The Price of Development:
The Penn-Balassa-Samuelson Effect Revisited*

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Abstract:

The Penn-Balassa-Samuelson effect is the stylized fact about the positive correlation between cross-country price level and per-capita income. This paper provides evidence that the price-income relation is actually non-linear and turns negative among low income countries. The result is robust along both cross-section and panel dimensions. Additional robustness checks show that biases in PPP estimation and measurement error in low-income countries do not drive the result. Rather, the different stage of development between countries can explain this new finding. The paper shows that a model linking the price level to the process of structural transformation captures the non-monotonic pattern of the data. This provides additional understanding of real exchange rate determinants in developing countries.

Keywords: Penn effect; Balassa-Samuelson hypothesis; developing countries; real exchange rate; structural transformation.

JEL Classifications: F3, F4, O11.

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1 Introduction

It is widely understood that market exchange rates do not give accurate measures of real income in different economies and that adjustment by purchasing power parity (PPP) factors is necessary for such measures. This understanding is based on an observed empirical regularity that richer countries have a higher price level than poorer countries.[1] The positive correlation between cross-country price level and per-capita income is generally regarded as a stylized fact. This result was documented for twelve developed countries in the seminal paper of Bela Balassa (1964), was confirmed for a large sample of countries as soon as data from the International Comparison Program (ICP) became available and is now renowned as the Penn-Balassa-Samuelson effect (Penn-BS).[2] [3]

The paper makes an important qualification to this general understanding. Using non-parametric estimation, it provides evidence that the price-income relation is non-linear and turns negative in low-income countries, both along a cross-section and a panel dimension. Standard regression analysis in subsamples of poor, middle-income and rich countries is consistent with this finding. The results of the paper are robust to possible sources of bias from PPP estimation and measurement error in low-income countries.

[1]Adjustment by PPPs is necessary as long as price levels vary across countries, even if the variation is not systematic with income.

[2]The Penn-BS effect was also documented by Summers and Heston (1991), Barro (1991), and Rogoff (1996). Samuelson (1994) stresses that the proper name for it should be *Ricardo-Viner-Harrod-Balassa-Samuelson-Penn-Bhagwati-et al. effect.*

[3]The Penn-BS effect should not be confused with the Balassa-Samuelson hypothesis The latter provides the mainstream explanation for the former. The Balassa-Samuleson hypothesis argues that richer countries have a higher relative productivity in the tradable sector; under certain assumptions, this leads to a higher relative price of non-tradables, hence to a higher aggregate price level.

This paper argues that the non-monotonicity of the price-income relation is due to the different stages of development that characterize low- and high-income countries. We present a model with three sectors (agriculture, manufacturing and services) tracing the effects of agricultural productivity, sectoral expenditure and employment shares on the price level of low-income countries. This model captures the non-monotonic pattern of the data, in a way that the standard Balassa-Samuelson hypothesis, focused on productivity differences between tradables and non-tradables, does not. The intuition is that, when a poor country starts to develop, its productivity growth lies mainly in the agricultural sector. Since, at an early stage of development, agriculture is primarily non-tradable and represents a big share of expenditure, this productivity growth reduces the relative price of agricultural goods, hence the overall price level.

In economics, empirical regularities are rare and important. As Solow (1956) and Easterly and Levine (2001) point out, economists build models to match relevant empirical regularities and they use these models to understand economic events and give policy suggestions. The Penn-BS effect is the empirical regularity that the seminal models of Balassa (1964) and Samuelson (1964) try to reproduce. The mechanisms of these models are at the basis of our understanding of long-run real exchange rate movements, are incorporated into many new open-economy macroeconomic models and have been the initial point of reference for a vast literature on this subject.[4] The paper shows that the empirical regularity, which models in the literature are supposed to match, namely the Penn-BS effect, is not actually present in

[4]The Balassa-Samuelson hypothesis hits more than 7,000 entries on Google Scholar; see Rogoff (1996) and Taylor and Taylor (2004) for extended reviews and Bordo et al. (2014) and Berka et al. (2014) for the most recent applications at the time of writing.

low income countries.[5]

The paper makes a significant empirical contribution by uncovering a twist to what has long been accepted as a well-established empirical regularity and offers a novel explanation of real exchange rate determinants in low income countries, based on the process of structural transformation. From a policy point of view, by showing that the price-income relation is negative in poor countries, the paper suggests that there is a "natural" depreciation of the real exchange rate along the development process. This is an important finding that central banks and governments of low-income countries should take into account as they formulate exchange rate policy. Moreover, the result of the paper suggests that current measures of real exchange rate undervaluation based on the Balassa-Samuelson hypothesis are biased for developing countries; for instance, once we account for the non-monotonic pattern of the price-income relationship, the Chinese Renminbi is 30% less undervalued than standard estimates suggest.[6] The new empirical regularity shown by the paper and its explanation can help us to better understand long-run real exchange rate movements in developing countries and lay the ground for further research on this subject.

The paper relates to the literature on PPPs and the Penn-BS effect as in Kravis, Summers, and Heston (1982), Heston and Summers (1992), and Feenstra et al. (2013). Our contribution is to identify the non-monotonic

[5]This can explain why there is not much evidence of the Balassa-Samuelson hypothesis in lower income countries as in Choudhri and Khan (2005) and Genius and Tzouvelekas (2008). Notice that they focus on the effect of relative productivity in the tradable sector on the real exchange rate (the Balassa-Samuelson hypothesis), whereas this paper focuses on the Penn effect which, to the best of our knowledge, is a novel contribution.

[6]Standard measures of undervaluation, as in Rodrik (2008), are the difference between the data and the fitted value of a linear regression of the price measure from Penn World Table on income.

pattern of the price-income relation as a novel stylized fact and link this non-monotonicity to a plausible model of structural transformation.

The paper refers to the debate on PPPs and real exchange rate determinants in the long run, as in Samuelson (1964), Balassa (1964), Bhagwati (1984), Rogoff (1996) and Taylor and Taylor (2004). Within this literature the papers close in spirit to our are Bergin et al. (2006) and Devereux (1999). The former shows that there is no Penn-BS effect before the 1970s; the latter presents a model of endogenous productivity growth in the distribution sector to explain real exchange rate depreciation in East Asian countries. Our paper provides a more generalized and systematic evidence of a counter Penn-BS effect and real exchange rate movements in developing countries.[7] Moreover, our explanation of this finding offers an original contribution of real exchange rate determinants in developing countries, based on structural transformation.

Finally, the paper is complementary to the literature on structural transformation and the role of agriculture as a driver of development as in Gollin et al. (2002, 2007) and Ngai and Pissarides (2007). We show the effect of structural transformation out of agriculture on the real exchange rate in developing countries.

The paper is structured as follows. Section 2 shows that the price-income relation is non-monotonic using both non-parametric and linear estimations. Section 3 establishes that the results are robust to measurement error, bias

[7]Notice that Feenstra et al. (2013) argue that the results of Bergin et al. (2006) are driven by interpolation issues of PPPs to past data; this critique does not apply to this paper because our main results are based on a cross-section dimension in benchmark years.

in the estimation of PPPs, and different databases. Section 4 argues that differences in economic structure can explain the results, derives a model that links the price level to the process of structural transformation, and analyzes the empirical prediction of the model, showing that it can capture the non-monotonicity of the data. Section 5 concludes by summarizing the main findings and discussing further research based on these results.

2 The price-income relation

In this section, we show that the price-income relation is non-monotonic. We provide evidence along a cross-section and panel dimension, through both linear and non-linear estimation. Following the literature on the Penn-BS effect, we measure income per capita in purchasing power parity (PPP) and define the price level as the ratio of PPP to the exchange rate with the US dollar.[8] Unless alternatively specified, the database of reference is the Penn World Table (PWT) 8.0 version.[9]

2.1 Cross-section dimension

In Figure 1.1, we can see an example of the little attention that the literature has paid to the Penn-BS effect in developing countries. The figure illustrates the positive price-income relation reported in the review of the purchasing power parity puzzle by Rogoff (1996). Since observations with an income

[8]We use income per capita at constant prices for the panel and time-series analysis and income at current prices for the cross-section analysis.

[9]The results presented in the paper also hold for the World Development Indicators database of the World Bank. We work with the Penn World Table because traditionally it is the database of reference for this literature.

per capita lower than Syria are gathered in a cloud of points, it is difficult to properly disentangle the relation between price and income in poor countries.

Therefore, in Figure 1.2, using the same data-set as in Rogoff (1996), we plot the log values of income per capita.[10] We investigate the price-income relation using a non-parametric estimation technique known as LOWESS (locally weighted scatter smooth), which allows us to impose as little structure as possible on the functional form.[11] This estimation suggests that the Penn-BS effect does not hold in the poorest 25 percent of countries in the sample, where the relation is actually downward sloping. The minimum point of the curve corresponds to an income level of around 1350 PPP $ (1985 prices), which is equivalent to the income of Senegal in the year 1990.

In commenting, the result of Figure 1.1, Rogoff (1996) stressed that "*The relation between income and prices is quite striking over the full data set (...); it is far less impressive when one looks either at the rich countries as a group, or at developing countries as group.* In this paper we take Rogoff's point further, using a non-parametric estimation that shows that the relation is actually striking when looking at rich countries as a group and negative when looking at poor countries as a group. According to our knowledge, the non-monotonicity of the price-income relation has not been previously documented in the literature.

[10]This is Penn World Table 5.6 (reference year 1985); he considers the year 1990.

[11]The LOWESS estimation works as follows: Consider an independent variable x_n and a dependent variable y_n. For each observation y_n, the LOWESS estimation technique runs a regression of x_n using a few data points around x_n. The regression is weighted so that the central point $(x_n; y_n)$ receives the highest weight, and points further away get less weight. The fitted value of this regression evaluated at y_n represents the smoothed value y_n^S, which is used to construct the non-parametric curve that links y and x. The procedure is repeated for each observation $(x_n; y_n)$. The number of regressions is equal to the number of observations, and the smoothed curve is the set of all $(x_n; y_n^S)$.

Next, we extend the analysis to PWT 8.0, the latest available, using only the benchmark countries and the benchmark year.[12] Using only the benchmark countries and year minimizes the source of measurement error.[13]

In Figure 2.1, we can confirm the strong positive relation predicted by the Penn-BS effect by running a standard linear estimation of price on income: the OLS coefficient is 0.21, with a t-statistic of 9.23.[14] However, once we allow for non-linearities, the Penn-BS effect breaks down for low income countries. Figure 2.2 shows the results of running a LOWESS estimation between price and income, imposing little restriction on the functional form.[15] We can see that the expected upward sloping relation holds only for middle- and high-income countries. The relation is downward sloping for low-income

[12] We exclude countries with less than one million people in the year 2000 and Zimbabwe and Tajikistan which are clear outliers; including these countries would reinforce the findings. The list of the countries included can be found in the appendix.

[13] All the results presented in the paper also hold using PWT 7.0 or older versions; results are not particularly affected by the upgrade from PTW 7.0 to PWT 8.0; see Feenstra et al. (2013) for a description of the new PWT. PWT 8.0 relies on the 2005 ICP round; a new 2011 ICP round has recently been made available, but it is not yet incorporated in the Penn World Table. Deaton and Aten (2014) show that the new round decreases prices in developing countries; however, using the preliminary available data, the non-monotonicity of the price-income relation also holds with the new round.

[14] We run an OLS regression, with robust standard errors, of the log of the price level of GDP (variable $pl-gdpe$ from PWT 8.0) and the log of GDP per capita in PPPs at current prices ($cgdpe/pop$ from PWT 8.0). We use the expenditure-side of real GDP and price because of comparability with past versions of Penn World Table and previous studies. Notice that the results of the paper are robust to using measures of real GDP and prices from the output-side, as newly introduced by PWT 8.0. See Inklaar and Timmer (2014) for an analysis of the Penn-effect using prices from the output-side for a sample of 42 countries.

[15] LOWESS estimation requires that the bandwidth of observations included in the regression of each point be chosen. Specifying a large bandwidth provides a smoother estimation, but increases the risk of bias by including observations from other parts of the density. A small bandwidth can better identify genuine features of the underlying density, but increases the variance of the estimation. In the paper, we use the default STATA bandwidth of 0.8, which is a conservative choice and provides a lower-bound of the non-monotonic pattern of the data. The Pseudo-R^2 of the LOWESS estimation is maximized at a bandwidth of 0.4, which delivers a stronger non-monotonicity at the cost of higher variance. Using a Kernel estimation rather than LOWESS conveys very similar results to the ones presented in the paper.

countries; this involves 20 percent of the countries in the sample. The turning point is at 1,448 PPP \$ per-capita (2005 prices), equivalent to the income of Senegal in the year 2005. The countries on the downward sloping path are listed in Table 1; we note that these are mainly African and Asian (no Latin-American).

Figure 3 reports 95% confidence bands of the LOWESS estimation derived from the standard errors of the smoothed values. The confidence interval confirms the non-monotonic pattern of the data. The Pseudo-R^2 of the non-parametric estimation is 0.6, which is higher than the 0.44 R^2 of the linear model. The F-test comparing the non-parametric model to the linear one rejects the null hypothesis that the non-linear model does not provide a statistically significant better fit.

Standard cross-country OLS regression supports the finding of the non-parametric estimation. Table 2 shows that a quadratic specification of the price-income relations confirms the non-monotonic pattern. Both $Income$ and $Income^2$ are statistically significant. The coefficient associated with the linear term is negative and the quadratic one is positive, indicating a convex relation. The marginal effect of income on price turns positive around 1,800 PPP \$ per-capita (2005 prices), which is equivalent to the income of Laos in the year 2005. The turning point from the quadratic specification is at a higher level of income than from the previous non-parametric estimation.

Given the functional form $Price_i = \alpha + \beta\, Income_i + \gamma\, Income_i^2 + \epsilon_i$, Lind and Mehlum (2011) show that in order to test for the presence of a U-relation, it is necessary to formulate the following joint null hypothesis:

$$H_0 : \beta + 2\,\gamma\, Income_{min} \geq 0 \; and/or \; \beta + 2\,\gamma\, Income_{max} \leq 0 \qquad (1)$$

against the alternative:

$$H_1 : \beta + 2\,\gamma\, Income_{min} < 0 \; and \; \beta + 2\,\gamma\, Income_{max} > 0 \qquad (2)$$

Lind and Mehlum (2011) build a test for the joint hypotheses using Sasabuchi's (1980) likelihood ratio approach. Table 3 shows that the marginal effect of income on price is negative and statistically significant at $Income_{min}$ and positive and statistically significant at $Income_{max}$. The bottom line of the table shows that the SLM test rejects H_0 in favor of the alternative and thus indicates that the result is consistent with the presence of a U-relation between price and income.

Finally in Table 4, we divide the sample by income groups according to the standard World Bank classification. The price-income relation is negative, sizable and significant for low-income countries; it is not statistically different from zero for the middle-income group; and it turns positive and significant for high-income countries. Also, the results of these regressions are consistent with the non-monotonicity of the price-income relation.[16]

Therefore, independently from the approaches we use to analyze the data, the results of this section provides evidence of a non-monotonic price-income relation.

[16] The observations per-income group are 36, 58, and 32 respectively. The World Bank threshold is 875 US$ (2005) for low-income countries and 10,276 US$ (2005) for middle-income countries.

2.2 Panel dimension

In this section, we analyze the price-income relation in a panel dimension. The ICP collects data prices only in benchmark years. Then, the PWT used to estimate prices for other years by rescaling according to the inflation rate differential with the US. The new version of the Penn World Table makes use of historical ICP benchmarks to extrapolate the time series of prices and real incomes; so, it relies on a better methodology. However, many countries, especially developing ones like China or India, did not participate in all the benchmark collections; this makes the computation of prices and real incomes in non-benchmark years more uncertain. Nevertheless, PWT are regularly used in empirical analyses with panels; moreover, panel regressions of price on income are commonly used to build measures of real exchange rate over/undervaluation. Thus, it is relevant to assess if the non-monotonicity of the price-income relation also holds along a panel dimension.

If we extend the analysis to a panel of countries between 1950-2009, standard linear estimation of price on income confirms the positive relation predicted by the Penn-BS effect: the OLS coefficient is 0.15, with a t-statistic of 32.7 (Figure 4.1).[17] However, non-parametric estimation shows that the price-income relation is also non-monotonic along a panel dimension. The Penn-BS effect holds for middle- and high-income countries, but in low-income countries the relation is negative (Figure 4.2).

Figure 4.3 reports the fitted value of the LOWESS estimation. The turning

[17]This is for a sample of 126 countries from 1950 to 2009, using PWT 8.0. Countries with less than one million people in the year 2000. We run an OLS regression of the log of the price level of GDP (variable $pl_g dpe$) and the log of GDP per capita in PPPs at constant chained prices ($rgdpe/pop$).

point is at 1421 PPP $ per-capita (2005 prices), which corresponds to the income of Senegal in the year 2000. The downward sloping arm of the curve includes 27% of the total observations and 45% of the countries in the sample. The countries on the downward sloping arm and their frequencies are reported in Table 5. We can see that some of the countries are persistently on the downward-sloping arm (i.e. Ethiopia and Tanzania); others moved along the curve (i.e. China and Vietnam).

Standard panel-data analysis, Table 6, confirms the result of the non-parametric estimation. We take 5-years averages of price and income between 1950-2009. We show that for developing countries the relation between price and income is negative and significant, with and without country fixed-effects. We do this by running a regression for the full sample and then only for developing countries.[18] This result comes despite a broad definition of developing countries and a linear restriction on the price-income relation.

3 Robustness checks

The data used to estimate the price-income relationship are PPPs, exchange rates, and GDP per-capita.[19] Most of the robustness analysis focuses on PPPs by looking at measurement error in prices and at bias in the construction of PPPs, which are arguably the main source of concern. Moreover, given that in developing countries official exchange rates can be different from black market rates, we control for this possible source of bias. Finally,

[18]We define developing countries as those below the World Bank's threshold of high-income countries; a stricter definition of developing countries reinforces our result. Notice that in the full sample with country fixed effects the coefficient is not significantly different from zero.

[19]We remind the reader that in the Penn World Table $p = \frac{PPP}{XRAT}$ and $y = \frac{GDP}{PPP}$

we show that results are robust to different versions of the Penn World Table.[20]

3.1 Classical measurement error

Chen et al. (2007) analyze the bias of the OLS estimation of price on income when there is measurement error in prices. In this case, the independent variable becomes correlated with the error term, so that the standard assumptions for a consistent and unbiased least square estimator break down.[21] Chen et al. (2007) conclude that the OLS estimate will be biased downwards and can become negative if the variance of the measurement error is sufficiently high. In fact, they show that:[22]

$$\text{plim } \hat{\beta} = \frac{\beta^{true} - \frac{\sigma_\eta^2}{\sigma_{y^*}^2}}{1 + \frac{\sigma_\eta^2}{\sigma_{y^*}^2}} \tag{3}$$

where σ_η^2 is the variance of measurement error and $\sigma_{y^*}^2$ is the variance of the true real income per-capita. From this expression, we can see that as the variance of the measurement error σ_η^2 increases, the estimated $\hat{\beta}$ can turn negative.

[20]In general we may also have measurement error in GDP data; however, these are of lower concern. Gollin et al. (2014) analyze the definitions and measurement approaches used in the construction of national accounts data in poor countries. They conclude that these aggregate data are robust to problems associated with informality or household production and that there is no reason to believe that they are intrinsically flawed. Therefore, we do not focus the robustness discussion on estimates of GDP per-capita.

[21]The econometric specification of the price-income relation is such that $p_i^* = \alpha + \beta y_i^* + \epsilon_i$, where variables are expressed in logs and p_i^* is the true price level without measurement error and $y_i^* = Y_i - p_i^*$ is the true real income per-capita. Consider the case where the measured price level p_i contains an error such that $p_i = p_i^* + \eta_i$, where η_i has mean zero and is normally distributed; then the regressor and the error term become correlated.

[22]Assuming that the measurement error is uncorrelated with the true dependent and independent variables, as well as with the equation error, equation (3) follows.

If we look at the group of low-income countries in Table 4, the OLS estimate of price on income is -0.21 (Table 4). What is the level of the measurement error's variance needed to drive this result? Assuming that measurement error is uncorrelated with the level of price, we can rewrite equation (3) as:[23]

$$\text{plim } \hat{\beta} = \frac{\beta^{true} - \frac{\sigma_\eta^2}{\sigma_{y^*}^2}}{1 + \frac{\sigma_\eta^2}{\sigma_{y^*}^2}} = \frac{\beta - \frac{\sigma_\eta^2}{\sigma_Y^2 + \sigma_p^2 + \sigma_\eta^2 - 2\sigma_{Yp}}}{1 + \frac{\sigma_\eta^2}{\sigma_Y^2 + \sigma_p^2 + \sigma_\eta^2 - 2\sigma_{Yp}}} \tag{4}$$

In the sub-sample of countries where the price-income relation is negative, we have $\sigma_Y^2 = 1.8$, $\sigma_p^2 = 0.18$, $\sigma_{Yp} = 0.66$ (remember that all the variables are expressed in logs).

The variance of measurement error that would lead to the negative estimation of -0.21 depends on the value of β^{true}. Let's suppose that β^{true} among the group of low-income countries is equal to the OLS estimation over the full sample (0.21). In this case, in order to get $\hat{\beta} = -0.21$, we would need $\sigma_\eta^2 = 0.74$: the measurement error on prices should have a variance four times higher than the variance of observed prices over the full sample. If instead, we assume that in low-income countries β^{true} is zero, we would need $\sigma_\eta^2 = 0.42$: hence, in this case, the variance of the measurement error on prices in this sub-sample of countries should be more than double than the variance of the observed prices.

Therefore, even if measurement error could potentially drive the results of the paper, an improbably high variance of the measurement error itself is

[23]From the specification of Chen et al. (2007), we have that $y_i^* = Y_i - p_i + \eta_i$; keeping the same independence assumptions of their paper, such that $Cov(Y, \eta) = 0$, which is plausible for the subsample of countries we are looking at, equation (4) follows.

required to obtain the negative price-income relation presented in the paper.

3.2 Purchasing power parities bias

The process of computing PPPs is subject to intrinsic fragilities, making the comparison of real income and prices across countries a difficult exercise. The PWT relies on data collected by the International Comparison Program (ICP). In each country, the ICP calculates prices for about 155 goods, called basic headings, by collecting prices for 1500-2000 items following a standardized product description (SPD).[24] A basic heading is the most disaggregated level at which expenditure data are available from national accounts statistics. The ICP collects quotes for different items within each basic heading and then computes a unique price through different procedures.[25] Once the prices of all 155 goods are obtained, the PWT computes a PPP index for each country following the Geary-Khamis (GK) method of aggregation, which compares domestic prices with world prices. In the GK method, the world price of a good is defined as a weighted average of its price in all countries, and the weights are given by a country's share of the global consumption of that good.

This process generates various potential sources of bias in the estimation of PPPs. The main ones are the following: the GK method of aggregation of

[24] A SPD lists the characteristics relevant to a particular cluster of products, and they are elaborated at a regional level with the collaboration of national statistical offices. An example of SPD is: " Men's shirt, well known brands, 100% cotton, light material, classic styling, uniform colour, short sleeves, classic collar, buttons fastner" (ICP, 2007). The ICP regions are Africa, Asia-Pacific, CIS, South America, OECD-Eurostat, Western Asia.

[25] For instance, for the basic heading *rice*, the ICP collects quotes for six different kinds of rice, including long-grained, short-grained, and brown rice. The country-product-dummy regression is the method mostly used to obtain a unique price of the basic heading *rice*. See Rao (2004) for a detailed explanation of the items' methods of aggregation.

basic headings into the PPP index; quality matching; and items' representativity (Deaton and Heston, 2010; ICP, 2007). The direction of the PPP bias can have a key influence on our results. Let's suppose that the true price-income relationship is flat. Figure 5 shows that that, if PPPs tend to be overestimated in low-income countries, a negative price-income relationship would arise because of that bias; however, if PPPs are underestimated, a Penn-BS effect would emerge.[26]

The literature has well established that PPPs in low-income countries are underestimated (Nuxoll, 1994; Neary, 2004, Hill, 2004; Deaton and Heston, 2010; Almas, 2012). This implies that the negative price-income relationship in poor countries shown in the paper is a lower bound of the true one.

The GK method of aggregation understates PPPs in poor countries. In fact, countries with a larger physical volume of consumption get a greater weight in the construction of world prices. This implies that the vector of international prices used as a reference is closer to the price of rich rather than poor countries.[27] This generates a Gershenkron effect for low income countries, according to which PPP is lower the more the price of a country differs from the price of reference (Gershenkron, 1947; Nuxoll, 1994). This effect stems from the substitution bias that characterizes indices with a single reference price vector, as in the GK method. These type of indices do not account for utility maximizing agents switching towards cheaper goods as relative prices change (Hill, 2000).[28]

[26]The underlying assumption of Figure 5 is that PPPs' bias only affects poorer countries.

[27]Nuxoll (1994) shows that international prices are closest to that of a moderately prosperous country like Hungary.

[28]Neary (2004) shows that the GK method of aggregation is exact if preferences are Leontief; in this case, goods are perfect complements, and the substitution bias does not arise. Different methods of aggregation, like the Elteto-Koves-Szulc (EKS) index used by

The method of aggregation is not the only source of bias of PPPs. Quality matching is also a problem, because the estimation of PPPs makes use of a set of homogeneous goods. As Deaton and Heston (2010) stress, one of the most criticized issues of ICP rounds is that lower quality goods and services in poor countries are often matched to higher quality items in rich countries. Quality mismatch leads to an underestimation of the price level in poor countries; hence, this source of bias reinforces the results of the paper.

Finally the representativity of the items whose prices are collected is also a potential source of bias. This relates both to the aggregation of items into a basic heading and to the urban bias in collecting prices. If an item within the basic heading is representative in some countries but not in others, PPPs may be estimated incorrectly.[29] This is a common problem for all ICP rounds.[30] Nevertheless, Diewert (2008) argues that if non-representative prices are well-distributed across all countries in a region, they may not cause serious distortions. Moreover, Deaton (2010) computes a Tornqvist index to measure how much different goods move the overall PPP-index in Africa and Asia.[31] He concludes that there is no evidence to support the idea that prices in Africa or in the Asia-Pacific region are systematically overstated by the representativity issue.

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the World Bank, mitigate the Gershenkron effect for poorer countries. The PPP-EKS index of a country takes a geometric mean over all the possible Fisher indexes of all the countries, with both the country in question and a reference country (for a discussion comparing the two methods see Deaton and Heston, 2010). Using the PPP-EKS index reinforces the non-monotonicity shown in the paper; results available upon request.

[29]See for example the wheat versus teff example in Deaton and Heston (2010).

[30]The Latin American region tried to overcome this issue in the 2005 round by using an extended CPD method, adding a representativity dummy. The OECD/Eurostat and CIS regions used an EKS method based on Javon indices of representative products between countries; see ICP (2007) for a brief description of this method.

[31]He estimates a pairwise Tornqvist index for the ring African countries vs. the UK and at regional level for Africa and Asia-Pacific vs. OECD/Eursotat.

Feenstra et al. (2013) show that in China, the price level has been overstated because of a urban bias in the data collection. In order to account for this bias, the PWT introduces a uniform reduction of 20% to the ICP prices. This adjustment is consistent with their estimates of China's real GDP. Our results account for this downward revision. However, there is no clear evidence of price overestimation for other countries due to the urban bias. Actually, Atkin and Donaldson (2015) show that the price of detailed products in Ethiopia and Nigeria are on average 5-12% higher in rural areas. Therefore, urban bias should not be driving the results of the paper.

To summarize, the method of aggregation and quality matching tend to bias downwards the estimation of PPPs in low-income countries, compared to the "true" values. Moreover, there is no evidence that products' representativity systematically biases PPPs upwards, or that the urban bias affects the countries on the downward sloping path of the price-income relation. Therefore, the non-monotonicity shown in Section 2 is actually a lower-bound.

3.3 Previous versions of the Penn World Table and black market exchange rates

The analysis of the paper makes use of the Penn World Table 8.0 database. This relies on the 2005 ICP round, which arguably provides the best available data for international comparisons of real income. The PPPs of many developing countries were revised upwards after this round, and these countries have a lower real income than what was previously thought (Deaton, 2010). Although higher PPPs in poor countries work in favor of our findings, the last ICP round does not drive the results of the paper, and they also hold for previous versions of the PWT.

In Figure 6, we run a series of cross-sectional LOWESS estimations of the price-income relation for benchmark years and benchmark countries of subsequent versions of the PWT.[32] The non-monotonicity of the price-income relation is also confirmed for these older versions of the PWT.[33] Moreover, it is interesting to observe that the relative income of the turning point of the relation decreases over time, so we observe an increasing Penn-Balassa-Samuelson effect as stressed by Bergin et al. (2006).

Another potential issue to account for is that the PWT uses official exchange rates to compute the price level, but in developing countries the official rates can greatly differ from the one actually used in daily transactions, particularly in the early years of our sample. Nevertheless, this issue does not undermine the finding of the paper. As Reinhart and Rogoff (2004) argue, multiple exchange rate arrangements decreased greatly over time and apply mainly until the 1980s, while the non-monotonicity of the price-income relation shown in the paper takes the year 2005 as a benchmark. However, we have run a non-parametric estimation of price on income using black market exchange rates for the year 1996, and the non-monotonicity of the relation is also confirmed in this case.[34]

[32]We use PWT 5.6 for 1985, PWT 6.1 for 1996, and PWT 7 for 2005

[33]The non-monotonicity also holds for the panel dimension; results available upon request

[34]We choose the year 1996 because this is the oldest benchmark year for which both black market rates and raw PPPs are available. Results available upon request. Data on black market rates are taken from Reinhart and Rogoff (2004). Prices are computed by dividing PPPs from PWT 6.1 by the black market exchange rates.

This section has shown that the results of the paper are robust to classical measurement error, bias in PPP's estimation, that they hold for different versions of the PWT and are not affected by using black market exchange rates. All this provides evidence that the non-monotonicity of the price-income relation is not a spurious result, but a hitherto-undocumented economic fact.

4 Theoretical explanation

4.1 Beyond the Balassa-Samuelson hypothesis

The most accepted explanation of the Penn-BS effect is the Balassa-Samuelson (BS) hypothesis. This explanation focuses on productivity differentials between the tradable and the non-tradable sector. Assuming free labor mobility across sectors and that the law of one price holds for tradables, the BS hypothesis shows that countries with higher relative productivity in the tradable sector have a higher price level. Since richer countries tend to have higher relative productivity in the tradable sector, the price level should then rise with per-capita income. [35]

This standard explanation cannot capture the non-monotonicity of the price-income relation. The paper argues that we need a modified BS framework that accounts for the relevance of the agricultural sector in poor countries and for the fact that low-income and high-income countries are at different stages of their process of structural transformation, defined as the realloca-

[35] Devereux (1999) shows that a counter Penn-BS effect can arise if there is higher productivity growth in the non-tradable sector, due to, for instance, improvements in the distribution of the service sector. Higher productivity in the non-tradable sector and a reclassification of the non-tradable sector are key in this paper.

tion of economic activity across agriculture, manufacturing and services.

Firstly, in Table 7, we consider the benchmark countries of PWT for the year 2005. We rank countries by their level of income and divide the sample by income group as defined by the World Bank. Then, following the tradition of the development macroeconomics literature, we focus on a sectoral division of the economy between agriculture, manufacturing, and services. We can see that countries in the bottom income group have a remarkably different structure in terms of sectoral valued added, expenditure, and employment shares. The most significant differences refer to the agricultural sector: the first group of countries, where the price-income relation is negative, have a 10 times higher valued-added share in agriculture, a five times higher expenditure share and a nine times higher employment share than the countries in the top group of income. This clearly reflects the stage of development that characterizes these countries, and it is consistent with the facts of structural transformation, as summarized by Herrendorf et al. (2014).

Secondly, Figure 7 shows that there is a non-monotonic pattern between the price level and expenditure and employment shares in agriculture, which are two key proxies for the stage of development at which countries are. This pattern is consistent with structural transformation being a determinant of the non-monotonic price-income relation.

Finally, we observe a different structure of relative prices by level of development. Using disaggregated data, kindly provided by the International Comparison Program at the World Bank, we can compute sectoral PPPs and price levels.[36] Perhaps contrary to conventional wisdom, the relative price of agriculture in terms of both services and manufacturing turns to be higher in low-income countries than in rich countries. [37] Moreover, the average price level of services and manufacturing increases by income group, but the price level of agriculture decreases between the bottom and the intermediate group. Non-parametric estimations of sectoral prices on income confirm this pattern: Figure 8 shows that the price dynamics of the agricultural sector account for most of the non-monotonicity of the overall price-income relation. All this hints to the fact that structural transformation and agriculture can play a key role in explaining the non-monotonic pattern of the price-income relation.

4.2 Structural change and the price level

In this section, we aim to improve the standard Balassa-Samuelson model with some features that allow us to connect the price level to the process of structural transformation. We then test if the new model can better capture the data.

The consumption-based price index derived in the classical version of the Balassa-Samuelson hypothesis is:

$$\log P_z^{BS} = \gamma_{zNT}(\log A_{zT} - \log A_{zNT}) \tag{5}$$

[36]The price level of sector i is given by $p_i = PPP_i/XRAT$ with $p_i^{US} = 1$. In order to preserve aggregation at the GDP level, we use the Geary-Khamis method to compute sectoral PPPs. See appendix A.5 for a detailed description of sectoral classification of goods; as suggested by Herrendorf and Valentinyi (2011), we map the agricultural sector with the food sector.

[37]Caselli (2005) hints at this possibility in a footnote. Lagakos and Waugh (2012) have a similar finding.

where γ_{zNT} is the expenditure share of non-tradables in country z, A_{zT} is TFP in the tradable sector, and A_{zNT} is TFP in the non-tradable sector. We can observe that, as richer countries have a higher relative productivity in the tradable sector, they will have a higher price level for any given expenditure share of non-tradables.

We develop a three-sector model (agriculture, manufacturing, and services) that links the price level of a country to its process of structural transformation. We take, as a reference, the model of Ngai and Pissarides (2007) and derive the price level implied by the model, so that it can reflect a country's stage of development.[38] We do so by staying as close as possible to the framework and assumptions of the Balassa-Samuelson model, so that we can preserve simplicity and comparability with the standard model. We derive the full model in the appendix. The solution to the price level equation is such that:

$$\log P^{BS+} = (\gamma_{zA}+\gamma_{zS}) \left[\log A_{zM} - \left(\frac{l_{zA}}{l_{zA}+l_{zs}} \log A_{zA} + \frac{l_{zS}}{l_{zA}+l_{zS}} \log A_{zS} \right) \right] \tag{6}$$

where A_{zi} is TFP of country z in sector i ($i = A, M, S$; agriculture, manufacturing and services); l_{zi} and γ_{zi} are employment shares and expenditures shares of country z in sector i. We label this price equation "Balassa-Samuelson+" because (5) and (6) are very similar. The differences are that in the "Balassa-Samuelson+", there is a better focus on the agricultural

[38] We choose Ngai and Pissarides (2007) as the main reference between the models of structural transformation along a generalized balanced growth path, because it can generate both a decline in the employment share of agriculture and a change in sectoral relative prices, which is consistent with what we observe in the data. Alternative models like Kongsamut et al. (2001) can generate a decreasing employment share of agriculture, but they imply constant relative prices, which is at odds with empirical evidence. See Herrendorf et al. (2014) for a detailed discussion of alternative models of structural transformation.

sector, and the sectoral TFPs of agriculture and services are weighted by the relative employment shares, so that the price index reflects the stage of structural transformation. If we shut down the focus on the agricultural sector by setting γ_{zA} and l_{zA} equal to zero, as if they were absorbed by the manufacturing sector, we are back to the standard Balassa-Samuelson hypothesis.

Looking at equation (6), the intuition behind a decreasing price-income relation is that as TFP of agriculture increases, which implies a decrease in the relative price of agriculture[39], given the high share of labor in agriculture in poor countries, the aggregate price level decreases. As countries advance in the process of structural transformation, employment in agriculture shrinks and the weight of agricultural TFP decreases. After a certain level of income, TFP in manufacturing relative to services becomes the main driver of the aggregate price-level, and we are back to the standard Balassa-Samuelson hypothesis.

An important element of this explanation is that agricultural goods are non-tradabale, so that there is no price equalization of agricultural products, and agricultural prices are relatively higher in poor countries because of lower productivity. More precisely, we do not assume that agricultural goods are intrinsically non-tradable, but that in practice are not traded, at least from the perspective of low-income countries. This assumption is consistent with empirical observations as reported in Gollin et al. (2007) and Tombe (2015). Tombe (2015) shows how trade costs lead to minimal food imports in poor countries, despite the low productivity in agriculture. Moreover, Gollin et al.

[39]See equation 25 in the appendix.

(2007) argue that *" it is reasonable to view most [poor] economies as closed from the perspective of trade in food"*. They show that in the year 2000 about 70% of arable land in 159 developing countries was devoted to staple food crops. With the exception of few developing countries, almost all of the resulting production was for domestic consumption. Using FAOSTAT data for 2005, we find that the share of cereal exports relative to overall production is respectively 3%, 12%, and 37% for the countries where the price-income relation is negative, flat, and positive. Moreover, food imports and food aid are not a major source of food for poor countries: imports of food supply around 5% of total calories consumed. Finally, consistently with the point stressed above, Figure 9 shows that there is a strong and negative relation between the price of wheat and income (FAOSTAT, 2005).[40]

Moreover, the mechanism described in the paper is consistent with the "labor push" hypothesis of structural transformation, as in Alvarez-Cuadrado and Poschke (2011). This hypothesis considers growth in agricultural productivity as the main driver of structural change. They show that this is the case after World War II, when TFP growth in agriculture became higher than in manufacturing thanks to key innovations in cultivation processes and mechanization.[41] This argument goes back to the seminal paper of Nurkse (1953), and it is a central aspect in the literature on structural transformation, as in Gollin et al. (2002, 2007) and Ngai and Pissarides (2007). It is also consistent with the findings of Duarte and Restuccia (2010), who show for a panel of 29 countries between 1956-2004 that productivity growth was

[40]The dependent variable refers to producer price in US$ per tonne. The coefficient is −21.7 and significant at the 1% level (robust t-stat is 4.87), over a sample of 70 countries for which data are available. Similar results hold for maize and other non-coarse cereals.

[41]For periods before World-War II, Alvarez-Cuadrado and Poschke (2011) show that "labor pull" - higher productivity growth in the manufacturing sector - was the main driver of the process of structural transformation.

4% in agriculture, 3% in manufacturing and 1.3% in services.

4.3 Quantitative results

We feed equations (5) and (6) with data on sectoral TFP, expenditure shares, and employment shares. We obtain sectoral estimates of TFP across countries, following the methodology of Herrendorf and Valentinyi (2011).[42] Employment shares are taken from the WDI database and from national sources. The consumption share in agriculture and services are given by the expenditure shares from the ICP database.[43]

Finally, we run a non-parametric estimation of the price levels implied by the two models and income per-capita. We then compare the two estimates with the one obtained using prices from the PWT.[44] Figure 10.1 shows the fitted values of the non-parametric estimation of the price-income relation, where prices are given by equation (5): we are able to confirm the strictly positive relation predicted by the Balassa-Samuelson hypothesis.

However, Figure 10.2 shows that the price implied by the "BS+" hypothesis allows for more flexibility in the price-income relation and can generate a negative pattern at low levels of development. Therefore, by taking into

[42] They present development accounting framework to compute sectoral productivities using the Penn World Table; see the appendix for a detailed description.

[43] We are able to compute the price levels for 60 countries out of 127 because of the lack of sectoral employment data in many poor countries and lack of investment data necessary for computing TFP in middle-income and former USSR countries; following Caselli (2005), we exclude countries with data on investment starting only after the '70s.

[44] Prices in the PWT are derived from prices of a set of goods across countries, collected in local currency units. In order to make these local prices comparable, they need to be converted and aggregated using an appropriate methodology (i.e. a PPPs conversion or simple conversion in USD). In the case of the PWT, this is done with a PPP conversion using the Geary-Khamis method. The theoretical prices computed by the models are the result of TFP levels, expenditure shares, and employment shares, which are directly comparable across countries, so there is no need to apply a Geary-Khamis method to these prices.

account that countries are at a different stage of their process of structural transformation, we are better able to match the actual pattern of the data reported in Figure 10.3.

Table 8 analyzes the quantitative fit: under the BS+ hypothesis, 26% of countries in the sample are on the downward sloping path of the price-income relation; in the standard BS hypothesis this is 0%, and in the actual data it is 20% of the sample. The variance of prices generated by the BS+ hypothesis is two and a half times higher than in the data (1.02 vs 0.41). Finally, the turning point of the BS+ model is around 3,000 PPP$, but in the data it is around 1,440 PPP$.

The quantitative result of the "Balassa-Samuleson+" hypothesis clearly outperforms that of the Balassa-Samuelson hypothesis. The model derived in this paper is relatively simple and a richer approach, that accounts for other factors like the tradability of agriculture in rich countries or the reduction of trade costs as a country develops, might deliver a better quantitative fit. However, the results presented are encouraging and lay the ground for further theoretical and empirical research on the relation between structural transformation and the real exchange rate.

5 Conclusions

We show that the relation between price and income is non-monotonic. To our knowledge, this is an original finding, and it is a hitherto undocumented empirical regularity. This result contradicts the conventional wisdom of a positive price-income relation, which draws upon a linear estimation. If we apply a non-parametric estimation or allow for non-linearities in standard regressions, the price-income relation turns out to be significantly negative in poor countries. This finding is robust along both cross-section and panel dimensions. The new evidence presented in this paper raises general questions about the relation between the process of economic development and the price level, as well as about the long-run determinants of real exchange rates in poor countries.

The paper shows that a simple model linking the price level to the process of structural transformation that characterizes developing countries can generate a non-monotonic pattern of the price-income relation. This result suggests that structural change and, more generally, inter-sectoral dynamics can be important determinants of real exchange rates movements.

Nevertheless, a richer theoretical approach could improve the quantitative fit. For instance, the model does not account for the role of trade costs. Trade costs are much higher than is generally recognized, even for traded goods: Anderson and Van Wincoop (2004) estimate that, for developed countries, trade costs average 170% of production costs, of which roughly half are international trade costs and half are internal trade costs. For developing countries, they claim that this ratio is often higher, and many studies do indeed show strikingly high transport costs for individual developing countries or groups thereof (Limao and Venables, 2001).

Trade costs and the ratio of trade costs to production costs may well vary systematically with the level of development. For example, as a low-income country starts developing, its infrastructure improves, reducing both internal and external trade costs, as well as the ratio of trade costs to production. This might turn out to be a key element in explaining the initial negative pattern of the price-income relation and deserves further investigation. This is consistent with Du et al. (2013), who show that transport infrastructure is an important determinant of exchange rate especially in developing countries.

The tradability of agriculture in more developed countries is another feature for which a richer model should account. In the current model, agriculture is completely non-tradable, and this could partly explain the high variance of prices and the turning point's high level of income that the model predicts.

Finally, a possible empirical extension of the paper could focus on regional variation within countries like India or China, where there are regions at very different stages of development. This kind of regional variation would provide interesting insights into the mechanisms of structural transformation as a driver of the non-monotonic price-income relation.

This paper lays the ground for further theoretical and empirical research on the relation between economic development and the price level. The results presented, although surprising, should not be disturbing. It is probable that Samuelson himself would not have been startled. In his 1994 article for the thirty-year anniversary of the Balassa-Samuelson model, he wrote that " *The Penn-Balassa-Samuelson effect is an important phenomenon of actual history but not an inevitable fact of life. It can quantitatively vary and,* ***in different times and places, trace to quite different processes***".

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A Appendix

A.1 Countries in the cross-section analysis of section

Albania
Angola
Argentina
Armenia
Australia
Austria
Azerbaijan
Bangladesh
Belarus
Belgium
Benin
Bolivia
Bosnia and Herz.
Botswana
Brazil
Bulgaria
Burkina Faso
Cambodia
Cameroon
Canada
Central Afr. Rep.
Chad
Chile
China
Colombia
Congo, Dem. Rep.
Congo, Rep. of
Cote d'Ivoire
Croatia
Czech Republic
Denmark
Ecuador
Egypt
Estonia
Ethiopia
Finland
France
Gabon
Gambia, The
Georgia
Germany
Ghana
Greece
Guinea
Guinea-Bissau
Hong Kong
Hungary
India
Indonesia
Iran
Iraq
Ireland
Israel
Italy
Japan
Jordan
Kazakhstan
Kenya
Korea
Kuwait
Kyrgyzstan
Laos
Latvia
Lebanon
Lesotho
Liberia
Lithuania
Macedonia
Madagascar
Malawi
Malaysia
Mali
Mauritania
Mauritius
Mexico
Moldova
Mongolia
Morocco
Mozambique
Namibia
Nepal
Netherlands
New Zealand
Niger
Nigeria
Norway
Oman
Pakistan
Paraguay
Peru
Philippines
Poland
Portugal
Romania
Russia
Rwanda
Saudi Arabia
Senegal
Serbia
Sierra Leone
Singapore
Slovak Rep.
Slovenia
South Africa
Spain
Sri Lanka
Sudan
Swaziland
Sweden
Switzerland
Syria
Taiwan
Tanzania
Thailand
Togo
Tunisia
Turkey
Uganda
Ukraine
United Kingdom
United States
Uruguay
Venezuela
Vietnam
Yemen
Zambia

A.2 Derivation of the Balassa-Samuelson+ Price Equation

A.2.1 Model setup

A representative consumer in country z maximizes the following utility function across three aggregate goods in agriculture, manufacturing, and services:[45]

$$U(c_a, c_m, c_s) = \left[\gamma_a^{\frac{1}{\theta}} c_a^{\frac{\theta-1}{\theta}} + \gamma_m^{\frac{1}{\theta}} c_m^{\frac{\theta-1}{\theta}} + \gamma_s^{\frac{1}{\theta}} c_s^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \tag{7}$$

Firms in each sector maximize a Cobb-Douglas production function technology with capital and labor, such that:

$$F_i(k_i, l_i) = A_i k_i^{\alpha} n_i^{1-\alpha}; \quad i = a, m, s \tag{8}$$

Market clearing must then satisfy:

$$\sum_{i=1}^{m} l_i = 1; \;\; \sum_{i=1}^{m} k_i = k; \tag{9}$$

Finally, we assume $F_i = c_i$ for $i = a, s$ and that manufacturing produces both a final consumption good and the economy's capital stock, so that $\dot{k} = F^m - c_m - (\delta + n)k$. This means that manufacturing is the only tradable good and that trade is balanced period by period.[46] This assumption implies that the effect of trade is to equalize the price of manufacturing across countries and that there is financial autarky across countries, which is a reasonable assumption for low-income countries.

[45] To save on notation, we dismiss the country subscript z for the rest of the appendix.
[46] This is similar to the one in the standard Balassa-Samuelson model, and it helps to keep our model as close and as comparable as possible to the standard one.

A.2.2 Utility maximization and the consumption-based price index

The consumption-based price index measures the least expenditure that buys a unit of the consumption index on which period utility depends. It is defined as the minimum expenditure:

$$r = P_a c_a + P_m c_m + P_s c_s \tag{10}$$

such that $c = \phi(c_a, c_m, c_s) = 1$ given P_i.

Consumer's utility maximization implies that:

$$\frac{MU_i}{MU_j} = \frac{P_i}{P_j} \tag{11}$$

so that:

$$\left(\frac{\gamma_a}{\gamma_m}\right)^{\frac{1}{\theta}} \left(\frac{c_m}{c_a}\right)^{\frac{1}{\theta}} = \frac{P_a}{P_m}; \quad c_a = \frac{\gamma_a}{\gamma_m} c_m \left(\frac{P_a}{P_m}\right)^{-\theta} \tag{12}$$

and

$$\left(\frac{\gamma_s}{\gamma_m}\right)^{\frac{1}{\theta}} \left(\frac{c_m}{c_s}\right)^{\frac{1}{\theta}} = \frac{P_s}{P_m}; \quad c_s = \frac{\gamma_s}{\gamma_m} c_m \left(\frac{P_s}{P_m}\right)^{-\theta} \tag{13}$$

Substituting c_a and c_s from (12) and (13) into (10) we have:

$$z = \frac{P_a^{1-\theta}}{P_m^{-\theta}} \frac{\gamma_a}{\gamma_m} c_m + P_m c_m + \frac{P_s^{1-\theta}}{P_m^{-\theta}} \frac{\gamma_s}{\gamma_m} c_m \tag{14}$$

so that rearranging:

$$c_m = \frac{\gamma_m P_m^{-\theta} z}{\gamma_a P_a^{1-\theta} + \gamma_m P_m^{1-\theta} + \gamma_s P_s^{1-\theta}} \tag{15}$$

and consequently:

$$c_a = \frac{\gamma_a P_a^{-\theta} z}{\gamma_a P_a^{1-\theta} + \gamma_m P_m^{1-\theta} + \gamma_s P_s^{1-\theta}} \tag{16}$$

$$c_s = \frac{\gamma_s P_s^{-\theta} z}{\gamma_a P_a^{1-\theta} + \gamma_m P_m^{1-\theta} + \gamma_s P_s^{1-\theta}} \tag{17}$$

Equations (15), (16), and (17) are the demands that maximize c given spending z. Thus, the highest value of the utility function c given z, is found by substituting these demands into (7):

$$\left[\gamma_a^{\frac{1}{\theta}} \left(\frac{\gamma_a P_a^{-\theta} z}{x}\right)^{\frac{\theta-1}{\theta}} + \gamma_m^{\frac{1}{\theta}} \left(\frac{\gamma_m P_m^{-\theta} z}{x}\right)^{\frac{\theta-1}{\theta}} + \gamma_s^{\frac{1}{\theta}} \left(\frac{\gamma_s P_s^{-\theta} z}{x}\right)^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \tag{18}$$

where $x = \gamma_a P_a^{1-\theta} + \gamma_m P_m^{1-\theta} + \gamma_s P_s^{1-\theta}$.

Since P is defined as the minimum expenditure z such that $c = 1$, we have:

$$\left[\gamma_a^{\frac{1}{\theta}} \left(\frac{\gamma_a P_a^{-\theta} P}{x}\right)^{\frac{\theta-1}{\theta}} + \gamma_m^{\frac{1}{\theta}} \left(\frac{\gamma_m P_m^{-\theta} P}{x}\right)^{\frac{\theta-1}{\theta}} + \gamma_s^{\frac{1}{\theta}} \left(\frac{\gamma_s P_s^{-\theta} P}{x}\right)^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} = 1 \tag{19}$$

from which the solution for P is:

$$P = \left(\gamma_a P_a^{1-\theta} + \gamma_m P_m^{1-\theta} + \gamma_s P_s^{1-\theta}\right)^{\frac{1}{1-\theta}} \tag{20}$$

This is the consumption-based price index consistent with the CES utility function. When $\theta = 1$ the utility function becomes Cobb-Douglas; in this case the price index becomes:

$$\log P = \frac{\log(\gamma_a P_a^{1-\theta} + \gamma_m P_m^{1-\theta} + \gamma_s P_s^{1-\theta})}{1-\theta} \tag{21}$$

Solving the problem for the Cobb-Douglas case can seem at odds with the explanation of structural transformation provided in the paper. This is because, under Cobb-Douglas preferences, expenditure and employment shares are constant for a country in a time series dimension. However, given the empirical data that our model is trying to match, we are solving the problem as a series of cross-sections, so that employment shares and expenditure shares are going to differ across countries and capture the point of structural transformation for each country. This approach allows us to keep the model easily comparable with the standard Balassa-Samuelson model, and it is consistent with the fact that we aim to match a cross-sectional empirical result.

Therefore, applying L'Hopital's rule we have:

$$\lim_{\theta \to 1} \frac{\log(\gamma_a P_a^{1-\theta} + \gamma_m P_m^{1-\theta} + \gamma_s P_s^{1-\theta})}{1-\theta} = \frac{f(\theta)}{g(\theta)} = \lim_{\theta \to 1} \frac{f'(\theta)}{g'(\theta)} = \gamma_a \log P_a + \gamma_m \log P_m + \gamma_s \log P_s \tag{22}$$

so that for the Cobb-Douglas case, the consumption-based price index is given by:

$$\log P = \gamma_a \log P_a + \gamma_m \log P_m + \gamma_s \log P_s \tag{23}$$

Accounting for the cross-country equalization of the price of manufacturing through trade and normalizing it to one, the consumption-based price index can be written as:

$$\log P = \gamma_a \log p_a + \gamma_s \log p_s \tag{24}$$

A.2.3 Production maximization, relative prices, consumption shares and employment shares

From supply-side, the static efficiency condition requires an equal marginal rate of technical substitution across sectors, so that $k_i = k$; while free movement of capital and labor leads to equal remuneration of the factors of production. Therefore, firms' profit maximization implies:

$$\frac{P_a}{P_m} = \frac{A_m}{A_a} \tag{25}$$

$$\frac{P_s}{P_m} = \frac{A_s}{A_a} \tag{26}$$

From consumer's optimality conditions (12) and (13) we can define the relative expenditure of agriculture and services with respect to manufacturing as:

$$\frac{P_a c_a}{P_m c_m} = \frac{\gamma_a}{\gamma_m}\left(\frac{P_a}{P_m}\right)^{1-\theta} \equiv x_a \tag{27}$$

$$\frac{P_s c_s}{P_m c_m} = \frac{\gamma_s}{\gamma_m}\left(\frac{P_s}{P_m}\right)^{1-\theta} \equiv x_s \tag{28}$$

We then define $X = x_a + x_s + x_m$, where clearly $x_m = 1$. We also define:

$$c \equiv \sum_{i=1}^{m} P_i c_i; \qquad y \equiv \sum_{i=1}^{m} P_i F^i \tag{29}$$

Using equations (27) and (28) and the efficiency conditions, we can rewrite equations (29) as:

$$c = P_m c_m X; \qquad y = P_m A_m k^{\alpha} \tag{30}$$

Notice that the technology parameter for output is TFP in manufacturing, not an average of all sectors.

As in Ngai and Pissarides (2007) we can link relative expenditure with the employment shares. If we substitute $F^i = c_i$ for $i = a, s$ in (27) and (28), using the market clearing conditions in (9), we can show that it results in the following:

$$l_a = \frac{c}{y}\frac{x_a}{X} \tag{31}$$

$$l_s = \frac{c}{y}\frac{x_s}{X} \tag{32}$$

The employment share in the manufacturing sector is derived by firstly observing that $l_m = 1 - l_a - l_s$, so that we have:

$$l_m = \frac{c}{y}\frac{x_m}{X} + \left(1 - \frac{c}{y}\right) \tag{33}$$

Let's consider the case where $\theta = 1$ and manufacturing is the numeraire. In this case the price index is given by $\log P = \gamma_a \log p_a + \gamma_s \log p_s$. By using firm's optimality conditions (25) and (26), as well as (31) and (32), we can write the price level as:

$$\log P = (\gamma_a + \gamma_s)\left[\log A_m - \left(\frac{l_a}{l_a + l_s}\log A_a + \frac{l_s}{l_a + l_s}\log A_s\right)\right] \tag{34}$$

A.3 Sectoral TFPs methodology

In order to compute sectoral TFPs, we use the methodology of Herrendorf and Valentinyi (2011) who introduce a sectoral development accounting framework that allows them to compute sectoral TFPs using the PWT. The key assumptions of their methodology are: competitive markets; factor's mobility across sectors; Cobb-Douglas production functions with factor shares common to all countries.

The production function for sector i in country z is given by:

$$y_i^z = A_i^z (k_i^z)^{\theta_i} (l_i^z)^{\phi_i} (h_i^z)^{1-\theta_i-\phi_i} \tag{35}$$

where k is capital, l is land, and h is human capital.
Under the assumption stated above, Herrendorf and Valentinyi (2011) show that the sectoral factors of production are:

$$k_i^z = \frac{\theta_i p_i^z y_i^z}{\sum_j \theta_j p_j^z y_j^z} \sum_i k_i^z \tag{36}$$

$$l_i^z = \frac{\phi_i p_i^z y_i^z}{\sum_j \phi_j p_j^z y_j^z} \sum_i l_i^z \tag{37}$$

$$h_i^z = \frac{(1-\theta_i-\phi_i) p_i^z y_i^z}{\sum_j (1-\theta_j-\phi_j) p_j^z y_j^z} \sum_i h_i^z \tag{38}$$

In order to compute sectoral TFPs, we take the sectoral factor shares from Herrendorf and Valentinyi (2011), who calculate them from the US input-output tables. Then, following their methodology, we compute the capital stock in the economy k^z, using the perpetual inventory method as in Caselli (2005). Land l^z is arable land for agriculture and urban land for manufacturing and services. We take data on arable land from FAOSTAT and following World Bank (2006) estimates, we set urban land equal to 24% of physical capital. Finally, we compute human capital h^z as in Caselli (2005), and it is an increasing function of average years of schooling per worker.

A.4 ICP 2005, classification of goods

Category	Basic Heading	*BS-SC framework:* **Sector allocation**	*BS-framework:* **Tradability**
	Rice	A	T
	Other cereals and flour	A	T
	Bread	A	T
	Other bakery products	A	T
	Pasta products	A	T
	Beef and veal	A	T
	Pork	A	T
	Lamb, mutton and goat	A	T
	Poultry	A	T
	Other meats and preparations	A	T
	Fresh or frozen fish and seafood	A	T
	Preserved fish and seafood	A	T
Food	Fresh milk	A	T
	Preserved milk and milk products	A	T
	Cheese	A	T
	Eggs and egg-based products	A	T
	Butter and margarine	A	T
	Other edible oils and fats	A	T
	Fresh or chilled fruit	A	T
	Frozen, preserved or processed fruits	A	T
	Fresh or chilled vegetables	A	T
	Fresh or chilled potatoes	A	T
	Frozen or preserved vegetables	A	T
	Sugar	A	T
	Jams, marmalades and honey	A	T
	Confectionery, chocolate and ice cream	A	T
	Food products n.e.c.	A	T

Category	Basic Heading	*BS-SC framework:* **Sector allocation**	*BS-framework:* **Tradability**
Beverages and tobacco	Coffee, tea and cocoa	M	T
	Mineral waters,soft drinks,fruit and veg juices	M	T
	Spirits	M	T
	Wine	M	T
	Beer	M	T
	Tobacco	M	T
Clothing and footwear	Clothing materials and accessories	M	T
	Garments	M	T
	Cleaning and repair of clothing	S	NT
	Footwear	M	T
	Repair and hire of footwear	S	NT
Housing, water, electricity and gas	Actual and imputed rentals for housing	S	NT
	Maintenance and repair of the dwelling	S	NT
	Water supply and miscellaneous services relating to the dwelling	S	NT
	Miscellaneous services relating to the dwelling	S	NT
	Electricity	M	T
	Gas	M	T
	Other fuels	M	T
Furniture, household equipment and maintenance	Furniture and furnishings	M	T
	Carpets and other floor coverings	M	T
	Repair of furniture, furnishings and floor coverings	S	NT
	Household textiles	M	T
	Major household appliances whether electric or not	M	T
	Small electric household appliances	M	T

Category	**Basic Heading**	*BS-SC framework:* **Sector allocation**	*BS-framework:* **Tradability**
Furniture, household equipment and maintenance	Repair of household appliances	S	NT
	Glassware, tableware and household utensils	M	T
	Major tools and equipment	M	T
	Small tools and miscellaneous accessories	M	T
	Non-durable household goods	M	T
	Domestic services	S	NT
	Household services	S	NT
Health	Pharmaceutical products	M	T
	Other medical products	M	T
	Therapeutical appliances and equipment	M	T
	Medical Services	S	NT
	Dental services	S	NT
	Paramedical services	S	NT
	Hospital services	S	NT
Transport	Motor cars	M	T
	Motor cycles	M	T
	Bicycles	M	T
	Fuels and lubricants for personal transport equipment	M	T
	Maintenance and repair of personal transport equipment	S	NT
	Other services in respect of personal transport equipment	S	NT
	Passenger transport by railway	S	NT
	Passenger transport by road	S	NT
	Passenger transport by air	S	NT

Category	Basic Heading	*BS-SC framework:* **Sector allocation**	*BS-framework:* **Tradability**
Transport	Passenger transport by sea and inland waterway	S	NT
	Combined passenger transport	S	NT
	Other purchased transport services	S	NT
Communication	Postal services	S	NT
	Telephone and telefax equipment	M	T
	Telephone and telefax services	S	NT
Recreation and culture	Audio-visual, photographic and information processing equipment	M	T
	Recording media	M	T
	Repair of audio-visual, photographic and information processing equipment	S	NT
	Major durables for outdoor and indoor recreation	M	T
	Other recreational items and equipment	M	T
	Gardens and pets	S	NT
	Veterinary and other services for pets	S	NT
	Recreational and sporting services	S	NT
	Cultural services	S	NT
	Games of chance	S	NT
	Newspapers, books and stationery	S	NT
	Package holidays	S	NT
Education	Education	S	NT
Restaurant and hotels	Catering services	S	NT
	Accommodation services	S	NT
Miscellaneous goods and services	Hairdressing salons and personal grooming establishments	S	NT
	Appliances, articles and products for personal care	S	NT

Category	Basic Heading	*BS-SC framework:* **Sector allocation**	*BS-framework:* **Tradability**
Miscellaneous goods and services	Prostitution	S	NT
	Jewellery, clocks and watches	M	T
	Other personal effects	M	T
	Social protection	S	NT
	Insurance	S	NT
	FISIM	S	NT
	Other financial services n.e.c	S	NT
	Other services n.e.c.	S	NT
Government expenditure	Government compensation of employees	S	NT
	Government intermediate consumption	M	T
	Government gross operating surplus	S	NT
	Government net taxes on production	S	NT
	Government receipts from sales	S	NT
Capital formation	Metal products and equipment	M	T
	Transport equipment	M	T
	Residential buildings	M	T
	Non-residential buildings	M	T
	Civil engineering works	M	T
	Other products	M	T
Inventories	Changes in inventories and acquisitions	M	T

A=agriculture; M=manufacturing; S=services; T=tradable; NT=non-tradable.

The sectoral allocation and the tradability allocation apply respectively to the estimation of the Balassa-Samuelson-Structural-Change and the Balassa-Samuelson framework in section 4.

Tables

Table 1: Countries on the downward sloping arm of the LOWESS estimation, cross-section dimension

Bangladesh	Liberia
Benin	Madagascar
Burkina Faso	Malawi
Central African Republic	Mali
Congo, Dem Rep.	Mozambique
Ethiopia	Nepal
Gambia	Niger
Ethiopia	Rwanda
Gambia	Sierra Leone
Guinea	Tanzania
Guinea-Bissau	Togo
Kenya	Uganda
Lesotho	Zambia

Table 2: Cross-country OLS regression: linear and quadratic specifications, year 2005

Dependent var: ln *price*	(1)	(2)
ln *income*	0.21***	-1.61***
	(9.23)	(-7.09)
ln $income^2$		0.11***
		(7.80)
N. Obs.	126	126
R^2	0.44	0.64

*** Significant at the 1% level; robust t-statistics in parenthesis.

Table 3: Tests for a U-shape

Dependent var: ln *price*	
Slope at $Income_{min}$	-0.44***
	(-5.68)
Slope at $Income_{max}$	0.72***
	(9.74)
SLM test for U-shape	5.68
p-value	0.00

*** Significant at the 1% level; robust t-statistics in parenthesis.

Table 4: Cross-country OLS regression by income groups, year 2005

Dependent var: ln *price*	ln income
Low income	-0.21**
	(-3.85)
Middle income	0.06
	(0.65)
High income	0.51***
	(2.29)
Full sample	0.21***
	(9.23)

*** Significant at the 1% level; ** significant at the 5% level; robust t-statistics in parenthesis.

Table 5: Countries on the downward sloping arm of the LOWESS estimation, panel dimension

Country	Frequency	Country	Frequency	Country	Frequency
Bangladesh	38	Guinea	24	Nigeria	14
Benin	53	Guinea-Bissau	52	Pakistan	20
Bolivia	7	India	45	Paraguay	5
Bosnia Herzegovina	4	Indonesia	15	Philippines	3
Botswana	16	Iraq	1	Romania	2
Brazil	2	Kenya	24	Rwanda	41
Burkina Faso	53	Korea	14	Senegal	4
Cambodia	35	Laos	24	Sierra Leone	48
Cameroon	15	Lesotho	51	Sudan	33
Central African Rep.	52	Liberia	33	Syria	16
Chad	44	Madagascar	52	Taiwan	2
China	30	Malawi	58	Tanzania	50
Congo, Dem. Rep.	62	Mali	48	Thailand	17
Congo, Republic of	20	Mauritania	26	Togo	52
Cote d'Ivoire	2	Mongolia	13	Tunisia	1
Egypt	34	Morocco	11	Uganda	46
Ethiopia	62	Mozambique	52	Vietnam	11
Gambia	52	Nepal	52	Yemen	15
Ghana	13	Niger	52	Zambia	20

Table 6: Panel evidence on price level and real income, 1950-2009 (5-year average)

Dependent var: ln *price*	**Full Sample**		**Developing Countries**	
	(1)	(2)	(1)	(2)
ln income	0.08***	0.002	-0.11***	-0.18***
	(2.38)	(0.04)	(-2.51)	(-2.79)
Country, fe	NO	YES	NO	YES
Time dummies	YES	YES	YES	YES
No. of countries	126	126	9.4	9.4
Avg obs per country	9.7	9.7	94	94

*** Significant at the 1% level; robust t- and z-statistics in parenthesis.

Table 7: Price-income relation and the stage of development

price-income relation		1st Tercile negative	2nd Tercile flat	3rd Tercile positive
Value-added share of GDP				
	Agriculture	30.46	11.09	2.84
	Manufacturing	26.42	37.00	31.95
	Services	43.12	51.92	65.21
Employment share				
	Agriculture	60.61	28.02	6.65
	Manufacturing	10.50	22.10	26.01
	Services	28.33	49.13	66.97
Expenditure share				
	Agriculture	35.08	20.45	8.47
	Manufacturing	41.71	43.86	41.42
	Services	20.28	25.15	29.91
Price level				
	Agriculture	0.67	0.63	1.06
	Manufacturing	0.56	0.63	1.03
	Services	0.19	0.27	0.77

Table 8: Data and models

	Data	BS+ Model	BS Model
Countries on the downward sloping path	20%	26%	0%
Price, Std. Deviation	0.41	1.02	0.02
Turning point	1,464 PPP$	3,070 PPP	-

Figures

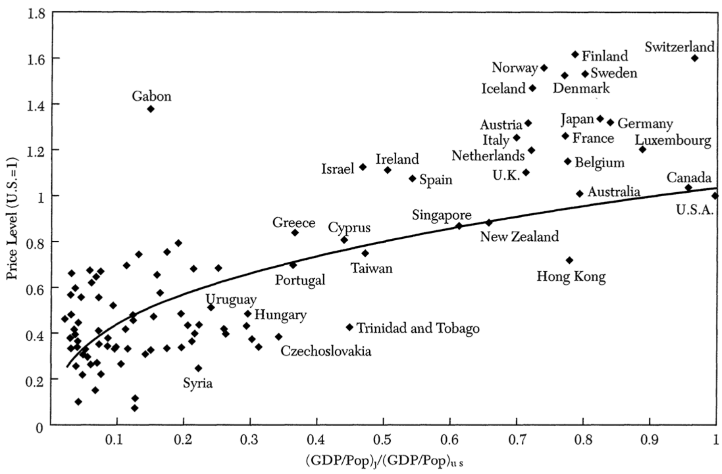

Figure 1.1: Price Level and Income - Rogoff (1996)

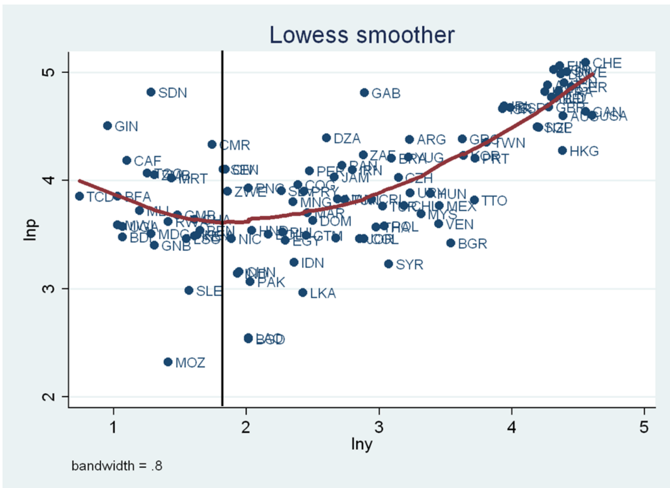

Figure 1.2: Price Level and Income - Rogoff (1996); log-income & non-param. estimation

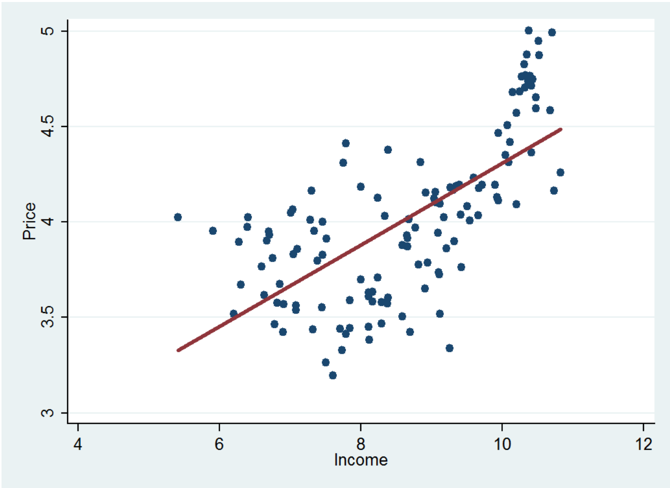

Figure 2.1: Price level and Income PWT 8.0, benchmark countries, 2005: Linear Estimation

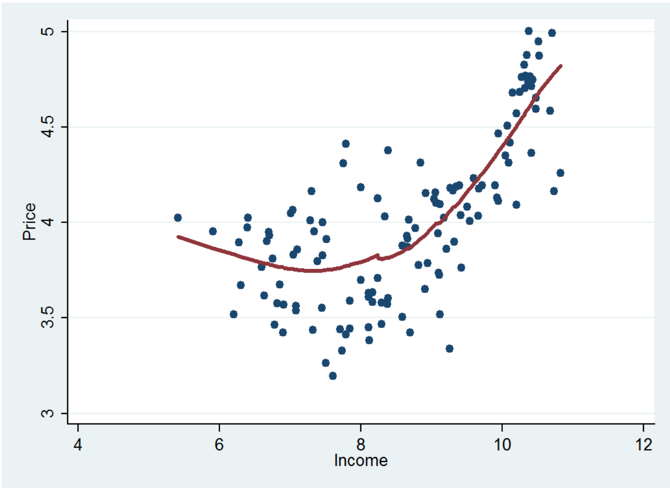

Figure 2.2: Price level and Income PWT 8.0, benchmark countries, 2005: Non-Parametric Estimation

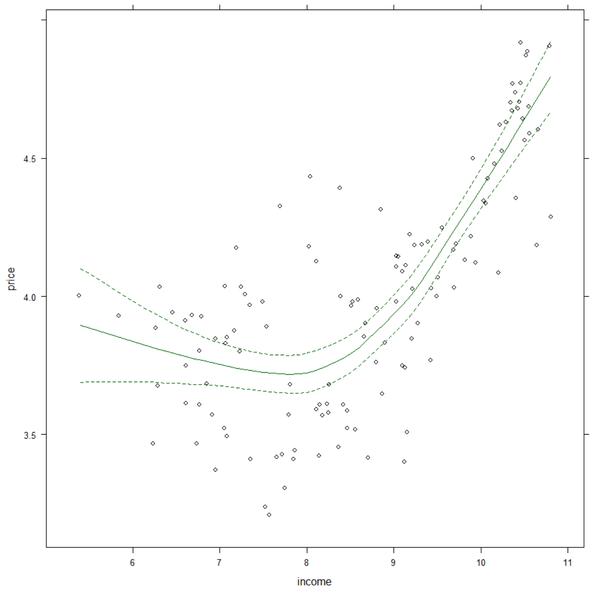

Figure 3: Price and Income PWT 8.0, benchmark countries, 2005: Non-Parametric Estimation, 95% confidence bands

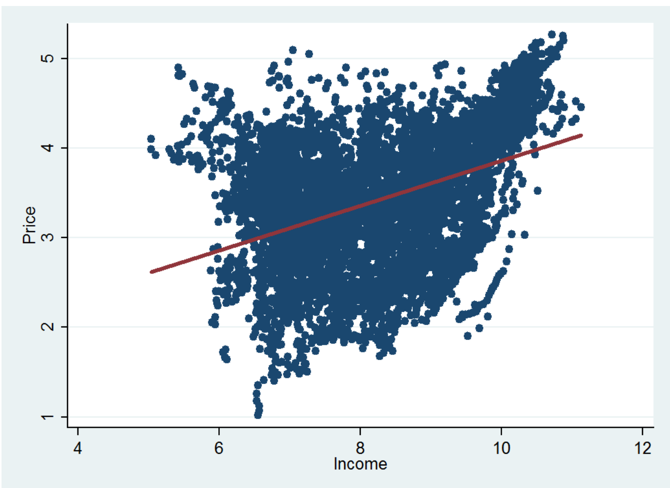

Figure 4.1: Prices and Income 1950-2011: OLS Estimation

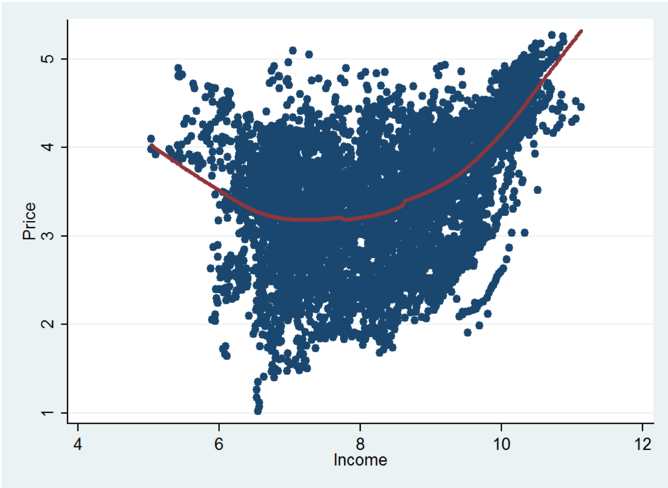

Figure 4.2: Prices and Income 1950-2011: Non-Parametric Estimation

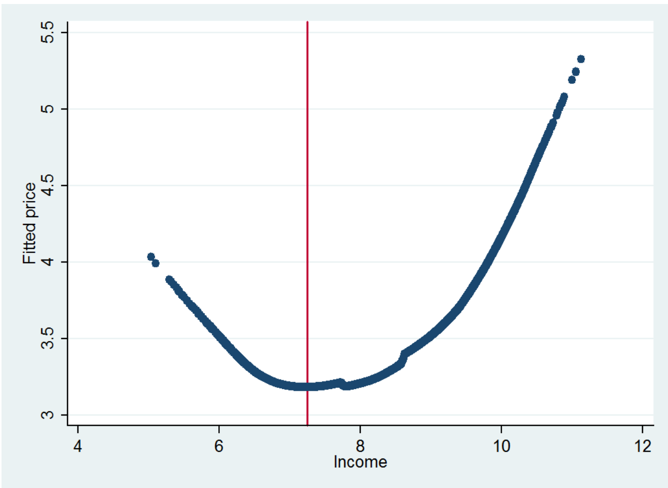

Figure 4.3: Prices and Income 1950-2011: Non-Parametric Estimation, fitted values

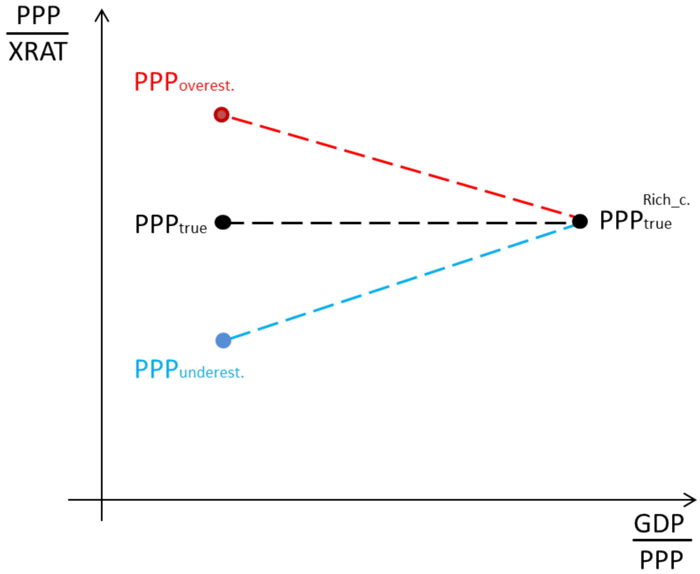

Figure 5: The effect of PPPs bias

Figure 6: Price and income: benchmark years and countries

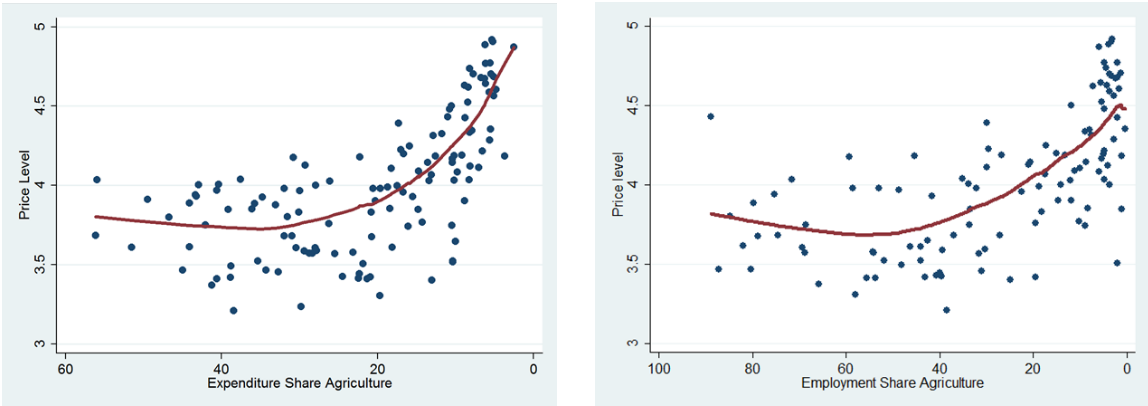

Figure 7: Price Level, Expenditure and Employment Share of Agriculture (reversed scale): Non-Parametric Estimation

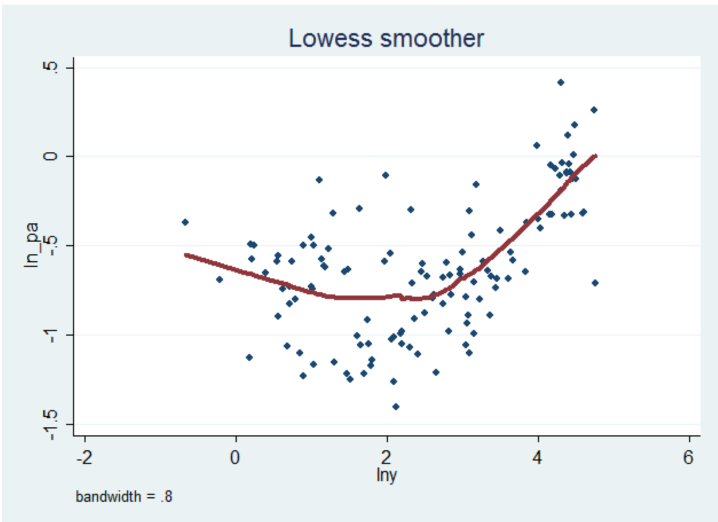

Figure 8.1: Price of Agriculture and Income: Non-Parametric Estimation

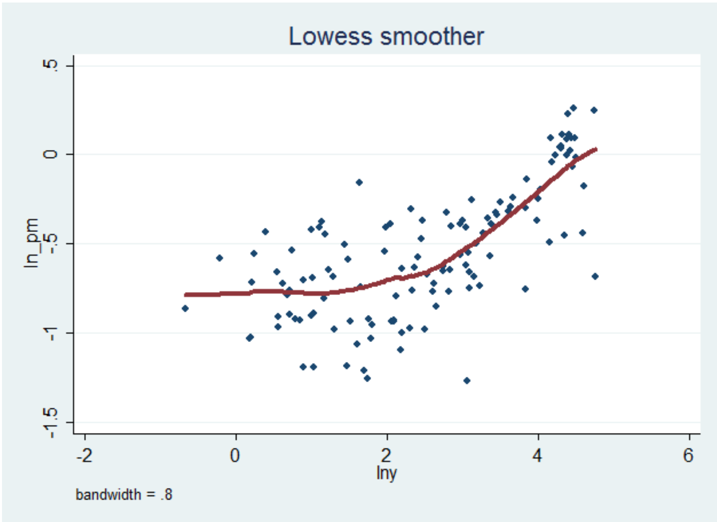

Figure 8.2: Price of Manufacturing and Income: Non-Parametric Estimation

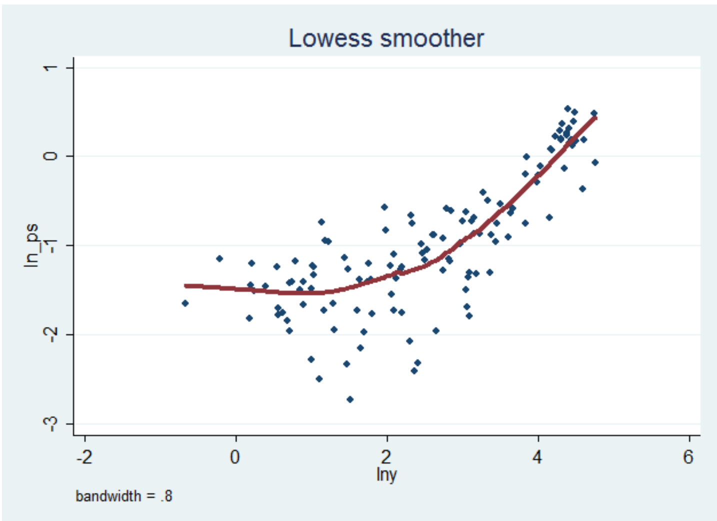

Figure 8.3: Price of Services and Income: Non-Parametric Estimation

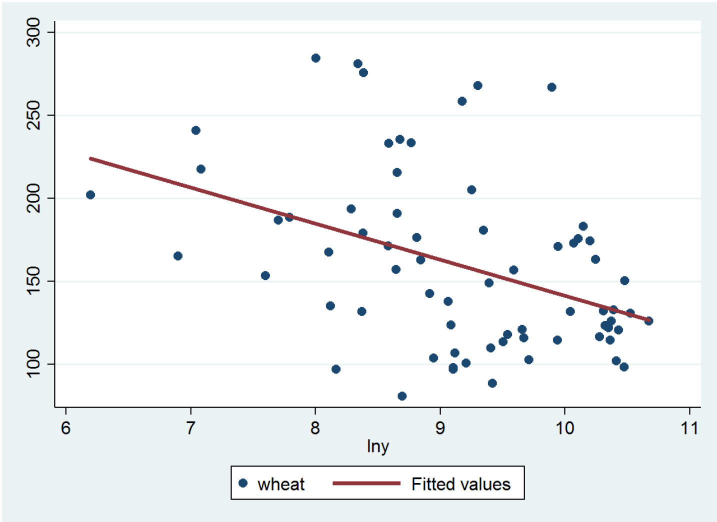

Figure 9: Price of wheat and level of income

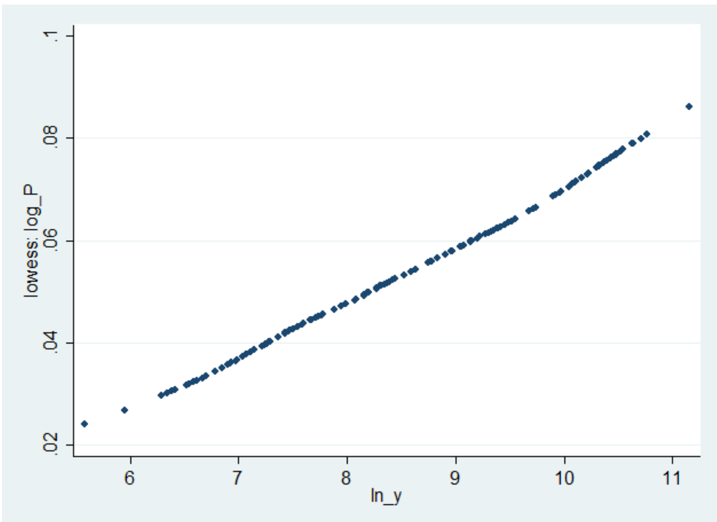

Figure 10.1: The price level in the Balassa-Samuelson hypothesis: non-parametric estimation of the price-income relation, fitted values

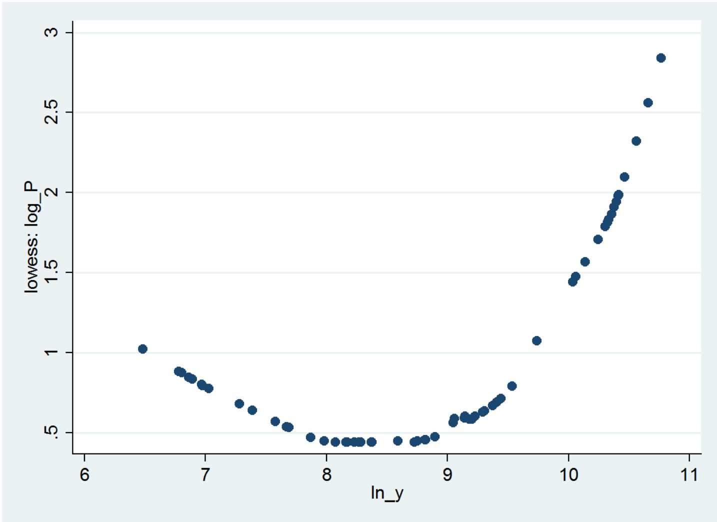

Figure 10.2: The price level in the Balassa-Samuelson+ hypothesis: non-parametric estimation of the price-income relation, fitted values

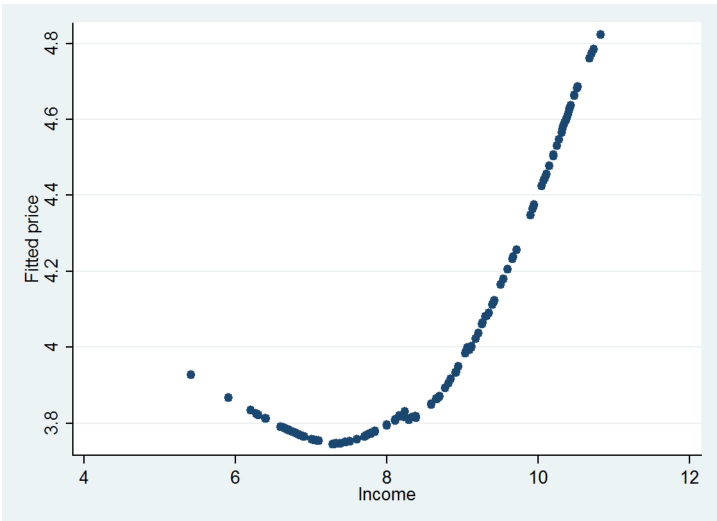

Figure 10.3: Penn World Table 8.0 (2005): non-parametric estimation of the price-income relation, fitted values