090, "Coffee, tea, mate, and seed spices," while a variety would be 090111-Colombia, "Coffee, not roasted, not decaffeinated" from Colombia, which is a different variety than 090111-Costa Rica. We have 164 goods in each country. In China, the median number of varieties per good was 300.5 in 1998 and grew to 406 in 2008. In Mexico, the median number of varieties per good rose from 150.5 in 1990 to 230.5 in 2008.

Using a methodology similar to that in Broda, Greenfield, and Weinstein (2006), we estimate an elasticity of substitution for each good in both China and Mexico. The mean and median elasticities are reported in table 1 and a complete listing of the estimated elasticities—as well as the estimation details—can be found in the appendix. Table 1 also provides a snapshot of the lambda ratios in the two countries. The distribution of lambda ratios is similar in both countries. The median lambda ratios are near 0.95 and the 95 percentile ratio is about 1.03. The bias in the aggregate import price index, over the 11 year period, is 0.96 for Mexico; the price of a unit of the composite import in Mexico has fallen by 4 percent over the period because of the increase in imported varieties. The composite import price in China fell by about 3 percent.

We can put these numbers into perspective by calculating the amount of income an agent is willing to give up in order to consume the extra varieties. This compensating variation is computed as

$$\nu = \prod_{g \in G} \left( \frac{\lambda_{gt}}{\lambda_{gt-1}} \right)^{-\omega_{Mt} \frac{\omega_{gt}}{\sigma_g - 1}}, \qquad (27)$$

which is the inverse of aggregate import price bias, weighted by the share of imports in total expenditure. We report the import weights and the compensating variation in table 1. The consumer in Mexico is willing to pay 0.94 percent of income—and in China, 0.55 percent of income—to access the new varieties of imports accumulated over the 11 year span. While GDP has grown faster in China than in Mexico, the welfare gains from new imported varieties are similar across countries.

We have followed Broda, Greenfield, and Weinstein (2006) in estimating country-specific elasticities. Our estimates imply that varieties are more substitutable in China than in Mexico, which contributes to the smaller gains from variety in China. As a robustness check, in column 5 of table 1, we calculate the compensating variation for China using the elasticities estimated from the Mexican data. Column 3 reports the Mexican compensating variation computed with the elasticities estimated from the Chinese data. Not surprisingly, the gains from varieties in Mexico fall and the gains in China increases. In either case, when measured with a common set of elasticities, the gains from variety in each country are similar.

## 7. Conclusion

To the extent that trade liberalization leads to higher productivity or higher rates of growth in real GDP, it does so through mechanisms that are, for the most part, outside of those analyzed in standard models. Determining the relation between trade liberalization and growth is not just a challenge for empirical research but also for theoretical research.

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**Table 1**

| | Mexico 1990-2000 | | China 1998-2008 | |
|---|---|---|---|---|
| Elasticities estimated from | Mexico | China | China | Mexico |
| Mean Elasticity | 3.702 | 6.088 | 6.088 | 3.702 |
| Median Elasticity | 3.298 | 5.455 | 5.455 | 3.298 |
| | | | | |
| 5 percentile lambda ratio | 0.832 | 0.832 | 0.789 | 0.789 |
| Median lambda ratio | 0.956 | 0.956 | 0.954 | 0.954 |
| 95 percentile lambda ratio | 1.028 | 1.030 | 1.031 | 1.031 |
| | | | | |
| Import price bias | 0.959 | 0.983 | 0.971 | 0.958 |
| Import log-change weight | 0.224 | 0.224 | 0.185 | 0.185 |
| Compensating variation (%) | 0.940 | 0.396 | 0.549 | 0.795 |

**Figure 1**

Growth in imports

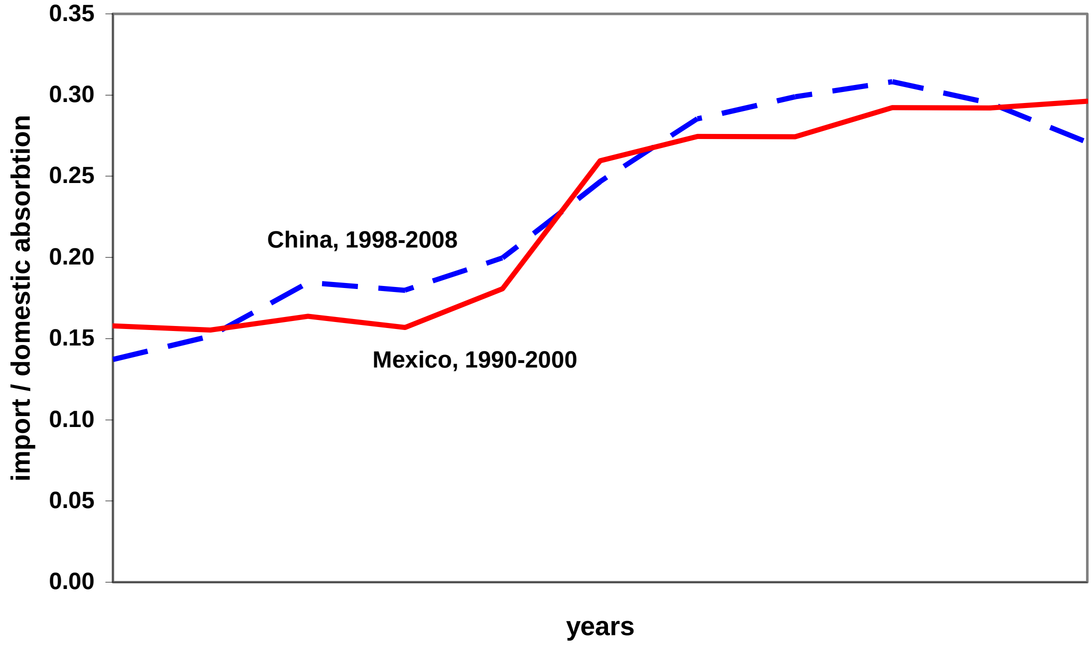



**Figure 2**

Growth in GDP per capita

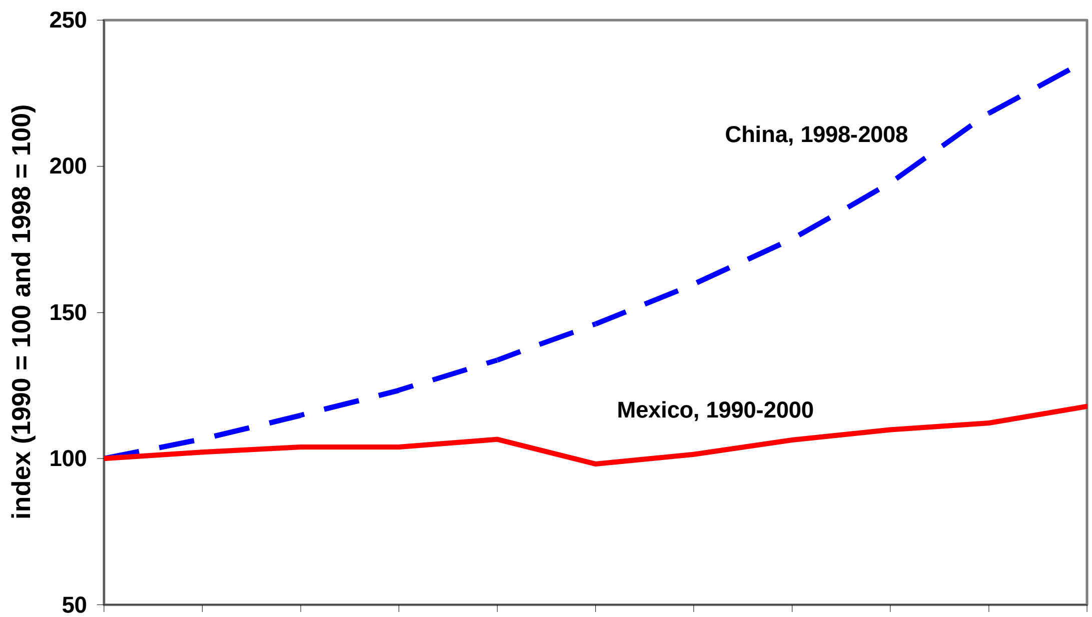


**Figure 3**

**Figure 4**

**Real GDP indices, capital-abundant country**

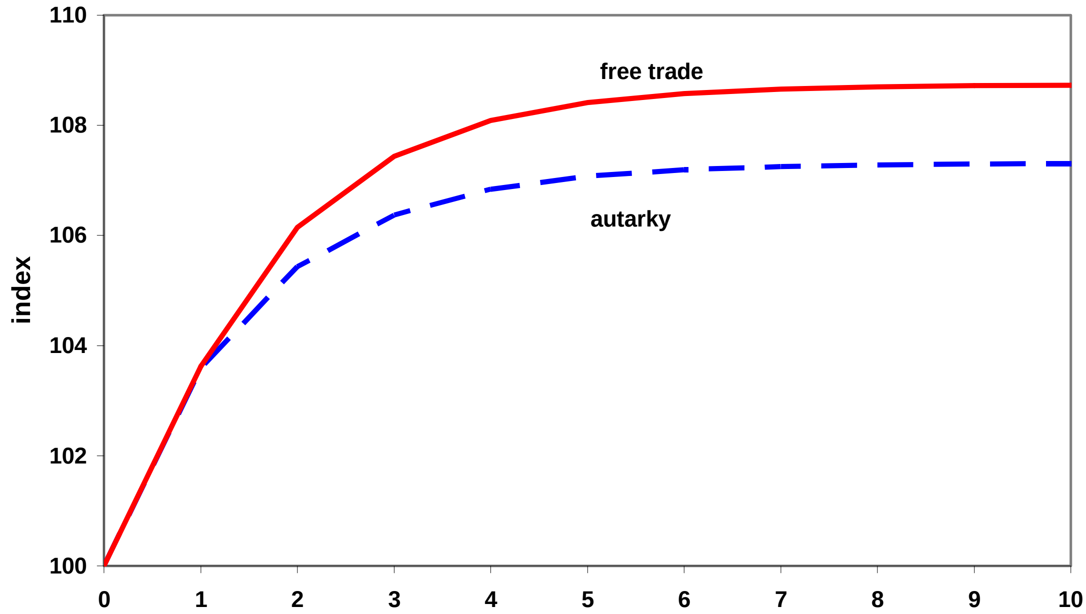



**Figure 5**

**Real GDP indices, capital-poor country**

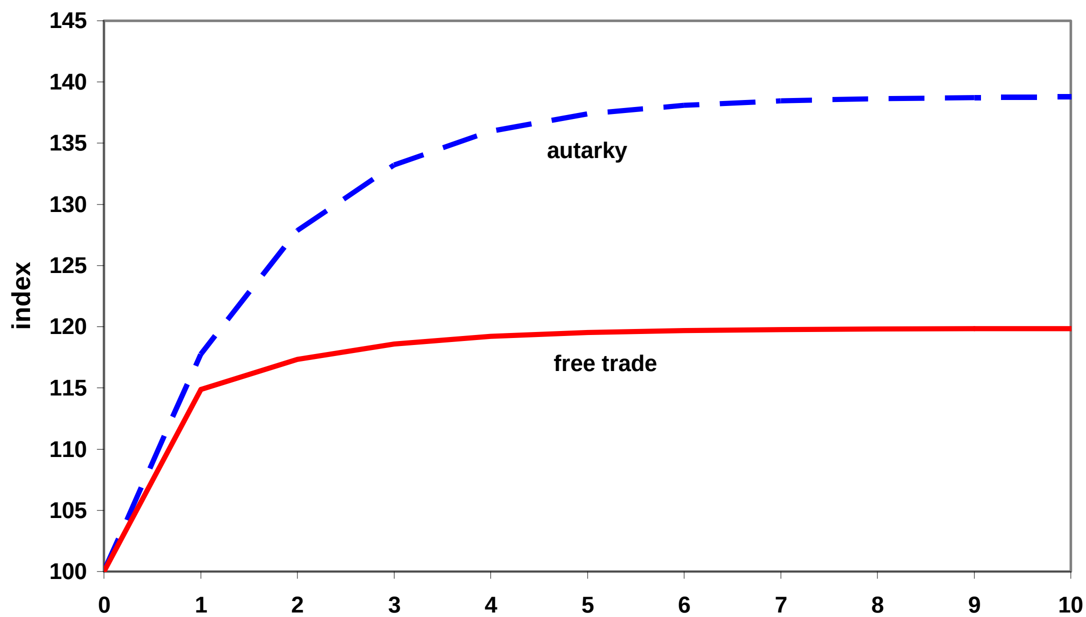
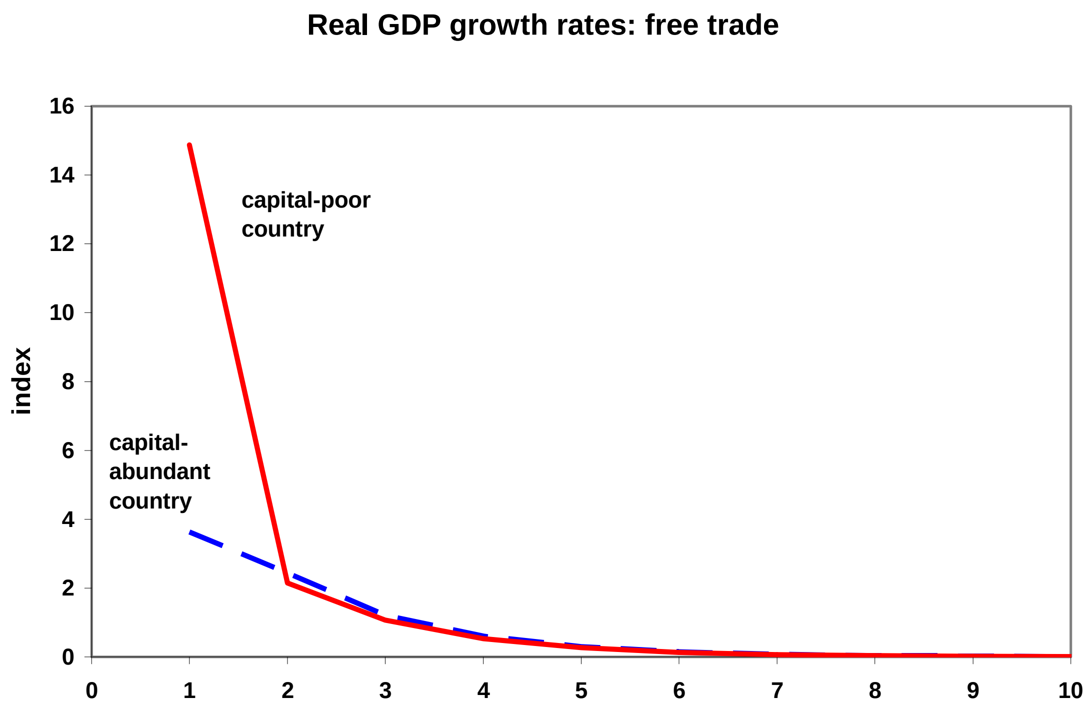


**Figure 6**


Real GDP growth rates: free trade
index
16
14
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capital-poor country
capital-abundant country