Real exchange rates, income per capita, and sectoral input multipliers*

Javier Cravino
University of Michigan
and NBER

Sam Haltenhof
University of Michigan

November 2016

Abstract

Aggregate price levels are positively related to income per capita across countries. We propose a mechanism to rationalize this observation that relies on sectorial differences in intermediate input intensities. As aggregate productivity and income grow, so does the cost of labor relative to intermediate inputs, which in turn increases the relative price of non-tradables if tradable sectors use intermediate inputs more intensively. In contrast to the Balassa-Samuelson hypothesis, this mechanism does not rely on sectorial differences in the level of productivity, and hence can be easily quantified using input-output data. We show that differences in intermediate input shares across sectors can account for about half the elasticiy of the aggregate price level with respect to GDP per capita. The mechanism also has stark implications for industry-level real exchange rates that are strongly supported by the data.

Keywords: Real Exchange Rates, PPP, Balassa-Samuelson, Penn Effect, Input Multiplier

JEL codes: F31, F41

*We thank Guangye Cao for superb research assistance, and seminar participants at the University of Michigan for helpful comments and suggestions. Email: jcravino@umich.edu; shalten@umich.edu.

1 Introduction

Aggregate price levels are positively related to income per capita across countries, as illustrated in Figure 1.[1] The leading explanation for this observation is the Balassa-Samuelson hypothesis, which postulates that productivity in tradable relative to non-tradable sectors increases with income. If the price of tradables is equalized across countries, then the aggregate price level will be higher in rich countries.

In spite of its popularity, empirical evidence supporting the Balassa-Samuelson hypothesis is scarce. An important limitation is that, since sectorial productivities are rarely measured in levels, the model's predictions for relative price levels (i.e. real exchange rate levels) cannot be confronted with data.[2] As a result, most of the empirical literature has focused on studying the model's predictions for the growth of the real exchange rate using proxies for sectorial productivity growth, often with mixed results.[3]

This paper proposes an alternative mechanism linking real exchange rates to income per capita which relies on sectorial differences in intermediate input intensities rather than on cross-country differences in sectorial productivities, and hence can be easily quantified using readily-available input-output data. The mechanism is an extension of that in Bhagwati (1984), who argued that the price level should grow with income per capita if tradable sectors are capital intensive. We extend this idea to incorporate sectorial differences in intermediate inputs shares, which we show are much larger in tradable than in non-tradable sectors. The extended theory implies that, as aggregate productivity and income grow, so does the cost of labor relative to intermediate inputs, which in turn generates an increase in the relative price of non-tradables and the aggregate price level.

We quantify this mechanism by incorporating differences in input intensities across tradable and non-tradable sectors into a textbook open economy model.[4] In the model, real exchange rate levels are shaped by two mechanisms. First, differences in price levels across countries depend on cross-country differences in sectorial technology, as in the standard Balassa-Samuelson model. As highlighted above, this effect cannot be quantified directly as the level of sectorial productivity in each country is not observable. Second, real exchange rate levels are also shaped by differences in the input multiplier across

[1] See Rogoff (1996) or Feenstra et al. (2015). The positive relation between relative prices and GDP per capita is often referred to as the 'Penn Effect', after Summers and Heston (1991).

[2] Measures of sectorial productivity are typically available in index form only. An important exception is a recent paper by Berka et al. (2014), who find evidence in favor of an amended the Balassa-Samuelson model using newly constructed indexes on productivity levels for 9 European countries.

[3] In particular, a large literature finds that the Balassa-Samuelson model does not do well in explaining real exchange rates except in the very long run. See for example De Gregorio et al. (1994), Rogoff (1996), Tica and Druzic (2006), Lothian and Taylor (2008) and Chong et al. (2012).

[4] See for example Obstfeld and Rogoff (1996).

sectors, coupled with differences in aggregate productivity across countries, as explained above. How input multipliers affect the relative price of non-tradables depends on intermediate input and capital compensation shares. How non-tradable prices affect the aggregate price level depends on the share of non-tradables in aggregate GDP. Crucially, since the second mechanism does not depend on the relative levels of sectorial productivity, it can be easily quantified using publicly available input-output and GDP data.

We show that sectorial differences in input multipliers account for the bulk of the relation between income per capita and the aggregate price level across countries. In particular, we compute real exchange rates in the model assuming that there are no differences in sectorial technology across countries. Under this assumption, sectorial differences in input multipliers are the only source of variation in real exchange rate levels. The resulting elasticity of the relative price level to GDP per capita is 0.11 in the model, versus 0.23 in the data.[5] Moreover, the mechanism accounts for 46 percent of the cross-country variation in aggregate price levels, as measured by the R-squared of a regression of observed real exchange rates on the real exchange rates produced by the model with no cross-country differences in sectorial technology. This model also accounts for about half of the elasticity of the growth of the real exchange rate to the growth of relative GDP, as the elasticity in growth rates is the same as the elasticity in levels both in the model and in the data.

The mechanism also has strong implications for the behavior of industry-level real exchange rates. It implies that, as income increases, industry-level prices should increase relative to the aggregate price of non-tradables for industries where the share of intermediate inputs is lower than for the non-tradable sector as a whole. We find strong support for this prediction using detailed industry-level relative price indexes from the International Comparison Program (ICP). We also calibrate the model to the industry-level data and show that it accounts for a significant fraction of the variation in industry-level real exchange rates. While the Balassa-Samuelson model can rationalize these industry-level predictions, it can only do so through specific assumptions on how industry-level productivities change with income. Instead, our model delivers these predictions out of observed input coefficients for different industries.

We note that in our model, even under the assumption that there are no differences in sectorial technologies across countries, differences in sectorial value-added productivity across countries arise endogenously from sectorial differences in input multipliers coupled with cross-country differences in aggregate productivity. This distinction between gross-output and value-added productivity does not arise in the textbook Balassa-Samuelson model without intermediate inputs. However, given value-added productiv-

[5]This elasticity is consistent with the estimates on Feenstra et al. (2015).

ities in each country and each sector, the two models have the same predictions for the level of the real exchange rate. An advantage of the mechanism highlighted in this paper is that the differences in sectorial value-added productivities arise endogenously from observed input multipliers. This allows us to quantify the mechanism using aggregate data.

Our paper contributes to the long literature that studies the relationship between price levels and GDP per capita. Most of this literature has looked at the relationship between productivity and real exchange rate growth, but in most cases has only found evidence of a long run relationship such as co-integration.[6] In a recent series of papers, Berka et al. (2014) and Berka and Devereux (2013) use newly-constructed data on Price Level Indices for countries in the EU to show evidence in favor of an amended Balassa-Samuelson model. Our paper complements these studies by proposing a mechanism through which differences in sectorial productivities arise endogenously from the differences in input intensities across sectors, in the spirit of Jones (2011). Since the mechanism does not require data on the level of sectorial productivity, we can quantify it both in growth rates and levels for a broad set of countries.

The rest of the paper is organized as follows. Section 2 uses a simple model to illustrate our main results relating real exchange rate levels to income per capita. Section 3 describes a more detailed model incorporating capital as a factor of production and a richer input-output structure and that will be used for our quantification. Section 4 describes the data. Section 5 presents the quantitative results. Section 6 concludes.

2 Intermediate input multipliers and sectorial relative prices

Consider a small open economy that produces two goods, tradables and non-tradables, using labor and intermediate inputs. For the moment assume that production does not use intermediate inputs that are produced in other sectors.[7] The price of tradables is equalized across countries and set as the numeraire, $P^T = 1$. The production function for good j is given by:

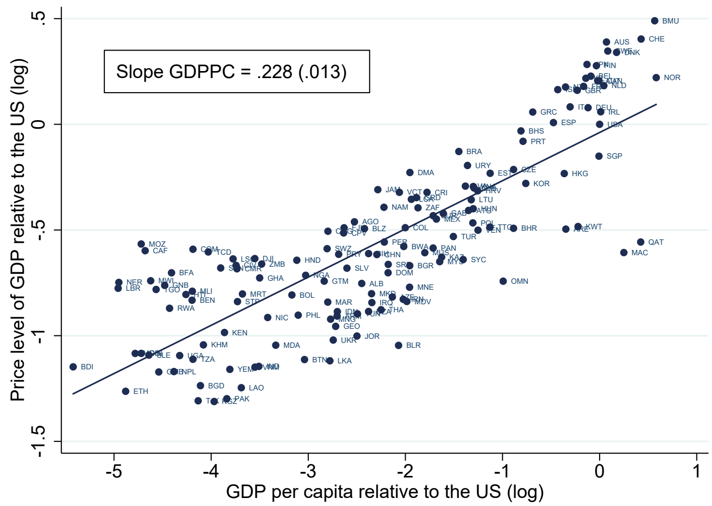
$$Y^j = Z\bar{A}^j L^{j\theta^j} M^{j1-\theta^j},$$

where L^j and M^j denote labor and intermediate inputs used in sector j, and $Z \times A^j$ is a productivity term that has an aggregate and a sector-specific component. All markets are

[6] See for example Asea and Mendoza (1994), De Gregorio et al. (1994), Canzoneri et al. (1999) and Lee and Tang (2007).

[7] That is, non-tradables are not used in the production of tradables, and vice-versa.

Figure 1: Price level of GDP and income per capita



Source: Penn World Table 9.0.

perfectly competitive, so the price of good j equals

$$P^j = \left[ZA^j\right]^{\frac{-1}{\theta^j}} W,$$

where $A^j \equiv \bar{A}^j \theta^{j\theta^j} \left[1-\theta^j\right]^{1-\theta^j}$. The price of non-tradables in terms of tradables is then:

$$P^N = \left[A^T W^{\theta^N - \theta^T}\right]^{\frac{1}{\theta^N}},$$

where we normalized $A^N = 1$ without loss of generality.

Let $P \equiv \left[P^N\right]^{\omega}$ denote the aggregate price level of GDP in terms of the tradable good, where ω is the share of non-tradables in GDP. In addition, let the lower case of a variable denote the log of the variable, with $\Delta x \equiv x - x_w$ denoting the log of a variable relative to the rest of the world. Noting that GDP per capita in this economy is given by the wage, we can write the log of price level relative to the rest of the world, $q \equiv \Delta p$, as:

$$q = \frac{\omega}{\theta^N}\left[\Delta a^T + \left[\theta^N - \theta^T\right]\Delta gdp\right], \tag{1}$$

where we used the equality $\Delta w = \Delta gdp$.

Equation (1) relates relative price levels to cross-country differences in relative sectorial productivities and cross-country differences in GDP per capita.[8] It postulates that the price level should be higher in countries that are relatively more productive in the tradable sector (high a^T). In the Balassa-Samuelson model, it is assumed that a^T is relatively high in rich countries, which leads to a positive correlation between the relative price level and income per capita. The equation also shows that, if the share of value added is larger in non-tradable sectors, $\theta^N > \theta^T$, prices should be higher in countries with a high level of GDP per capita, even if there are no cross-country differences in sectorial productivity $\Delta a^T = 0$.[9]

Value-added production functions and mapping to the Balassa-Samuelson model We can write the production functions in this model in value-added, rather than in gross-output terms. Substituting intermediate input demands into the value-added production functions, $V^j \equiv \theta^j Y^j$, we obtain

$$V^j = B^j L^j, \tag{2}$$

where $B^j \equiv \left[ZA^j\right]^{\frac{1}{\theta^j}}$.[10] The equation shows that even if there are no differences in gross-output productivity across sectors, $A^j = 1$, sectorial differences in value-added productivity B^j can arise endogenously from differences in the share of intermediate inputs in production, θ^j. The intuition for this result is that, as noted by Jones (2011), intermediate inputs deliver a multiplier similar to the multiplier associated with capital in the neoclassical growth model. If the multiplier is greater in the tradable sector, $\theta^T < \theta^N$, this implies that a given increase in aggregate productivity Z has a larger impact in tradable than in non-tradable output.

This observation makes clear that the theoretical predictions of the model for the real exchange rate are isomorphic to a Balassa-Samuelson model with production functions given by equation (2). We highlight two important advantages of incorporating differences in the intermediate-input multiplier across sectors explicitly in the model. First, while the Balassa-Samuelson model simply assumes how differences in sectorial productivities change with development (i.e. the model assumes a correlation between B^T/B^N

[8]The relation between relative price levels and GDP evaluated at world prices (that is, PPP adjusted GDP), $gdp^{ppp} \equiv gdp - q$, is:

$$q = \frac{\omega}{\bar{\theta}} \left[\Delta a^T + \left[\theta^N - \theta^T\right] \Delta gdp^{ppp}\right],$$

where $\bar{\theta} \equiv \omega\theta^T + \theta^N\left[1-\omega\right]$. We evaluate this relation in our robustness exercises.

[9] Note that this includes the case in which there are no differences in productivities across sectors.

[10]This follows from the input demands that minimize costs, $M^j = \left[\left[1-\theta^j\right] Z\bar{A}^j\right]^{\frac{1}{\theta^j}} L^j$.

and GDP per capita), in our model these differences arise endogenously from differences in the intermediate input multiplier across sectors and differences in aggregate productivity Z across countries. Perhaps more importantly, differences in the relative level of productivity across sectors and countries are not measured by statistical agencies -i.e. neither a^T nor b^T is measured in levels- which makes it virtually impossible to take the Balassa-Samuelson hypothesis to the data in levels. In contrast, differences in the share of intermediate inputs across sectors are easily quantifiable, so the input multiplier channel can be confronted with data directly. A back of the envelope calculation using equation (1) reveals that this channel is potentially large: using US values for θ^N =0.61, θ^T =0.35, and ω =0.84, indicates that, given relative sectorial productivities, the elasticity of the relative price level of GDP with respect to relative GDP per capita is 0.38 vs. 0.23 in the data in Figure 1. The remainder of the paper measures the importance of this channel in a more detailed quantitative framework that incorporates capital as a factor of production, allows for a richer input-output structure, and allows for differences in factor shares across countries.

3 Quantitative framework

We now extend the simple model from Section 2 to incorporate capital as a factor of production and to allow for a more realistic input-output structure and for differences in factor shares across countries. As in the previous section, we consider a small open economy that produces 2 types of goods,[11] tradables and non-tradables, using labor, capital, and intermediate inputs. The price of the tradable good is equalized across countries and taken as the numeraire, $P_t^T = 1$. All markets are perfectly competitive.

Production The production function for good $j = T, N$ is given by:

$$Y_{i,t}^j = Z_{i,t} \bar{A}_{i,t}^j \left[L_{i,t}^{j\,1-\alpha_i^j} K_{i,t}^{j\,\alpha_i^j} \right]^{\theta_i^j} \prod_{j'} \left[M_{i,t}^{j',j} \right]^{\sigma_i^{j'j} \left[1-\theta_i^j\right]}, \tag{3}$$

where $Y_{i,t}^j$ and $L_{i,t}^j$ and $K_{i,t}^j$ denote gross output, employment, and capital in country i and sector j, and $M_{i,t}^{j',j}$ is the quantity of intermediate inputs from sector j' used in the production of sector j. θ_i^j and α_i^j denote the share of value added in gross output and the share of capital in value added respectively. The share of inputs used in sector j that

[11] We distinguish among different non-tradable products in our extension of Section 3.1.

originate in sector j' is given by $\sigma_i^{j'j} \times \left[1-\theta_i^j\right]$, where $\sum_{j'} \sigma_i^{j'j} = 1$. Note that production in sector j can potentially use inputs from every other sector j'. As in the previous section, $Z_{i,t} \times \bar{A}_{i,t}^j$ is a productivity term that has an aggregate and a sector-specific component.

Prices Perfect competition implies that the price of good j is given by:

$$P_{i,t}^j = \bar{\gamma}_i^j W_{i,t}^{\left[1-\alpha_i^j\right]\theta_i^j} R_{i,t}^{\alpha_i^j \theta_i^j} \left[\prod_{j'} \left[P_{i,t}^{j'}\right]^{\sigma_i^{j'j}\left[1-\theta_i^j\right]}\right] / \left[\bar{A}_{i,t}^j Z_{i,t}\right],$$

where $W_{i,t}$ and $R_{i,t}$ denote the wage and the rental rate of capital in country i in units of the tradable good and where $\bar{\gamma}_i^j$ is a constant.[12] Normalizing $\bar{A}_{i,t}^N = 1$ we can write the price of non-tradables in terms of tradables as:

$$P_{i,t}^N = \left[\frac{\bar{\gamma}_i^N}{\bar{\gamma}_i^T} \bar{A}_{i,t}^T W_{i,t}^{\theta_i^N - \theta_i^T} \left[\frac{R_{i,t}}{W_{i,t}}\right]^{\alpha_i^N \theta_i^N - \alpha_i^T \theta_i^T}\right]^{\frac{1}{\bar{\theta}_i^N}},$$

where $\bar{\theta}_i^N \equiv \theta_i^N + \sigma_i^{TN}\left[1-\theta_i^N\right] + \sigma_i^{NT}\left[1-\theta_i^T\right]$.

Relative prices and GDP per-capita We are interested in understanding the relation between the aggregate price level and GDP per capita. Let $1-\bar{\alpha}_i \equiv W_{i,t}L_{i,t}/GDP_{i,t}$ and $\bar{\alpha}_i \equiv R_{i,t}K_{i,t}/GDP_{i,t}$ denote the aggregate labor share and capital share in country i, where $L_{i,t} = \sum_j L_{i,t}^j$ and $K_{i,t} = \sum_j K_{i,t}^j$ are the aggregate labor supply and the aggregate capital stock. Factor prices are related to factor supplies by:

$$\frac{R_{i,t}}{W_{i,t}} = \frac{\bar{\alpha}_i}{1-\bar{\alpha}_i} \frac{L_{i,t}}{K_{i,t}}.$$

We can then write the (log) price of non-tradables in terms of tradables as:

$$p_{i,t}^N = \frac{a_{i,t}^T}{\bar{\theta}_i^N} + \frac{\alpha_i^T \theta_i^T - \alpha_i^N \theta_i^N}{\bar{\theta}_i^N} k_{i,t}^y + \frac{\theta_i^N\left[1-\alpha_i^N\right] - \theta_i^T\left[1-\alpha_i^T\right]}{\bar{\theta}_i^N} gdp_{i,t}, \tag{4}$$

where $k_{i,t}^y$ is the log of the capital-output ratio in the economy, $gdp_{i,t}$ is the log of GDP per capita measured in units of the tradable good, and $a_{i,t}^T$ captures country-specific produc-

[12] The constant is given by $\left[\bar{\gamma}_i^j\right]^{-1} \equiv \left[\left[1-\alpha_i^j\right]^{1-\alpha_i^j} \alpha_i^{j\alpha_i^j}\right]^{\theta_i^j} \theta_i^{j\theta_i^j} \left[1-\theta_i^j\right]^{1-\theta_i^j} \left[\prod_{j'} \sigma_i^{j'j \sigma_i^{j'j}}\right]^{\left[1-\theta_i^j\right]}$.

tivity differences across the two sectors.[13] Equation (4) links the price of non-tradables to income per capita and the capital-labor ratio in the economy. The equation shows that, if the share of labor in gross output is relatively high in the non-tradable sector, $\theta_i^N \left[1-\alpha_i^N\right] > \theta_i^T \left[1-\alpha_i^T\right]$, the price of non-tradables increases with income per capita. Intuitively, as productivity grows, labor gets more expensive relative to intermediate inputs, which increases the price in sectors that use labor more intensively. In addition, if the non-tradable sector uses capital more intensively, $\alpha_i^N \theta_i^N > \alpha_i^T \theta_i^T$, the price of non-tradables decreases with the capital-output ratio in the economy, $k_{i,t}^y$.

Decomposing relative price levels We now decompose the determinants of real exchange rates in the model. To facilitate comparisons with the data in Figure 1 we focus on the price level of GDP in each country relative to the US. The log of the price level of GDP in country i is defined as $p_i = \omega_i^N p_i^N$, where ω_i^j denotes the share of sector j in country i's GDP. Letting $\Delta x_i \equiv x_i - x_{us}$ denote the log difference of a variable relative to the US, we can write the log-price of GDP in country i relative to the US, $q_{i,t} \equiv \omega_i^N \Delta p_i^N$, as:[14]

$$q_{i,t} = \omega_i^N \Delta \bar{a}_{i,t}^T + \omega_i^N \frac{\alpha_i^T \theta_i^T - \alpha_i^N \theta_i^N}{\bar{\theta}_i^N} \Delta k_{i,t}^y + \omega_i^N \frac{\theta_i^N \left[1-\alpha_i^N\right] - \theta_i^T \left[1-\alpha_i^T\right]}{\bar{\theta}_i^N} \Delta gdp_{i,t}, \quad (5)$$

where

$$\Delta \bar{a}_{i,t}^T = \Delta \left[\frac{a_{i,t}^T}{\bar{\theta}_i^N}\right] + k_{us,t} \times \Delta \left[\frac{\alpha_i^T \theta_i^T - \alpha_i^N \theta_i^N}{\bar{\theta}_i^N}\right] + gdp_{us,t} \times \Delta \left[\frac{\theta_i^N \left[1-\alpha_i^N\right] - \theta_i^T \left[1-\alpha_i^T\right]}{\bar{\theta}_i^N}\right].$$

Equation (5) decomposes cross-country differences in the price level into three terms. The first term, $\Delta \bar{a}_{i,t}^T$, captures differences in the price level that arise from cross-country differences in sectorial technology, which encompass both cross-country differences in the relative level of sectorial productivity present in the Balassa-Samuelson model, $\bar{A}_i^T$, and cross-country differences in sectorial factor shares α_i^j, θ_i^j, and $\bar{\theta}_i^N$. Note that this term cannot be measured with standard national accounts data, as it requires not only data on the relative level of sectorial productivity, $\bar{A}_i^T$, but also data on the level of US GDP measured in units of tradables (which requires taking a stand on the level of the dollar price of tradable goods).

[13] That is, $k_{i,t}^y \equiv log \frac{K_{i,t}}{GDP_{i,t}}$, $gdp_{i,t} \equiv log \frac{GDP_{i,t}}{L_{i,t}}$, and $a_{i,t}^T \equiv log \left[\frac{\bar{\gamma}_i^N}{\bar{\gamma}_i^T} \bar{\alpha}_i^{\alpha_i^N \theta_i^N - \alpha_i^T \theta_i^T} \left[1-\bar{\alpha}_i\right]^{\theta_i^N \left[1-\alpha_i^N\right] - \left[1-\alpha_i^T\right] \theta_i^T} \bar{A}_{i,t}^T\right]$.

[14] Note that, in line with the price level index estimates of the ICP, our relative price level focuses on weighted averages of relative price differences ($\sum_j \omega_i^j \left[p_i^j - p_{us}^j\right]$) as opposed to differences in the weighted average or price levels ($\sum_j \omega_i^j p_i^j - \sum_j \omega_{us}^j p_{us}^j$).

The second term captures how cross-country differences in the capital-output ratio affect relative price levels, and states that the relative price level should increase with the capital-output ratio if the production of tradables is more intensive in capital $\alpha_i^T \theta_i^T > \alpha_i^N \theta_i^N$. This mechanism resembles the one highlighted by Bhagwati (1984). Note that if the share of value added in the tradable sector is low enough, the price level can actually decrease with the capital-output ratio even if the capital share in value added is higher in the tradable sector $\alpha_i^T > \alpha_i^N$. Indeed, in contrast to what is postulated in Bhagwati (1984), $\alpha_i^T \theta_i^T < \alpha_i^N \theta_i^N$ for the vast majority of countries for which input-output data is available.[15]

Finally, the last term captures the differences in aggregate price levels that arise from differences in GDP per capita across countries coupled with differences in the input and capital multipliers. It states that, if the multipliers are larger in the tradable sector ($\theta_i^N \left[1 - \alpha_i^N\right] > \theta_i^T \left[1 - \alpha_i^T\right]$) countries with higher GDP per capita should have a higher price level. This effect is the main focus of this paper and is measured in the quantitative section below.

3.1 Industry-level real exchange rates

Before moving to our quantitative exercises, we extend the model to derive predictions for industry-level real exchange rates. In particular, we assume there are $l = 1, ..., L$ non-tradable industries within the non-tradable sector, each of which is produced with the production function

$$Y_{i,t}^N(l) = \bar{A}_{i,t}^N(l) Z_{i,t} \left[L_{i,t}^N(l)^{1-\alpha_i^N} K_{i,t}^N(l)^{\alpha_i^N} \right]^{\theta_i^N(l)} \prod_{j'} \left[M_{i,t}^{j',N}(l) \right]^{\sigma_i^{j'N}\left[1-\theta_i^N(l)\right]}.$$

The production function above allows the share of value added $\theta_i^N(l)$ and the relative level of productivity $\bar{A}_{i,t}^N(l)$ to differ across non-tradable industries. For simplicity, we assume that all non-tradable industries have the same capital and intermediate input share (α_i^N and $\sigma_i^{j'N}$ are the same across l). Let $\omega_i^N(l)$ denote the share of industry l in the non-tradable sector. We can write the log of the non-tradable price index as:

$$p_{i,t}^N = \sum_{l \in N} \omega_i^N(l) \, p_{i,t}^N(l),$$

[15] Equation (5) can also be written as $q_{i,t} = \omega_i^N \left[\Delta \bar{a}_{i,t}^T + \frac{\alpha_i^T \theta_i^T - \alpha_i^N \theta_i^N}{\theta_i^N} \Delta k_{i,t} + \frac{\theta_i^N - \theta_i^T}{\theta_i^N} \Delta gdp_{i,t} \right]$, where $k_{i,t}$ is the capital-labor ratio (rather than the capital-output ratio) in the country. I this case, the second term captures exactly differences in capital abundance, as postulated by Bhagwati (1984). We write (5) in terms of the capital-output ratio to better isolate the effect of relative GDP per capita on the relative price level, as the capital output-ratio is not related to GDP per capita in the data. We discuss this in detail in Section (5).

where $p^N_{i,t}(l)$ is the (log of the) price level in industry l. From the production function we can write the price of the good produced in industry l as a function of GDP per capita as:

$$p^N_{i,t}(l) = a^N_{i,t}(l) - a^N_{i,t} + \beta^k_i(l)\, k^y_{i,t} + \beta^{gdp}_i(l)\, gdp_{i,t},$$

with

$$\beta^{gdp}_i(l) = \left[\theta^N_i(l) - \theta^N_i\right]\left[1-\alpha^N_i\right] + \frac{\theta^N_i\left[1-\alpha^N_i\right]}{\bar{\theta}^N_i} - \frac{\theta^T_i}{\bar{\theta}^N_i}\left[1-\alpha^T_i\right],$$

and

$$\beta^k_i(l) = \frac{\alpha^T_i\theta^T_i - \alpha^N_i\theta^N_i}{\bar{\theta}^N_i} + \alpha^N_i\theta^N_i - \alpha^N_i\theta^N_i(l).$$

The price in industry l in country i relative to the US is:

$$\Delta p^N_{i,t}(l) = \Delta\left[a^N_{i,t}(l) - a^N_{i,t}\right] + \beta^k_i(l)\,\Delta k^y_{i,t} + \beta^{gdp}_i(l)\,\Delta gdp_{i,t}, \tag{6}$$

In addition, we can write the price of industry l relative to the price of non-tradables, relative to the US as:

$$\Delta\left[p^j_{i,t}(l) - p^N_{i,t}\right] = \Delta a^N_{i,t}(l) + \alpha^N_i\left[\theta^N_i - \theta^N_i(l)\right]\Delta k^y_{i,t} + \left[1-\alpha^N_i\right]\left[\theta^N_i(l) - \theta^N_i\right]\Delta gdp_{i,t}. \tag{7}$$

Equation (7) states that, as income grows, industry-level prices will rise relative to the price of non-tradables in industries where the share of intermediate inputs is relatively high, $\theta^N_i(l) < \theta^N_i$.

4 Data

To evaluate the relation between prices and income per capita derived in the previous section, we need data on relative price levels, GDP per capita, and the capital-output ratio across countries. We also need to assign values to the share of value added in each country and sector, θ^j_i, the labor share in each country and sector, $1-\alpha^j_i$, the intermediate inputs shares, $\sigma^{j'j}_i$, and the share of non-tradables in GDP, ω^N_i.

Relative price levels, income per-capita and capital-output ratio: Our cross-country data on relative prices comes from the Penn World Table 9.0 (PWT). Our baseline relative price measure is the price level index of GDP relative to the US.[16] We complement this data with the benchmark ICP 2011 data containing sector-specific price level indices and expenditure shares.[17] In addition, we use GDP per capita at market prices from the ICP. We take GDP per capita at PPP dollars and the capital-output ratio in PPP dollars from the PWT as well.

Finally, in our robustness we also use data on relative price levels and relative income per capita across US states from the regional price parities and nominal personal income from the Regional Economic Accounts published by the BEA, and across EU regions from EUROSTAT.

Value added, factor, and intermediate input shares: Input-Output coefficients come from the OECD Inter-Country Input-Output (ICIO) Tables, which provides input-output tables for 62 countries between 1995-2011. We classify sectors in the ICIO and the ICP into tradables and non-tradables following Crucini et al. (2005).[18] We compute θ_i^j as the ratio of value added to gross output in each sector, and the parameters $\sigma_i^{j'j}$ as the ratio of the value of inputs from sector j' to the total value of inputs used in sector j.

Unfortunately, the shares of labor compensation in value added, $1 - \alpha_i^j$, are not directly observable in the ICIO tables. In particular, I-O tables report the share of compensation to employees relative to value added for each sector. It is well known that compensation to employees understates labor compensation as it does not include payments to self employed workers.[19] The PWT adjusts the labor income of employees to account for the income of self-employed workers to obtain an aggregate measure of the labor share. We follow this approach and rescale the sectorial ratios of compensation to employees to value added that we observe in the ICIO to match the aggregate labor shares reported in the PWT. In particular, for each country in the ICIO we compute

$$\alpha_i^j = \frac{\text{Compensation to employees}_i^j}{\text{Value added}_i^j} \times \frac{\text{Labor compensation}_i / \text{Value added}_i}{\text{Compensation to employees}_i / \text{Value added}_i}, \quad (8)$$

where the sectorial and aggregate ratios of compensation to employees to value added

[16] This is variable PL_GDP^o in the PWT. See Feenstra et al. (2015) for a description of the new PWT. We focus on a subsample of 128 countries, for which the data is balanced for the 1990-2014 period.

[17] While the benchmark PLIs in the detailed ICP data are defined relative to the world, we divide by the US PLIs to work with price indices of consumption relative to the US.

[18] See Table A1 in the Appendix

[19] See Gollin (2002) and Feenstra et al. (2015).

come from the ICIO, and the aggregate ratio of labor compensation to value added is obtained from the PWT. For countries not available in the ICIO tables, we impute the cross-country average of the observed θ_i^j, $\sigma_i^{j,j}$ and compensation-to-employees-to-value-added ratio, and use equation (8) to obtain sectorial measures of the labor share that are consistent with the PWT. In all cases, we use the shares as measured in 2011. The industries in ICIO are mapped to the industries in the ICP program with the concordance in Appendix Table A1. We compute the share of non-tradables in GDP, ω_i^N, from the expenditure data that underly the construction of the relative prices levels in the ICP program.

Appendix Table A2 reports the share of labor compensation in gross output, $\left[1-\alpha_i^j\right] \times \theta_i^j$, for the countries in our sample. Non-tradable sectors are significatively more labor intensive than tradable sectors for every country in the sample. For the average country, the share of labor in gross output in tradable sectors is about half than in the non-tradable sectors (0.154 vs 0.307).

5 Quantitative results

This section evaluates the predictions of the model derived in Section 3. First, we use equation (5) to evaluate whether sectorial differences in input multipliers coupled with cross-country differences in income per capita can account for the observed differences in price levels across countries. Second, we use equations (6) and (7) to test the industry-level predictions of the model. Third, we show that the model does well in accounting for the relation between price levels and income per capita measured at PPP prices, for the relation between the growth of the price level and income per capita across countries, and for the relation between prices and income per capita across US states and European regions.

5.1 Price levels and income per capita

We first evaluate the model's predictions for the relation between the aggregate price level and GDP per capita. In particular, we use equation (5) to compute the price level in each country relative to the US under the assumption that there are no cross-country differences in sectorial technology, $\Delta\bar{a}_{i,t}^T = 0$.[20] Abstracting from these differences allows

[20]That is, we assign values to the model parameters as described in Section 4 and use the data on the capital-output ratio and GDP per capita to compute $q_{i,t}^{base} = \omega_i^N \frac{\alpha_i^T\theta_i^T - \alpha_i^N\theta_i^N}{\bar{\theta}_i^N}\Delta k_{i,t}^y +$

us to focus on the role of sectorial input multipliers, as opposed to the standard Balassa-Samuelson effect highlighted in the literature.[21]

Figure 2 compares the relation between real exchange rate levels and GDP per capita in the model to that in the data. The first panel shows that the elasticity of the relative price of GDP to GDP per capita in the model is 0.105, almost half the 0.23 elasticity observed in the data. The second panel compares the relative price levels predicted by the model to those in the data. The observed differences in sectorial input multipliers coupled with the observed differences in GDP per capita account for a large share of the variation in relative price levels across countries, the R-squared of a regression of the real exchange rate levels in the data on those predicted by the model is 0.46 . Cross-country differences in sectorial technology can potentially still be important in accounting for the remaining variation in real exchange rate levels.

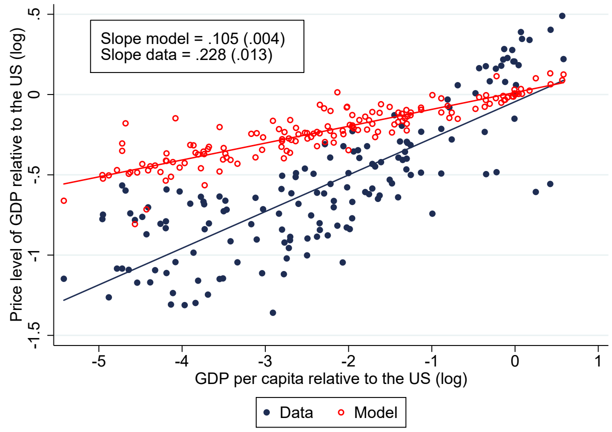
Figure 3 decomposes how cross-country differences in income per capita, $\Delta gdp_{i,t}$, and in the capital output ratio, $\Delta k^y_{i,t}$, shape real exchange rate levels in the model. The figure shows that the predictions of the model that ignores differences in the capital-output ratio across countries are almost identical to the baseline predictions of the model depicted in the first panel of Figure 2. In contrast, a model that focuses only on differences the capital-output ratio across countries generates almost no cross-country differences in price levels. This is not surprising as the capital-output ratio is not highly correlated to income per-capita and because the elasticities $\frac{\alpha_i^T\theta_i^T-\alpha_i^N\theta_i^N}{\bar{\theta}_i^N}$ are relatively small.[22] In fact, in contrast to the postulate of Bhagwati (1984), differences in the capital-output ratio generate a decreasing relation between price levels and income per capita, since in the data $\alpha_i^T\theta_i^T < \alpha_i^N\theta_i^N$, even though $\alpha_i^T > \alpha_i^N$. We conclude that the variation in real exchange rate levels in the model is almost entirely generated by cross-country differences in income per capita, $\Delta gdp_{i,t}$.

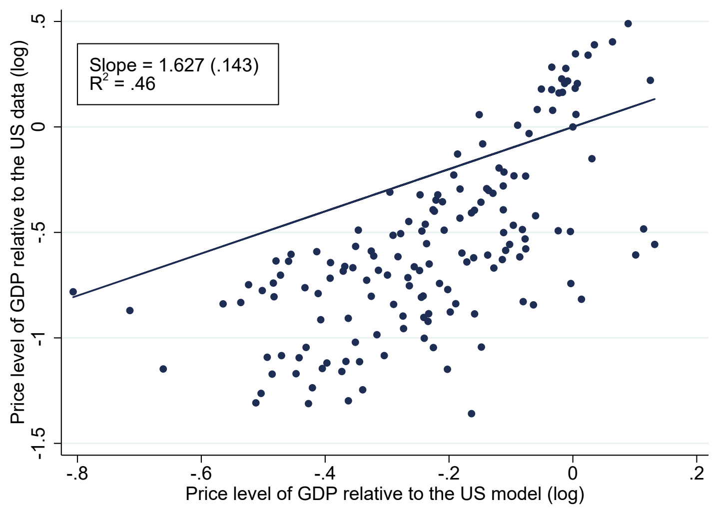
$\omega_i^N\frac{\theta_i^N[1-\alpha_i^N]-\theta_i^T[1-\alpha_i^T]}{\bar{\theta}_i^N}\Delta gdp_{i,t}$ for each country i.

[21] In addition, as we argued above, these effects cannot be measured in levels with available data.

[22] Neoclassical growth theory implies that the the capital-output ratio does not depend on the aggregate level of productivity. Feenstra et al. (2015) shows that the capital output ratio is not correlated to GDP per capita in the PWT 8.0. In the PWT 9.0, the elasticity of the capital output ratio to GDP per capita is 0.5.

Figure 2: Real exchange rate levels and GDP per capita



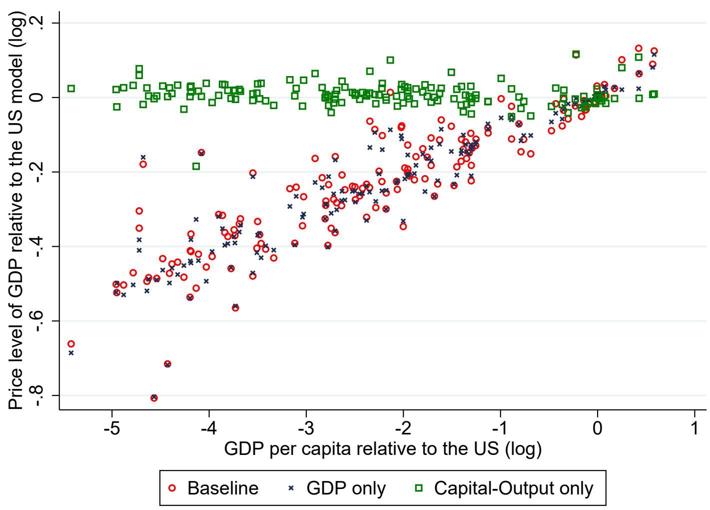


Notes: This figure plots the relation between the log of the price level of each country relative to the US and the log of GDP per capita relative to the US measured at market prices. 'Data' refers to the relative price of GDP relative to the US obtained from the PWT. 'Model' is the relative price implied by equation (5) in the model of section 3 under the assumption that there are no cross-country differences in sectorial technology, $\Delta \bar{a}_{i,t}^{T} = 0$.

5.2 Industry level real exchange rates

We now evaluate the model's implications for industry-level relative prices derived in Section (3.1). We first show that the basic predictions of our model for relative prices across countries work well at the industry level. Figure 4 plots industry-level real exchange rates computed using equation (6) and assuming no differences in sectorial technology and compares them to those in the data. There is a strong positive relation be-

Figure 3: Real exchange rate levels, income per capita and the capital output ratio



Notes: Baseline corresponds to the relative price level of our baseline model that under the assumption that there are no cross-country differences in sectorial technology, obtained by setting $\Delta \bar{a}^T_{i,t} = 0$ in equation (5). GDP only corresponds to the prediction of the model also assuming that there are no cross-country differences in the capital-output ratio, $q^{gdp}_{i,t} \equiv \omega^N_i \frac{\theta^N_i[1-\alpha^N_i]-\theta^T_i[1-\alpha^T_i]}{\bar{\theta}^N_i} \Delta gdp_{i,t}$. Capital-output only corresponds the prediction of the model that allows for differences in the capital-output ratio but ignores differences in gdp per capita, $q^k_{i,t} \equiv \omega^N_i \frac{\alpha^T_i \theta^T_i - \alpha^N_i \theta^N_i}{\bar{\theta}^N_i} \Delta k^y_{i,t}$.

Table 1: Sectorial labor shares in gross output

Sector	$1-\alpha^{l}_{AVG}$	$1-\alpha^{l}_{MED}$
Education	0.72	0.72
Health	0.51	0.51
Recreation	0.34	0.34
Agg. Non-tradables	**0.31**	**0.29**
Restaurants	0.28	0.29
Transport	0.23	0.23
Communications	0.22	0.22
Agg. Tradables	**0.16**	**0.17**

Notes: The Table reports the average and median sectorial labor shares for the countries in our sample
Source: Authors calculations base on ICIO Tables and the PWT.

tween industry-level real exchange rates in the model and those observed in the data. The aggregate predictions for relative prices also hold well industry-by-industry.

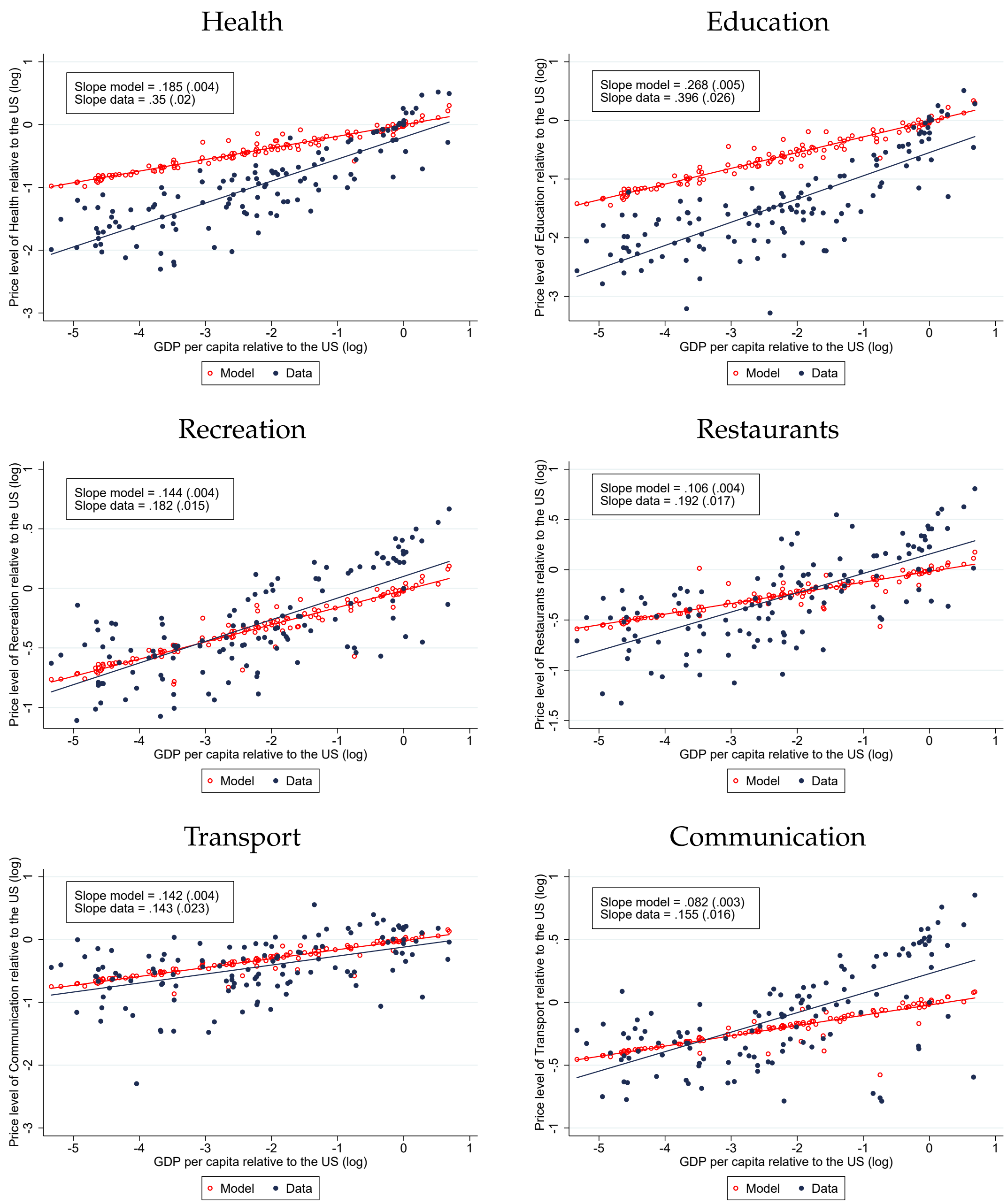
The model makes even sharper predictions for the behavior of industry-level relative prices. In particular, equation (7) implies that as GDP per capita grows, industry-level prices should increase relative to the aggregate price of non-tradables for industries where the share of labor in gross output is lower than for the non-tradable sector as a whole.

Table 1 shows the share of labor in gross output for the countries in ICIO for 6 non-tradable sub-sectors for which the ICP reports detailed price indexes.[23] The share of intermediate inputs in Education, Health, and Recreation is lower than for the non-tradable sector as a whole, and is higher in Transport, Communication, and Restaurants. Figure 5 verifies these predictions of the model. The price of Education and Health relative to the price of non-tradables grows with GDP per capita, and the opposite is true for Restaurants, Transport and Communication remaining the non-tradable sectors.

Finally, Figure 6 evaluates how the price of each industry relative to the aggregate price of non-tradables changes across countries in the data and in the model without cross-country differences in industry-level technology. The model matches the ranking of the relative price changes for the Health, Education, Transport and Restaurants. In contrast, the model does not generate much variation across countries in the prices of Recreation and Comunication relative to the price of non-tradables. Overall, the model does is succesful in matching the relation of industry-level real exchange rates and GDP per capita. We highlight that while the Balassa-Samuelson can accommodate these sectorial patterns, it can only do so under specific assumption of the behavior of sectorial

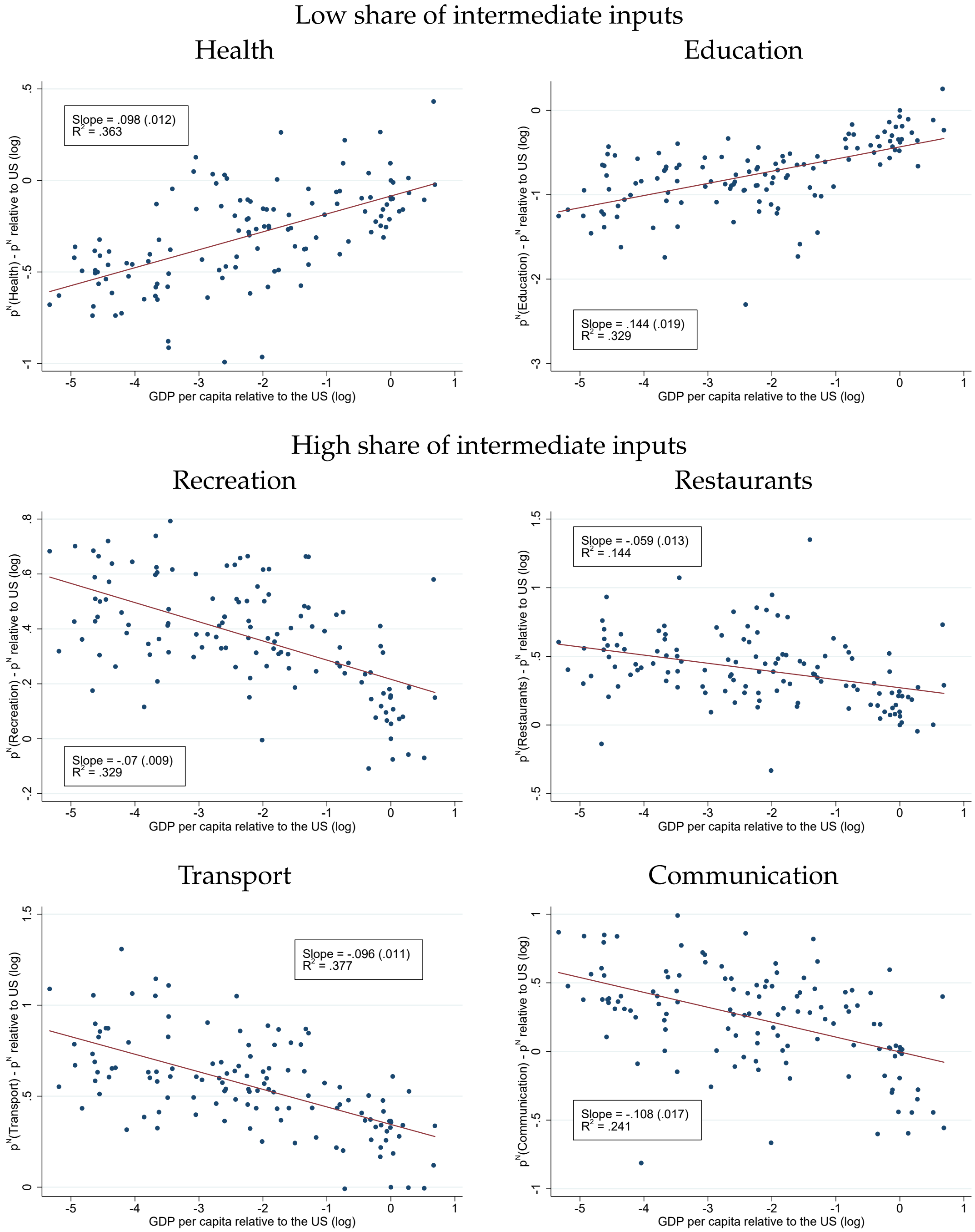
[23] Appendix Table A2 reports these shares for each country in our sample

Figure 4: Industry-level relative prices: model vs data



Notes: This figure plots industry-level real exchange rates from the ICP data and from equation (6) in the model assuming no cross-country differences in sectorial technology.

Figure 5: Sectorial real exchange rates and GDP per capita



Notes: The y-axis plots the price of industry l relative to the price of non-tradables relative to the US, obtained from the detailed data on the ICP. High (Low) share of intermediate inputs refers to industries where the share of intermediate inputs is higher (lower) than the share of intermediate inputs for the non-tradable sector.

productivity.

5.3 Robustness

5.3.1 Relative prices and GDP per capita evaluated at US prices.

This section shows that our quantitative results don't change if we focus on the relation between the real exchange rate and GDP measured in PPP dollars. With this in mind, we write differences in the relative price level as a function of the difference in GDP per capita evaluated as US prices, $gdp_{i,t}^{ppp} \equiv gdp_{i,t} - q_{i,t}$:

$$q_{i,t} = \beta_{i,t}^{a} \Delta \bar{a}_{i,t}^{T} + \beta_{i,t}^{k} \Delta k_{i,t}^{y} + \beta_{i}^{gdp^{ppp}} \Delta gdp_{i,t}^{ppp}, \tag{9}$$

where the elasticities are given by:

$$\beta_{i,t}^{a} = \frac{\omega_i^N \bar{\theta}_i^N}{\bar{\theta}_i^N - \omega_i^N \left[\theta_i^N \left[1-\alpha_i^N\right] - \theta_i^T \left[1-\alpha_i^T\right]\right]},$$
$$\beta_{i,t}^{k} = \frac{\omega_i^N \left[\alpha_i^T \theta_i^T - \alpha_i^N \theta_i^N\right]}{\bar{\theta}_i^N - \omega_i^N \left[\theta_i^N \left[1-\alpha_i^N\right] - \theta_i^T \left[1-\alpha_i^T\right]\right]},$$

and

$$\beta_{i}^{gdp^{ppp}} = \frac{\omega_i^N \left[\theta_i^N \left[1-\alpha_i^N\right] - \theta_i^T \left[1-\alpha_i^T\right]\right]}{\bar{\theta}_i^N - \omega_i^N \left[\theta_i^N \left[1-\alpha_i^N\right] - \theta_i^T \left[1-\alpha_i^T\right]\right]}.$$

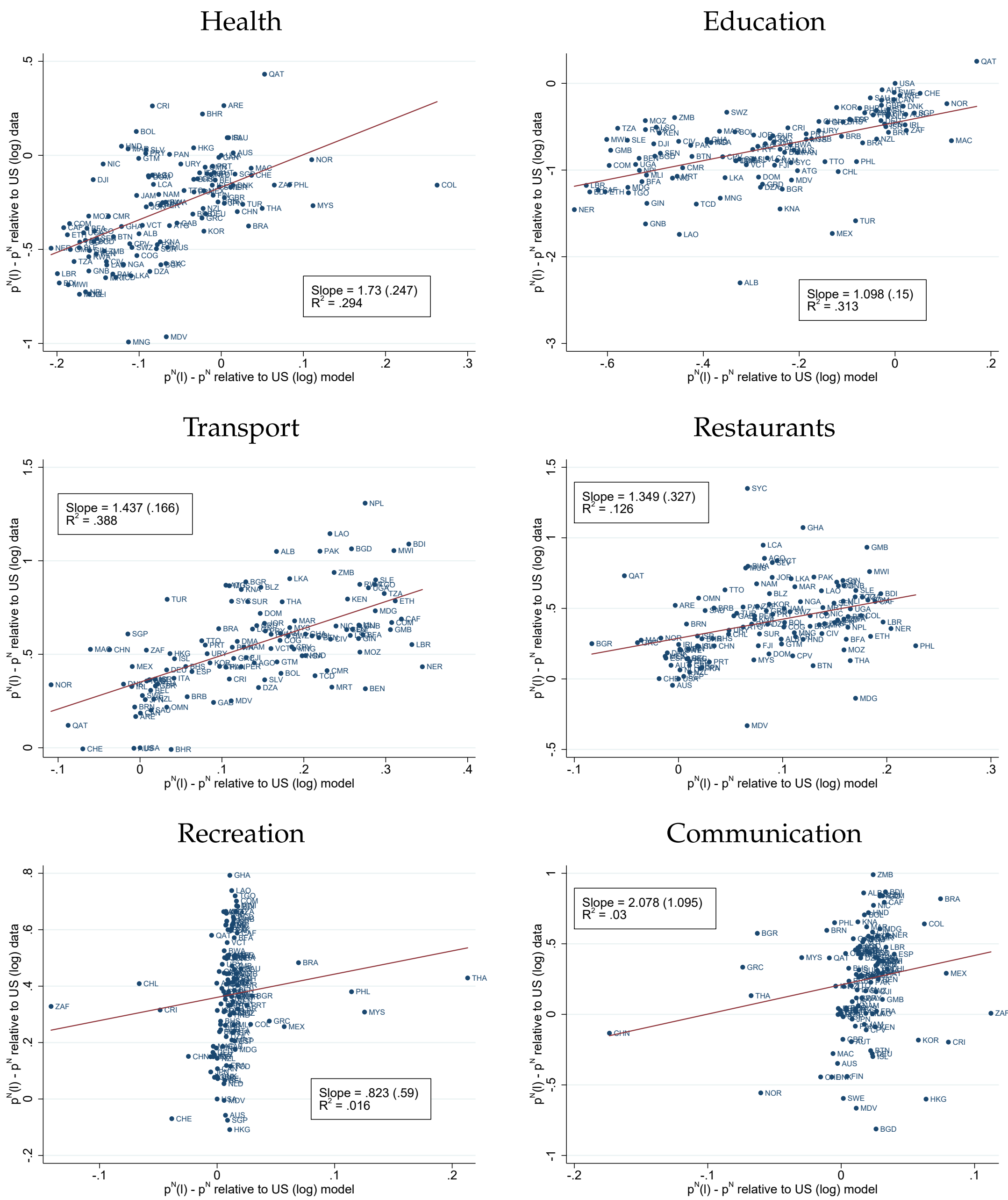
We evaluate the real exchange rates implied by the model in the absence of differences in sectorial technologies across countries, $\Delta \bar{a}_{i,t}^{T}$. Appendix Figure A.1 shows a strong positive relation between the relative price of consumption and PPP adjusted GDP per capita, both in the model and in the data. In particular, the elasticity of the real exchange rate in the model relative to ppp adjusted GDp per capita is about half the elasticity seen in the data (0.12 vs 0.24).

5.3.2 Real exchange rates and GDP growth

This section evaluates the model's prediction for the growth of the real exchange rate. Taking differences across time in equation (9) and using hats to denote log-changes, we obtain an expression for the change in the (GDP-based) real exchange rate:

$$\hat{q}_{i,t} = \beta_{i,t}^{a} \Delta \hat{\bar{a}}_{i,t}^{T} + \beta_{i,t}^{k} \Delta \hat{k}_{i,t}^{y} + \beta_{i}^{gdp^{ppp}} \Delta \widehat{gdp}_{i,t}^{ppp}. \tag{10}$$

Figure 6: Industry-level relative prices: model vs data



Notes: This figure plots the price relative to the price of non-tradables, relative to the US from the ICP data and from equation (7) in the model.

Equation (10) establishes that, if $\theta_i^N \left[1 - \alpha_i^N\right] > \theta_i^T \left[1 - \alpha_i^T\right]$, fast growing countries should appreciate .

We now evaluate the model's implications for the relation between the growth of the real exchange rate and relative GDP. Both the data and the model reveal a similar slope for the growth of the real exchange rate relative to the growth of GDP per capita, consistent with equation (10). Appendix Figure A.2 compares the real exchange rate levels predicted by the model's to those in the data. Finally, the figure also shows that the model does a good job in matching the observed real exchange rate changes over the 1997-2014 period. This is not surprising, as we already established that the slope of the relation between relative prices and GDP per capita is similar when computed in levels or in growth rates, as it is implied by our model.

5.3.3 Relative prices within the EU and within US states

Finally, we evaluate the model's predictions for the relation between the real exchange rates and income per capita within US and European regions. The first panel of Appendix Figure A.3 evaluates the predictions of the model across countries within the EU using price data from the Price Level Indexes published by Eurostat. For each EU country, the figure plots the relative price of consumption and GDP per-capita relative to France.[24] The figure shows that the slope of the relation is higher in this sample both in the data and in the model. The slope of the relation is 0.26 in the model, relative to 0.35 in the data.

The second panel of Appendix Figure A.3 plots the model's predictions of the relative price of consumption across US states. Again, the model captures about two thirds of the observed relation between GDP per capita and the price of consumption across states. We conclude that the model is quite successful in generating the relation between the relative price of consumption and GDP per capita both across and within regions.

6 Conclusion

This paper proposes a mechanism to account for the relation between real exchange rates and GDP per capita. If the share of intermediate inputs in the production of tradables is relatively high and the price of tradables is equalized across countries, the price of non-tradables should increase with income per capita even if productivity is common across sectors. The intuition is that the input multiplier will be larger for tradables in this case. Since this mechanism acts independently of the differences in the level of productivities

[24] We use France as the reference country for this exercise since the EU does not publish PLIs for the US.

across sectors, it can be easily evaluated using input-output data. The mechanism can account for about half the variation in real exchange rates across countries.

References

Asea, Patrick K and Enrique G Mendoza, "The Balassa-Samuelson Model: A General-Equilibrium Appraisal," *Review of International Economics*, October 1994, *2* (3), 244–67.

Berka, Martin and Michael B. Devereux, "Trends in European real exchange rates," *Economic Policy*, 04 2013, *28* (74), 193–242.

_ , Michael Devereux, and Charles Engel, "Real Exchange Rates and Sectoral Productivity in the Eurozone," NBER Working Papers 20510, National Bureau of Economic Research, Inc 2014.

Bhagwati, Jagdish N, "Why Are Services Cheaper in the Poor Countries?," *Economic Journal*, 1984, *94* (374), 279–86.

Canzoneri, Matthew B., Robert E. Cumby, and Behzad Diba, "Relative labor productivity and the real exchange rate in the long run: evidence for a panel of OECD countries," *Journal of International Economics*, April 1999, *47* (2), 245–266.

Chong, Yanping, Oscar Jorda, and Alan M. Taylor, "The Harrod Balassa Samuelson Hypothesis: Real Exchange Rates And Their Long Run Equilibrium," *International Economic Review*, 05 2012, *53* (2), 609–634.

Crucini, Mario J., Chris I. Telmer, and Marios Zachariadis, "Understanding European Real Exchange Rates," *American Economic Review*, June 2005, *95* (3), 724–738.

Feenstra, Robert C., Robert Inklaar, and Marcel P. Timmer, "The Next Generation of the Penn World Table," *American Economic Review*, October 2015, *105* (10), 3150–82.

Gollin, Douglas, "Getting Income Shares Right," *Journal of Political Economy*, April 2002, *110* (2), 458–474.

Gregorio, Jose De, Alberto Giovannini, and Thomas H Krueger, "The Behavior of Nontradable-Goods Prices in Europe: Evidence and Interpretation," *Review of International Economics*, October 1994, *2* (3), 284–305.

Jones, Charles I., "Intermediate Goods and Weak Links in the Theory of Economic Development," *American Economic Journal: Macroeconomics*, April 2011, *3* (2), 1–28.

Lee, Jaewoo and Man-Keung Tang, "Does Productivity Growth Lead to Appreciation of the Real Exchange Rate?," July 2007, *1*, 276–299.

Lothian, JamesR. and MarkP. Taylor, "Real Exchange Rates Over the Past Two Centuries: How Important is the Harrod-Balassa-Samuelson Effect?," *Economic Journal*, October 2008, *118* (532), 1742–1763.

Obstfeld, Maurice and Kenneth S. Rogoff, *Foundations of International Macroeconomics*, Vol. 1 of *MIT Press Books*, The MIT Press, 1996.

Rogoff, Kenneth, "The Purchasing Power Parity Puzzle," *Journal of Economic Literature*, 1996, *34*, 647–668.

Summers, Robert and Alan Heston, "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950 - 1988," *The Quarterly Journal of Economics*, 1991, *106* (2), 327–368.

Tica, Josip and Ivo Druzic, "The Harrod Balassa Samuelson Effect: A Survey of Empirical Evidence," EFZG Working Papers Series 0607, Faculty of Economics and Business, University of Zagreb September 2006.

Table A1: ICP-ICIO Concordance

ICP	ICIO	ICIO	Tradable
Health	Health & Social Work	85	N
Transport	Transport & Storage	60t63	N
Communication	Post & Telecommunications	64	N
Recreation & Culture	Other community, Social & Personal Services	90t93	N
Education	Education	80	N
Restaurants & Hotels	Hotels & Restaurants	55	N
Food & Non-Alcohol	Food Products, Beverages & Tobacco	15t16	Y
Alcohol, Tobacco, & Narcotics	Food Products, Beverages & Tobacco	15t16	Y
Clothing & Footwear	Textiles, Textile Products, Leather & Footwear	17t19	Y

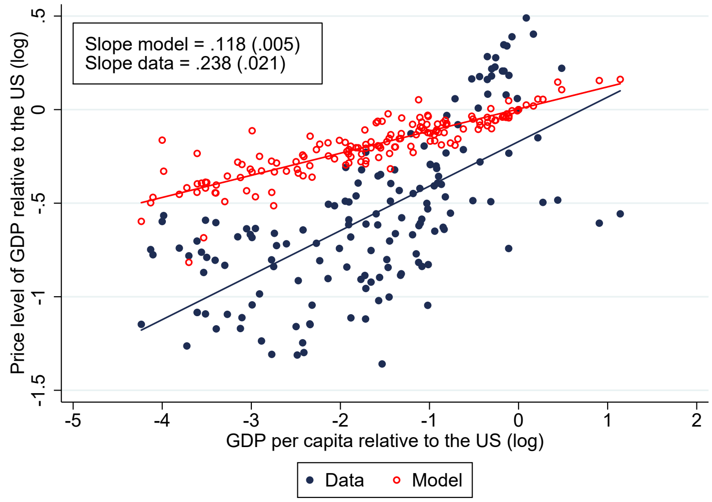
Table A2: Share of labor compensation in gross output by sector

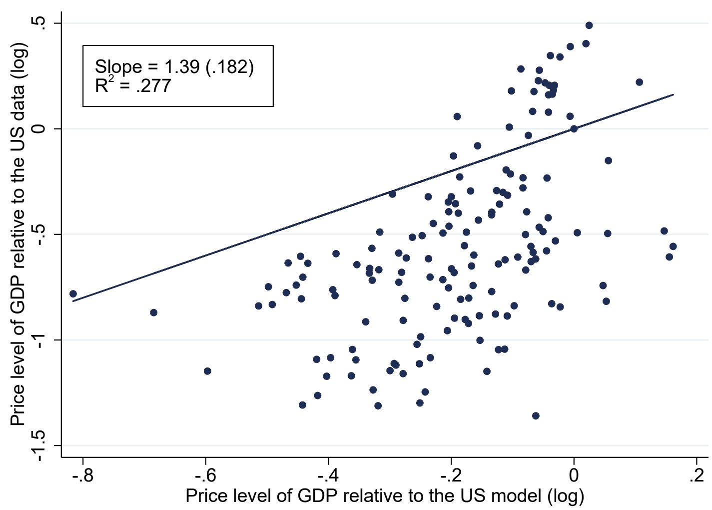
Country	Tradables	Non-tradables	ω^N	Health	Transport	Comm.	Rec.	Educ.	Rest.
AUS	0.161	0.312	0.804	0.593	0.237	0.192	0.444	0.706	0.336
AUT	0.181	0.304	0.787	0.523	0.279	0.229	0.315	0.779	0.227
BEL	0.150	0.302	0.849	0.474	0.211	0.269	0.271	0.881	0.234
BGR	0.127	0.234	0.723	0.479	0.138	0.127	0.255	0.688	0.407
BRA	0.154	0.350	0.758	0.491	0.233	0.187	0.407	0.774	0.230
CAN	0.193	0.386	0.777	0.677	0.389	0.296	0.435	0.730	0.451
CHE	0.226	0.369	0.789	0.585	0.252	0.337	0.226	0.636	0.382
CHL	0.137	0.278	0.685	0.442	0.166	0.093	0.488	0.729	0.258
CHN	0.141	0.214	0.525	0.350	0.166	0.141	0.208	0.581	0.146
COL	0.193	0.423	0.670	0.552	0.207	0.249	0.409	1.088	0.368
CRI	0.189	0.379	0.771	0.694	0.195	0.250	0.273	0.889	0.221
CYP	0.125	0.320	0.910	0.487	0.175	0.143	0.152	0.505	0.216
CZE	0.132	0.210	0.716	0.453	0.182	0.204	0.174	0.608	0.198
DEU	0.223	0.330	0.754	0.496	0.228	0.247	0.295	0.731	0.313
DNK	0.183	0.339	0.831	0.611	0.173	0.243	0.330	0.649	0.289
ESP	0.186	0.358	0.832	0.605	0.276	0.159	0.418	0.831	0.255
EST	0.172	0.262	0.772	0.547	0.139	0.137	0.317	0.649	0.284
FIN	0.152	0.320	0.790	0.582	0.246	0.251	0.339	0.654	0.305
FRA	0.153	0.361	0.867	0.566	0.348	0.147	0.396	0.784	0.304
GBR	0.224	0.323	0.855	0.424	0.319	0.324	0.296	0.670	0.324
GRC	0.163	0.345	0.863	0.438	0.152	0.309	0.344	0.916	0.165
HKG	0.102	0.288	0.983	0.657	0.161	0.088	0.361	0.419	0.370
HRV	0.221	0.352	0.762	0.681	0.343	0.270	0.421	0.891	0.386
HUN	0.122	0.328	0.733	0.529	0.259	0.272	0.299	0.651	0.304
IDN	0.174	0.290	0.495	0.420	0.212	0.234	0.302	0.708	0.232
IND	0.151	0.329	0.664	0.339	0.187	0.293	0.543	0.460	0.101
IRL	0.090	0.257	0.705	0.461	0.191	0.217	0.165	0.723	0.360
ISL	0.217	0.373	0.782	0.541	0.201	0.334	0.420	0.551	0.392
ISR	0.201	0.321	0.831	0.299	0.242	0.208	0.346	0.614	0.332
ITA	0.193	0.269	0.804	0.496	0.241	0.206	0.270	0.842	0.249
JPN	0.202	0.377	0.798	0.439	0.489	0.122	0.482	0.807	0.198

Table A2: (cont) share of labor compensation in gross output by sector

TWN	0.091	0.291	0.719	0.438	0.167	0.445	0.316	0.698	0.313
Country	Tradables	Non-tradables	ω^N	Health	Transport	Comm.	Rec.	Educ.	Rest.
KOR	0.088	0.277	0.657	0.412	0.187	0.191	0.287	0.628	0.179
LTU	0.138	0.311	0.753	0.593	0.214	0.187	0.351	0.750	0.436
LVA	0.155	0.238	0.805	0.586	0.177	0.142	0.326	0.755	0.273
MEX	0.101	0.333	0.686	0.681	0.306	0.202	0.146	1.004	0.233
MLT	0.176	0.225	0.842	0.528	0.135	0.163	0.077	0.766	0.230
MYS	0.091	0.316	0.531	0.410	0.151	0.166	0.229	0.905	0.285
NLD	0.137	0.328	0.808	0.566	0.266	0.175	0.283	0.675	0.280
NOR	0.138	0.353	0.637	0.720	0.193	0.219	0.341	0.726	0.389
NZL	0.156	0.302	0.788	0.571	0.291	0.179	0.335	0.773	0.345
PHL	0.111	0.233	0.660	0.375	0.186	0.122	0.474	0.536	0.160
POL	0.162	0.286	0.749	0.520	0.214	0.167	0.346	0.947	0.350
PRT	0.160	0.329	0.835	0.479	0.249	0.173	0.342	0.835	0.280
ROU	0.187	0.215	0.667	0.464	0.151	0.190	0.275	0.670	0.203
SAU	0.060	0.336	0.397	0.439	0.279	0.148	0.325	0.856	0.238
SGP	0.073	0.201	0.789	0.405	0.118	0.138	0.256	0.467	0.266
SVK	0.132	0.258	0.742	0.546	0.219	0.226	0.259	0.835	0.340
SVN	0.200	0.339	0.759	0.574	0.216	0.244	0.322	0.783	0.358
SWE	0.165	0.294	0.803	0.548	0.158	0.153	0.300	0.502	0.271
THA	0.088	0.239	0.562	0.323	0.150	0.190	0.136	0.740	0.100
TUN	0.166	0.335	0.668	0.592	0.169	0.286	0.746	0.780	0.217
TUR	0.123	0.245	0.706	0.427	0.146	0.270	0.449	0.945	0.190
USA	0.157	0.384	0.841	0.538	0.324	0.192	0.399	0.687	0.393
ZAF	0.165	0.295	0.745	0.219	0.198	0.143	0.420	0.278	0.185
Mean	**0.154**	**0.307**	**0.746**	**0.507**	**0.220**	**0.209**	**0.330**	**0.722**	**0.279**

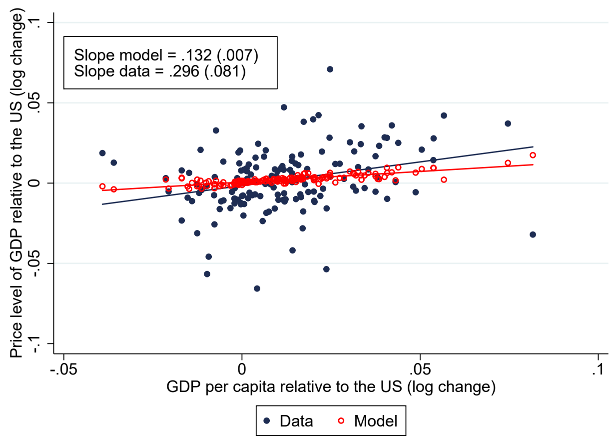
Figure A.1: Real exchange rates and income per capita: model vs. data





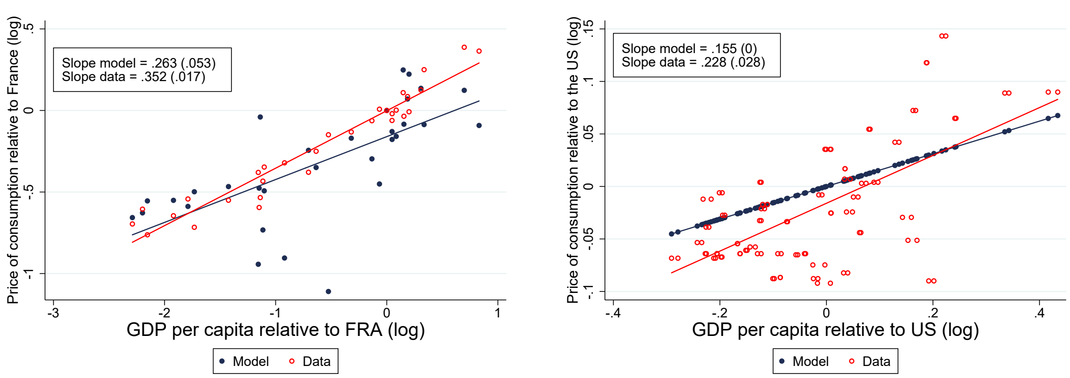
Notes: This figure plots the relation between the log price level of each country relative to the US to the log of GDP per capita relative to the US. 'Data' refers to the relative price of GDP relative to the US obtained from the PWT. 'Model' is the relative price implied by equation (9) in the model of section 3 under the assumption that there are no cross-country differences in sectorial technology, $\Delta \bar{a}^T_{i,t} = 0$.

Figure A.2: Aggregate prices and GDP growth



Notes: This figure plots the relation between the log change in the price level of each country relative to the US to the log of change GDP per capita relative to the US. 'Data' refers to the log change of relative price of GDP relative to the US obtained from the PWT. 'Model' is the log change of the relative price implied by equation (10) in the model of section 3 under the assumption that there are no cross-country differences in sectorial technology.

Figure A.3: Relative prices and income per capita across regions



Notes: GDP per capita relative to France is taken from the ICP. State GDP per capita relative to the US is taken from the BEA regional accounts. EU data is the relative price of consumption of each European country relative to France from the Eurostat Price Level Indices. US states data is the relative price of consumption of each US state country relative to the average price level in the US, obtained from the BEA regional accounts. 'Model' refers to the model's prediction for the level of the real exchange rate in equation (5).