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THE RELATIVE PRICE OF SERVICES

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Prices of GDP relative to the exchange rate increase with income per capita, which is known as the Penn-effect. This is generally attributed to services being cheaper relative to goods in poorer countries. In this paper we re-examine the Penn-effect based on a new set of PPPs for industry output. These are estimated in an augmented Geary–Khamis approach using prices for final goods, exports, and imports. The resulting multilateral PPPs cover 35 industries in 42 countries for the year 2005. We find large variation in relative prices of various services industries. In particular the Penn-effect appears to be mostly due to the rapidly rising output prices of non-market services. This seems related mainly to the high labor intensity of that sector.

JEL Codes: C43, F4, O11, O47

Keywords: Geary-Khamis system, Penn-effect, PPP, prices, services

1. INTRODUCTION

A stylized fact that has proven very durable in the economic literature is that price levels of GDP relative to the exchange rate rise with income per head, with empirical support going back as far as (at least) Balassa (1964).[1] This empirical regularity is known as the "Penn-effect" (Samuelson, 1994). It has been explained by arguing that rising income is related to technical change that leads to higher productivity growth in the tradable goods sector, relative to non-tradables. This leads to higher overall wages, driving up prices in the non-tradable services sector. This mechanism of sector-biased technological change is known as the Harrod–Balassa–Samuelson (HBS) effect and has been dominant in the standard trade literature.[2] As an alternative explanation, Bhagwati (1984) has argued that services are labor-intensive and poor countries are labor-abundant, leading to low prices for services relative to goods. As capital accumulates, countries grow richer and less labor-abundant, and therefore the prices of services increase faster even when

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[1]For more recent discussion, see Bergin *et al.* (2006) and Feenstra *et al.* (2012).
[2]Harrod (1939) was the first to hypothesize this effect and Samuelson (1964) also made a theoretical argument. See also Kravis *et al.* (1982).

technical change is sector-neutral. Both theoretical arguments are based on differences in output prices and factor usage across sectors, but to date the empirical evidence for the HBS effect is solely based on expenditure prices for final goods. In this paper we revisit the debate using a new set of cross-country output price levels.

There are also other reasons to reconsider the conventional arguments underlying the HBS effect. The services sector has grown in importance, accounting for more than 70 percent of GDP in mature economies, and is highly heterogeneous (Jorgenson and Timmer, 2011). Not all services industries can be considered as "stagnant," as productivity growth in market services industries has been considerable in the United States and other countries since the mid-1990s.[3] Furthermore, not all services industries are labor-intensive as services are amongst the most intensive users of information and communications technologies (ICT).[4] This calls for a new analysis of the Penn-effect based on data on relative prices of industry output for a wide range of countries.

The main contribution of this paper is to estimate such relative prices, for a set of 42 countries covering all income levels and 35 industries covering the total economy in 2005. We define a relative price as a purchasing power parity (PPP) divided by the nominal exchange rate. In the literature, there are two main approaches to estimating relative industry output prices. The first is the so-called industry-of-origin approach that was pioneered by Paige and Bombach (1959) in a comparison of the United Kingdom and the United States.[5] This approach aims to directly observe industry output prices, mostly by calculating unit values for specific products. In the past two decades, this method was further developed and used in the ICOP project (International Comparisons of Output and Productivity) at the University of Groningen; see Maddison and van Ark (2002) for an overview. However, the lack of readily available producer price surveys has limited price estimates based on the industry-of-origin approach to a modest number of industries and countries.

An alternative to the industry-of-origin approach is to use data from internationally coordinated surveys on expenditure prices such as in the International Comparisons Program (ICP) under the auspices of the United Nations and the World Bank.[6] These price comparisons are based on purchasers' prices of final goods and services with a detailed product specification. To apply these to output and productivity comparisons by industry, the relative prices need to be mapped from expenditure categories to industries, an approach that was pioneered by Jorgenson *et al.* (1987) and has been more recently applied by, for example, van Biesebroeck (2009) and Sørensen and Schjerning (2008). In general, relative prices based on expenditure price surveys suffer less from quality problems than unit values as product comparisons are based on detailed specifications. However, the approach also has a number of drawbacks for comparisons of output at the industry level, as it requires detailed adjustments for margins, taxes, and

[3]See, e.g. Inklaar *et al.* (2008) or Timmer and de Vries (2009).
[4]See, e.g. Stiroh (2002) and Jorgenson and Timmer (2011).
[5]The earlier work was conveniently summarized by Kravis (1976).
[6]See, e.g. Kravis *et al.* (1982), Summers and Heston (1991), and World Bank (2008). Since the early 1980s, the OECD has regularly published estimates of expenditure PPPs, derived from its joint program with Eurostat.

international trade. Furthermore, by definition these relative prices only cover prices for final expenditure and do not reflect relative prices of intermediate goods.

In this paper we outline a methodology that deals with the problems in using relative expenditure prices for the derivation of relative industry output prices by improving on the existing studies in two important ways. First, we expand the range of price information by also considering export and import prices. The export and import prices are quality-adjusted unit values from Feenstra and Romalis (2012) and these allow us to greatly expand the scope of products for which we have price data. Moreover, we integrate the expenditure and trade prices within a consistent framework of input–output data. Our second contribution is to develop estimates of industry prices that are consistent in methodology and outcomes with the cross-country GDP comparisons of the Penn World Tables (PWT). So we do not just estimate gross output, but also value added prices by accounting for price differences of imported and domestically sourced intermediate inputs. While Jorgenson *et al.* (1987) were also able to achieve this in a bilateral comparison, we greatly improve the scope by comparing 35 industries in 42 countries. In our own previous work (Inklaar and Timmer, 2009) we covered 30 countries, but this is the first study to compare a significant number of emerging economies, including China and India. Moreover, the output prices are consistent with GDP price levels. In due time, these estimates will be part of the next generation of the PWT to complement the estimates from the expenditure side (Feenstra *et al.*, 2012).

Our third contribution is using the industry-level output prices to relate relative price and income levels. Consistent with many earlier studies, we find that in a cross-section of countries, aggregate price levels increase with income. We also find that the prices of manufacturing industries increase at a much slower rate than those of services. Within services, there is a striking difference between market and non-market services. Prices of non-market services (which we define to include public administration, health, education, and real estate) increase rapidly, while prices of market services (such as communication, business and transport services, etc.) increase much more modestly. Consistent with the theory of Bhagwati (1984), we find that with rising income, industries that are more labor-intensive show a greater increase in prices. Since non-market services are very labor-intensive, this finding can explain why prices of non-market services industries rise so rapidly with increasing income.

The remainder of the paper is as follows. In Section 2 we outline the methodology for estimating industry prices, which is a variant of an augmented Geary–Khamis system introduced in Feenstra *et al.* (2009). In Section 3 we describe our basic data sources and implementation. In Section 4 we analyze the relation between price and income levels, and Section 5 concludes.

2. Methodology and Implementation

Suppose there are $i = 1, \ldots, N$ final goods that may also be used as intermediate inputs. All goods are domestically produced and/or internationally traded. To relate domestic demand, international trade, and production of these goods we rely on a supply–use framework. Supply–use tables are the basic building block of statistics collected in the National Accounts. In this framework the fundamental equality is between the total demand and total supply of each good, both in quantities and in nominal values. For each country $j = 1, \ldots, C$ denote domestic final demand by q_{ij}, intermediate demand by z_{ij}, output by y_{ij}, exports by x_{ij}, and imports by m_{ij} for all i. We assume that all quantities are non-negative. Total demand in country j is given by $q_{ij} + x_{ij} + z_{ij}$ and total supply by $y_{ij} + m_{ij}$. Hence the equality between demand and supply is

$$(1) \qquad q_{ij} + x_{ij} + z_{ij} = y_{ij} + m_{ij}, \forall i.$$

Let p denote prices such that p_{ij}^{q}, p_{ij}^{z}, p_{ij}^{y}, p_{ij}^{x}, and p_{ij}^{m} denote corresponding prices in country j for the various goods. We allow the prices of exports and imports to differ from domestic output and consumption prices. Such price differences occur in practice, which is why we want to allow for them here without considering why the price differences arise.

Multiplying each element in (1) by its price we obtain the second equality between supply and use in nominal terms:[7]

$$(2) \qquad p_{ij}^{q} q_{ij} + p_{ij}^{x} x_{ij} + p_{ij}^{z} z_{ij} = p_{ij}^{y} y_{ij} + p_{ij}^{m} m_{ij}, \forall i.$$

Summing over all goods, and rearranging, we obtain:

$$(3) \qquad \sum_{i=1}^{N} \left(p_{ij}^{q} q_{ij} + p_{ij}^{x} x_{ij} - p_{ij}^{m} m_{ij} \right) = \sum_{i=1}^{N} \left(p_{ij}^{y} y_{ij} - p_{ij}^{z} z_{ij} \right).$$

The left-hand side of equation (3) equals nominal GDP from the expenditure side: domestic final demand plus exports minus imports. The right-hand side equals GDP from the production side defined as total output of all goods minus those goods used for intermediate inputs.

For this paper we are interested in deriving real measures of value added by industry. Assume that each industry produces one product only, but may use many products as intermediates. An industry will sell its product to domestic final consumers (qd), to other domestic producers for intermediate use (zd), or to foreign buyers, as exports. In turn, this industry uses intermediate inputs, partly from other domestic producers and partly from foreign producers. We assume that each industry, indexed by k (= 1, . . . , K), produces one product. Let zd^k denote intermediate demand by industry k of domestically produced goods and m^k demand for imports by industry k. Total demand for imports of good i in the country is then $\sum_k m_{ij}^{k} \le m_{ij}$, and if this inequality is strict then there are additional imports coming in for final demand. Nominal value added of industry k can be expressed as:

$$(4) \qquad \begin{aligned} p_{kj}^{v} v_{kj} &= p_{kj}^{y} y_{kj} - \sum_{i=1}^{N} p_{ij}^{z} z_{ij}^{k} \\ &= p_{kj}^{qd} qd_{kj} + p_{kj}^{zd} zd_{kj} + p_{kj}^{x} x_{kj} - \sum_{i=1}^{N} p_{ij}^{z} z_{ij}^{k} \\ &= p_{kj}^{qd} qd_{kj} + p_{kj}^{zd} zd_{kj} + p_{kj}^{x} x_{kj} - \sum_{i=1}^{N} \left[p_{ij}^{zd,k} zd_{ij}^{k} + p_{ij}^{m} m_{ij}^{k} \right] \end{aligned}$$

[7]Ignoring net taxes on products that should be added to the right-hand side.

In equation (4), subscript k indicates the supply of industry k and a superscript k denotes that a term represents demand from industry k. Summing over all industries then gives GDP as in equation (3)

$$(5)\qquad \sum_{k=1}^{K} p_{kj}^{v} v_{kj} = \sum_{k=1}^{K}\left(p_{kj}^{qd} qd_{kj} + p_{kj}^{zd} zd_{kj} + p_{kj}^{x} x_{kj} - \sum_{i=1}^{N}\left[p_{ij}^{zd,k} zd_{ij}^{k} + p_{ij}^{m} m_{ij}^{k} \right]\right) = \sum_{i=1}^{N}\left(p_{ij}^{q} q_{ij} + p_{ij}^{x} x_{ij} - p_{ij}^{m} m_{ij} \right)$$

The latter equality follows because imports are partly for intermediate use and partly for final use such that $p_j^{qd} qd_j - \sum_k p_j^m m_j^k = p_j^q q_j - p_j^m m_j$ and total intermediate demand for domestic production cancels out the total domestic production for intermediate demand: $\sum_{k=1}^{K} p_{kj}^{zd} zd_{kj} = \sum_{k=1}^{K}\sum_{i=1}^{N} p_{ij}^{zd,k} zd_{ij}^{k}$. This relationship was used by Feenstra *et al*. (2009) to estimate real GDP from the production side without consideration of prices of intermediate inputs. However, the key contribution of this paper is to show how production-side GDP can be estimated while at the same time providing estimates of industry value added. Therefore we also need to estimate prices of intermediates.

For this estimation, we set up an augmented Geary–Khamis (Geary, 1958; Khamis, 1970) system (henceforth GK-system).[8] In the GK-system, average "reference prices" for goods and purchasing power parities (PPPs) are obtained by solving a set of simultaneous equations. In PWT this system is normally only applied to goods for final domestic demand. Instead, we expand the augmented GK-system proposed by Feenstra *et al*. (2009) and also include reference prices for imports, exports, and intermediate goods. We formulate the following GK-system, with reference prices given by:

$$(6)\qquad \pi_i^{qd} = \sum_{j=1}^{C}\left(p_{ij}^{qd} / PPP_j^{o}\right) qd_{ij} \Big/ \sum_{j=1}^{C} qd_{ij}, \forall i$$

$$(7)\qquad \pi_i^{zd} = \sum_{j=1}^{C}\left(p_{ij}^{zd} / PPP_j^{o}\right) zd_{ij} \Big/ \sum_{j=1}^{C} zd_{ij}, \forall i$$

$$(8)\qquad \pi_i^{x} = \sum_{j=1}^{C}\left(p_{ij}^{x} / PPP_j^{o}\right) x_{ij} \Big/ \sum_{j=1}^{C} x_{ij}, \forall i$$

$$(9)\qquad \tilde{\pi}_i^{zd,k} = \sum_{j=1}^{C}\left(p_{ij}^{zd,k} / PPP_j^{o}\right) zd_{ij}^{k} \Big/ \sum_{j=1}^{C} zd_{ij}^{k}, \forall i, k$$

[8]See Balk (2008) for a more in-depth discussion of the GK system, as compared with other index numbers.

(10)
$$\pi_i^m = \sum_{j=1}^{C} \left(p_{ij}^m / PPP_j^o\right) m_{ij} \Big/ \sum_{j=1}^{C} m_{ij}, \forall i.$$

And the purchasing power parity for GDP from the production side (PPP°) as nominal GDP divided by real GDP at reference prices:

(11)
$$PPP_j^o = \frac{\sum_{k=1}^{K} \left(p_{kj}^{qd} qd_{kj} + p_{kj}^{zd} zd_{kj} + p_{kj}^{x} x_{kj} - \sum_{i=1}^{N} \left[p_{ij}^{zd,k} zd_{ij}^k + p_{ij}^m m_{ij}^k \right] \right)}{\sum_{k=1}^{K} \left(\pi_k^{qd} qd_{kj} + \pi_k^{zd} zd_{kj} + \pi_k^{x} x_{kj} - \sum_{i=1}^{N} \left[\tilde{\pi}_i^{zd,k} zd_{ij}^k + \pi_i^m m_{ij}^k \right] \right)}, \forall j$$

If the main goal is to come up with estimates of PPP_j^o, then a simpler procedure would suffice since all domestic intermediate deliveries, *zd*, cancel out for the economy as a whole as explained above. This was the insight used by Feenstra *et al.* (2009) to estimate real GDP from the production side without estimating intermediate input prices. However, the main benefit of the procedure from equations (6)–(11) is that it allows for the calculation of real value added by industry. We define the value added PPP for industry k in country j (PPP_{kj}^v) as:

(12)
$$PPP_{kj}^v = \frac{p_{kj}^{qd} q_{kj} + p_{kj}^{zd} zd_{kj} + p_{kj}^{x} x_{kj} - \sum_{i=1}^{N} \left[p_{ij}^{zd,k} zd_{ij}^k + p_{ij}^m m_{ij}^k \right]}{\pi_k^{qd} q_{kj} + \pi_k^{zd} zd_{kj} + \pi_k^{x} x_{kj} - \sum_{i=1}^{N} \left[\tilde{\pi}_i^{zd,k} zd_{ij}^k + \pi_i^m m_{ij}^k \right]}, \forall k, j$$

Such that real value added of this industry is given by nominal value added divided by the PPP

(13)
$$GDP_{kj}^v = p_{kj}^v v_{kj} \big/ PPP_{kj}^v$$

Summing across all industries k then gives real GDP from the production side.

Note that this system has two sets of prices for intermediate inputs: p_i^{zd} and $p_i^{zd,k}$, where the first indicates the price received by the industry for delivery of its good i to another domestic industry, whereas the latter indicates the price paid by industry k for the domestically produced good i. There is however little data available that allows one to measure both sets of prices independently. At best we have data on prices received by the producing industry, but not by the purchasing industry. Fortunately, there is little a priori reason to assume that these prices would vary greatly, as both sets of prices are measured at the basic price concept in our empirical application (which excludes net taxes and margins, see next section). In addition, we have no data on the basic prices paid by the final consumer for domestically produced goods (p_i^{qd}). Therefore, in order to be able to empirically implement the system, we simplify it by assuming that in each country the basic price of a product is independent of its use. This means that the price paid for good i by any domestic industry k or by any final domestic consumer is equal to the output price received by the domestic industry producing i, given by p_i^q. So we assume that

$$p_i^q = p_i^{qd} = p_i^{zd} = \tilde{p}_i^{zd,k}, \forall i, k. \tag{14}$$

Given these assumptions, the GK-system described in equations (6)–(11) is simplified as follows:

$$\pi_i^{qd} = \sum_{j=1}^{C} \left(p_{ij}^q / PPP_j^o\right)\left(qd_{ij} + zd_{ij}\right) \Big/ \sum_{j=1}^{C} \left(qd_{ij} + zd_{ij}\right), \forall i \tag{15}$$

$$\pi_i^x = \sum_{j=1}^{C} \left(p_{ij}^x / PPP_j^o\right) x_{ij} \Big/ \sum_{j=1}^{C} x_{ij}, \forall i \tag{16}$$

$$\pi_i^m = \sum_{j=1}^{C} \left(p_{ij}^m / PPP_j^o\right) m_{ij} \Big/ \sum_{j=1}^{C} m_{ij}, \forall i \tag{17}$$

This follows because with assumption (14), equation (9) becomes redundant, given equation (7). Moreover, we take equations (6) and (7) together to form equation (15) as they both rely on the basic output price p_{ij}^q. Then the purchasing power parity for GDP from the production side, PPP^o, is defined as nominal GDP divided by real GDP at reference prices:

$$PPP_j^o = \frac{\sum_{k=1}^{K}\left(p_{kj}^q\left(qd_{kj} + zd_{kj}\right) + p_{kj}^x x_{kj} - \sum_{i=1}^{N}\left[p_{ij}^q zd_{ij}^k + p_{ij}^m m_{ij}^k\right]\right)}{\sum_{k=1}^{K}\left(\pi_{kj}^q\left(qd_{kj} + zd_{kj}\right) + \pi_k^x x_{kj} - \sum_{i=1}^{N}\left[\pi_{kj}^q zd_{ij}^k + \pi_i^m m_{ij}^k\right]\right)}, \forall j \tag{18}$$

The number of reference prices in this system given by equations (14)–(18) is equal to 3N. The system can be estimated by choosing starting values for either reference prices or PPPs, say setting them equal to 1, and then iterating between equations (14)–(17) on the one hand and equation (18) on the other, until reference prices and PPPs converge. Convergence is not guaranteed in theory but occurred in practice after a limited set of iterations. Also, a normalization is required and commonly, one of the PPPs is set equal to 1, in this case the United States.

3. Data Sources

To estimate the reference prices and PPPs, we combine a number of international sources to create a dataset of prices and nominal values of final expenditure, import, and export for our set of 42 countries. This set of countries is determined by the availability of international input–output data and contains all major economies in the world, together covering more than 80 percent of world GDP. In this section we discuss the various data sources and the practical implementation of the GK-system defined above.

Our analysis requires two sets of data, one on nominal values and one on relative prices. Information by industry is required on the different purchasers of industry output and suppliers of intermediate inputs. Our main data on nominal values is drawn from (a draft version of) the World Input–Output Table (WIOT), which is available for 2005. This table is constructed out of national supply and use tables in combination with bilateral trade statistics as described in Timmer (2012) and can be found at www.wiod.org. This data allows us to distinguish domestic and foreign buyers of industry output and distinguish domestic and foreign suppliers of intermediate inputs. The table is in basic prices and margin values are included in the trade and transport industries. This means that margins are treated as intermediate inputs, with the margin industry as the supplying industry, and the buying industry or consumer as the user. The 39 countries covered in the WIOT together cover more than 80 percent of world GDP in 2005. To broaden our coverage, we also include Argentina, Chile, and South Africa using national input–output tables from these countries and the OECD (for South Africa). Appendix Table A1 gives a full list of countries and Appendix Table A2 lists the 35 industries.

Our dataset on prices is eclectic and drawn from a number of sources to use the broadest set of information. The backbone of our price dataset is formed by the basic heading parities and expenditure data from the 2005 ICP benchmark described in World Bank (2008). These parities refer to 126 items of final expenditure and cover household consumption, investment, and government consumption. The transformation of these expenditure prices to a basic price concept is described below.

We also include output prices and quantities for up to 168 agricultural products from the Food and Agriculture Organization (FAO) of the United Nations.[9] These cover both livestock and crops and are useful to estimate the output prices of the agricultural sector which cannot be derived from expenditure prices as output in this sector consists predominantly of intermediate, rather than final goods. Finally, we rely on quality-adjusted unit values and values of exports and imports for up to 762 products, provided by Feenstra and based on Feenstra and Romalis (2012). These products cover all of merchandise trade and export prices given as free-on-board (fob) prices, while import prices are at cif (cost–insurance–freight).[10] The quality-adjustment is based on a model for the demand and supply of the quality of a product. The demand side is similar to Hallak and Schott (2011) and infers that quality is high if prices are high and demand is not low. On the supply side, firms will ship their highest-quality products to destinations for which the trade costs are largest, the so-called "Washington apples" effect. The importance of quality for a specific product is then estimated using a regression relating cif and fob prices for the same product and trade route. Based on this estimation, all import and export unit values are adjusted for quality differences.

These sources provide us with detailed value and price data (up to 1056 individual products for each country), but we aim to estimate value added PPPs for 35 industries only; see Appendix Table A2 for the industry list. We therefore normalize our detailed output, final expenditure, exports, and imports values to the control totals from the WIOT for each of the 35 industries. We allocate goods to specific industries for each of the data sets in the following fashion.

[9]Downloaded from http://faostat.fao.org on October 27, 2010.
[10]We are grateful to Robert Feenstra for providing us with these data.

First, expenditure categories are allocated to industries based on their name. For example, "Fresh or frozen fish and seafood" is allocated to the "Food, beverages, and tobacco" industry. In addition, we assume that all consumption goods are bought through the retail trade industry, while all investment goods are purchased through the wholesale trade industry; more on this below. Finally, there are a number of industries that only produce intermediate products. In those cases, we apply the prices of downstream industries to their upstream counterparts. So, for example, the prices for mining include the prices for petroleum, non-metallic mineral products, and metal products. For business services, the overall consumption price is used, following the practice in ICP for financial intermediation services indirectly measured (FISIM). Second, all crops and livestock products are allocated to the agriculture, forestry, and fishing industry. Third, the export and import data are classified by SITC rev. 2, 4-digit level. We use a concordance table to ISIC rev. 2 and from there to ISIC rev. 3, the classification used in the WIOT.

The augmented GK-system described in the previous section is based on the concept of basic prices and it is crucial to distinguish this from the purchasers' price concept both in theory and in the empirical implementation. The basic price of a good is the price received when sold by the producer (ex-factory gate), and the purchasers' price is the price paid by the user. They are linked in the following way (System of National Accounts, 1993, section VI.J):

> Purchasers' price = basic price of the product received by the producer + taxes on the product[11] – subsidies on the product + trade and transport margins in delivering the product to the purchaser

We use this relationship to derive industry output PPPs based on the expenditure PPPs for 126 detailed basic headings that are underlying the calculation of real GDP by the World Bank (2008). We derive the basic price of final goods, p_{ij}^q, by "peeling off" the domestic margin from the purchasers' prices $\tilde{p}_{ij}^q$ for final domestic demand. We define

$$p_{ij}^q = \frac{\left(1 + r_{i,US} + t_{i,US}\right)}{\left(1 + r_{ij} + t_{ij}\right)} \tilde{p}_{ij}^q, \forall i \tag{19}$$

r_i = trade and transport margin rate on supplied product i and t_i = net tax rate on supplied product i . That is, we adjust the expenditure PPP for each country, by the ratio of the margin rates in the country itself and the U.S., our benchmark country. The margins for each product group and country are derived from the input–output data. In fact, this adjusted expenditure PPP has been used as a proxy for output prices by, for example, Jorgenson *et al.* (1987), Lee and Tang (2000), and most recently by van Biesebroeck (2009) and Sørensen and Schjerning (2008).[12]

The relative prices of exports and imports are much closer to the domestic basic price concept than consumer prices. Import prices are measured at the port

[11]Taxes include any taxes on products at the sales point such as a sales or a value-added tax.

[12]Ideally further adjustments are needed for international trade and intermediate use but these have not been implemented successfully so far (see Hooper, 1996; Inklaar and Timmer, 2013).

of entry and hence do not include any domestic margins. And while goods for final domestic demand flow through the wholesale and retailing systems, goods destined for export have only some wholesale trade margins from the plant to the port of exporting. The latter margin is relatively small, and we do not adjust export prices further.

Two industries require special attention. Agricultural output consists almost exclusively of products used for intermediate input by other firms, not for final consumption. Therefore, there are no expenditure PPPs that can be used as a proxy for agricultural output PPPs. Instead, the agricultural PPPs for this study are developed along the same lines as earlier ICOP work on agriculture (Prasada Rao, 1993). We rely exclusively on output PPPs based on producer prices from the FAOSTAT Database of the FAO. This database contains a very extensive set of quantities and farm-gate prices for up to 168 agricultural products. For the distribution sector, we use expenditure basic headings to reflect the relative sales prices of wholesale and retail trade. As argued by Timmer and Ypma (2006), the relative sales prices should also be adjusted for the difference in the margin-to-sales ratio to better approximate the margin–output concept in the National Accounts. Since we lack such data for our set of countries, we omit this adjustment.

We use these datasets to implement the system of equations (15)–(18) with prices for up to 1056 products across 35 industries in 42 countries. In total, we estimate 42 PPP^os and 2242 reference prices. To solve the GK system, we first set all PPPs equal to the exchange rate to calculate the reference prices from equations (15)–(17). We use these reference prices in equation (18) to update our PPP estimates. A normalization has to be chosen, so we set the U.S. PPP^o equal to one. Results do not depend on this normalization. We then iterate between a new estimate of PPPs and new estimates of references prices based on these PPPs until the system converges. Despite the large number of reference prices, convergence takes less than 15 iterations.

4. Sector PPPs and the Penn-Effect

Starting with Kravis *et al.* (1982), the stylized fact that services are cheaper in poorer countries, also known as the "Penn-effect," has taken firm root. For instance, consider the title of Bhagwati's (1984) article "Why are Services Cheaper in the Poor Countries?" This could be driven by sector-biased technological change as in the Harrod–Balassa–Samuelson model, whereby productivity gains in the traded sector drive up the overall wage level and hence the prices of non-traded services that have much lower productivity growth. Bhagwati's (1984) alternative explanation focused on different endowments of rich and poor countries, arguing that with increasing income, capital accumulates and thus wages increase relative to rental prices. As a result, labor-intensive services industries would become more expensive as income increases. For example, Nordhaus (2008) found these patterns for prices of U.S. industries based on long-term time series analysis.

We are now in a position to evaluate whether the value added prices of services are indeed lower in poorer countries and how this relates to income levels. We start with establishing the Penn-effect with our data in Table 1. Column 1 shows the price level of GDP—the GDP PPP relative to the exchange rate—and columns 2 and 3 show GDP per capita relative to the U.S. based on exchange rate and PPP conversion, respectively. Countries are ranked by GDP per capita levels based on the GDP PPP. This table shows how PPP-converted GDP per capita is generally higher than exchange-rate-converted GDP per capita in poorer countries and that this differences decreases and even reverses for richer countries. Equivalently, the GDP price level (the ratio of column 3 over column 2) increases with GDP per capita, as evidenced by the high correlations shown at the bottom of Table 1.

Compared with GDP PPP estimates from other sources, such as the World Bank (2008) or PWT, our estimates differ conceptually because we also account for differences in the prices of exports and imports, as advocated in Feenstra *et al.* (2009). For domestic prices, we use the same ICP basic headings as the latest edition of PWT, version 7.1. One empirical difference is that we weight prices by industry output and inputs, while PWT and World Bank weight using expenditure. Another difference is that we use the GK index number approach, while the estimates of PWT and World Bank are based (at least in part) on the GEKS index number approach.[13] Despite these differences, our GDP price levels are very similar in terms of country rankings, with correlations of 0.98 with the World Bank (2008) numbers and 0.99 with PWT 7.1. Our price levels do differ by, on average, about 10 percent with the ICP and World Bank estimates, but much of this could well be due to differences in export and import prices. Feenstra *et al.* (2009) found that accounting for differences in export and import prices affected price levels by similar magnitudes.

We continue the analysis with some simple graphs indicating correlations, before applying regression techniques. To begin with, Figure 1 shows the overall economy price level in a country (PPP for GDP divided by the exchange rate) in relation to its GDP per capita relative to the U.S. (converted using PPPs). We label each country using the 3-letter ISO code; see Appendix Table A1 for the list of countries and codes. The positive relationship is the same as implied by the correlation from Table 1. We omit Luxembourg from this figure as its high GDP per capita makes it an outlier, but the positive correlation also holds when Luxembourg is included, as evident from Table 1. The main pattern is also very similar if the price level and GDP per capita are expressed in logs, as also commonly done in this type of analysis.

As a next step, we split our 35 industries into goods-producing industries (agriculture, mining, manufacturing, utilities, and construction) and services industries, and the value added PPP for each sector is divided by the exchange rate. Charting these prices in Figure 2 confirms the stylized fact that the price of services increases faster as income rises than the price of goods-producing industries.[14] While prices increase significantly in both sectors, the slope is almost twice as large in services as in goods-producing industries, 1.00 versus 0.52. In Figure 3 we split the group of goods-producing industries into manufacturing and other goods (agriculture, mining, utilities, and construction); the group of services is split into

[13]See Balk (2008) for a comparison of these and other index number methods.

[14]Luxembourg and Malta are excluded from Figures 2 and 3 due to an outlying GDP per capita level of Luxembourg and an outlying price level for other goods in Malta. Both countries are included in the regression analysis later on.

TABLE 1
GDP Price Levels and GDP Per Capita Relative to the U.S. in 2005

	GDP Price Level	GDP Per Capita Relative to the U.S.	
	(GDP PPP/XR)	XR-Converted	PPP-Converted
India	0.24	0.02	0.07
Indonesia	0.33	0.03	0.09
China	0.29	0.04	0.14
South Africa	0.69	0.11	0.16
Brazil	0.58	0.10	0.18
Romania	0.48	0.10	0.21
Bulgaria	0.35	0.08	0.22
Chile	0.65	0.16	0.25
Argentina	0.47	0.12	0.25
Turkey	0.59	0.16	0.26
Russia	0.41	0.11	0.28
Mexico	0.65	0.18	0.28
Latvia	0.52	0.15	0.30
Lithuania	0.51	0.17	0.32
Poland	0.52	0.18	0.34
Estonia	0.61	0.22	0.37
Slovakia	0.52	0.20	0.39
Hungary	0.61	0.24	0.39
Malta	0.73	0.31	0.43
Portugal	0.85	0.38	0.45
Czech Republic	0.60	0.28	0.46
Slovenia	0.78	0.39	0.50
Cyprus	0.91	0.48	0.53
South Korea	0.72	0.41	0.57
Greece	0.80	0.47	0.59
Spain	0.89	0.58	0.65
Italy	0.93	0.67	0.72
France	1.03	0.76	0.73
Germany	0.96	0.75	0.78
Belgium	1.02	0.80	0.79
Finland	1.03	0.82	0.80
Japan	1.06	0.84	0.80
United Kingdom	1.05	0.85	0.81
Netherlands	1.01	0.87	0.86
Australia	0.93	0.81	0.86
Austria	0.95	0.82	0.87
Denmark	1.18	1.03	0.87
Canada	0.91	0.79	0.88
Sweden	1.03	0.91	0.88
United States	1.00	1.00	1.00
Ireland	1.06	1.07	1.01
Luxembourg	1.12	1.81	1.61
Correlation with GDP price level		0.90	0.88

Notes: PPP: purchasing power parity, XR: exchange rate.

market services and non-market services. Non-market services includes government, health, education, and real estate and market services includes all other services industries, such as wholesale trade, transport services, and finance; see Appendix Table A2 for the full list of groupings.

This figure reveals important heterogeneity in both goods-producing industries and services. Prices in manufacturing come closest to the law of one price,

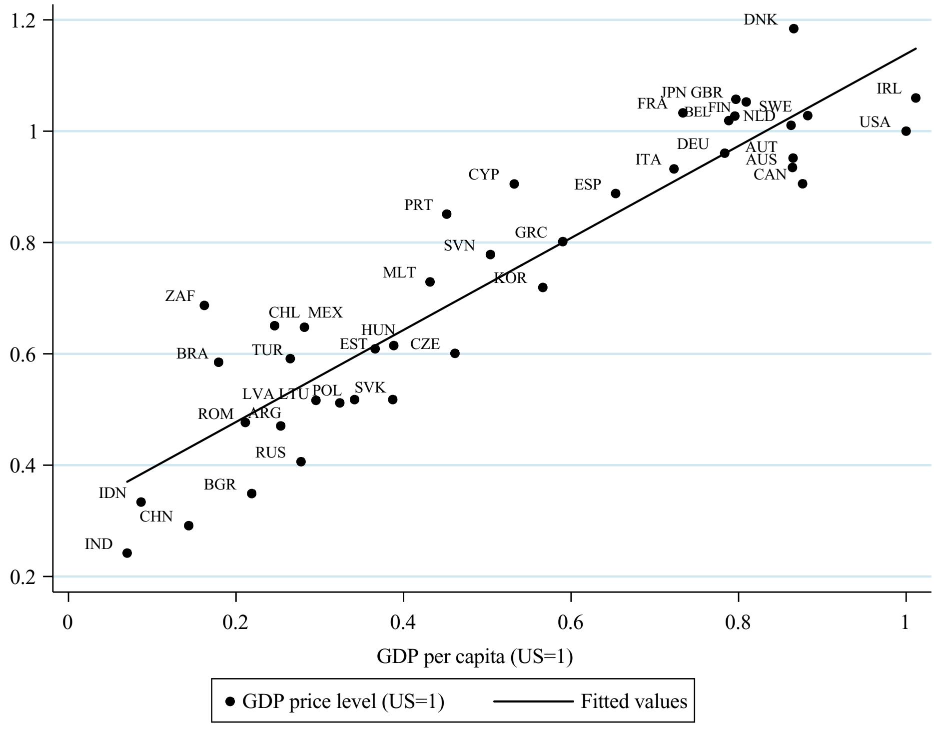

Figure 1. GDP Price Level and GDP Per Capita, 2005

Notes: Authors' calculations based on equation system given in (15)–(18). GDP PPP relative to the exchange rate on the y-axis. GDP per capita (PPP converted) on the x-axis.

with output prices increasing only modestly with increasing income levels. The slope coefficient is significantly positive, but only 0.20, compared to 0.52 for the goods-producing sector as a whole. Prices of other goods increase more rapidly, with a slope coefficient of 1.25. This is not surprising as this sector includes many products that are barely internationally traded (utilities, construction) or in markets distorted by tariffs and subsidies (agriculture). More striking is that within services, relative prices for market services increase much less strongly than for non-market services, with a slope coefficient of 0.81 versus 1.31. Of course, this finding could be due to heterogeneity at an even lower level of aggregation, as these services groups consist of a large number of industries (13 and 4, respectively) with varying characteristics. We therefore run the following regressions at the level of individual industries:

(20) $$\log(p_{ij}) = \beta_i + \beta_1 \log(Y_j) + \beta_2 \log(Y_j)\cdot Ser_i + \varepsilon_{ij}$$

(21) $$\log(p_{ij}) = \beta_i + \beta_1 \log(Y_j) + \beta_3 \log(Y_j)\cdot Mfg_i + \beta_4 \log(Y_j)\cdot MSer_i + \beta_5 \log(Y_j)\cdot NMser_i + \varepsilon_{ij}$$

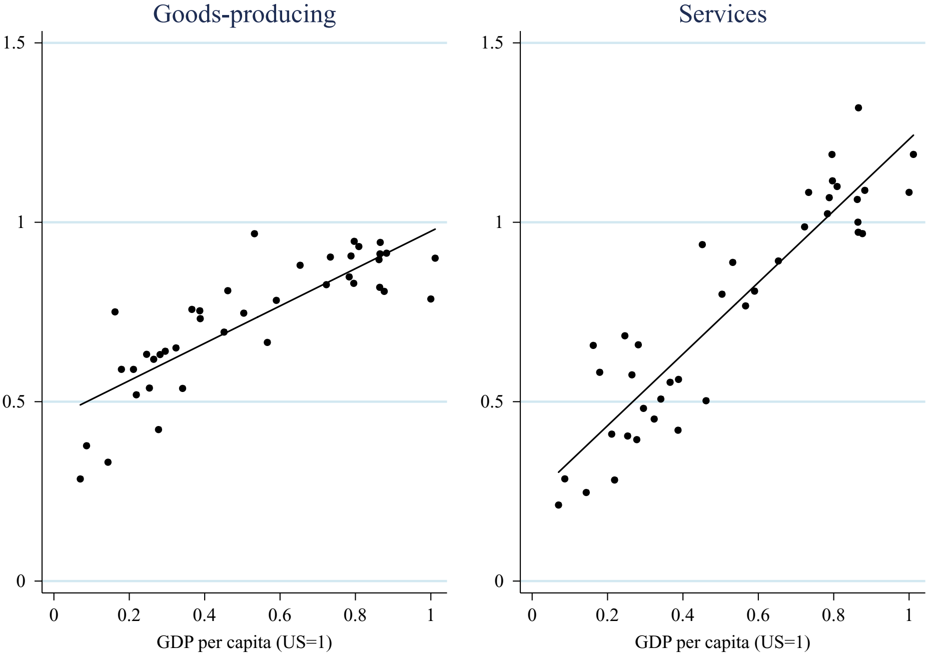

Figure 2. Relative Price of Goods-Producing and Services Industries and GDP Per Capita, 2005
Note: Prices relative to exchange rates for 42 countries, see Figure 1.

Here p_{ij} is the relative price level of gross output in industry i in country j, Y_j is GDP per capita relative to the U.S., and the remaining variables are dummies equal to one for services industries (Ser_i), manufacturing industries (Mfg_i), market services industries ($Mser_i$), and non-market services industries ($NMser_i$). The omitted group in equation (20) consists of goods-producing industries, and in equation (21) it is other goods-producing industries. Industry dummies are included in both equations to focus on the interplay between industry prices and income levels for different industry groups. The spread of price levels at the detailed industry level is much greater than at the sectoral or aggregate level, so we take logs of price levels and relative GDP per capita. We also move from value added prices to gross output prices, partly because that is the level at which we expect to see a relationship but also because value added prices tend to be more sensitive to measurement error.[15] Results are qualitatively similar using value added prices, though.

Table 2 shows the result of estimating equations (20) and (21) based on 1432 industry–country observations.[16] Column (1) shows that, on average, industry prices increase with GDP per capita, and columns (2)–(4) show the industry heterogeneity apparent from Figures 2 and 3. Column (2) shows that prices in

[15]See, e.g. Hill (1971) for more discussion.

[16]There is one observation where the estimated output PPP is negative and there are a number of country–industry pairs for which no input–output data are available. This is why there are fewer than 1470 (42 countries · 35 industries) observations.

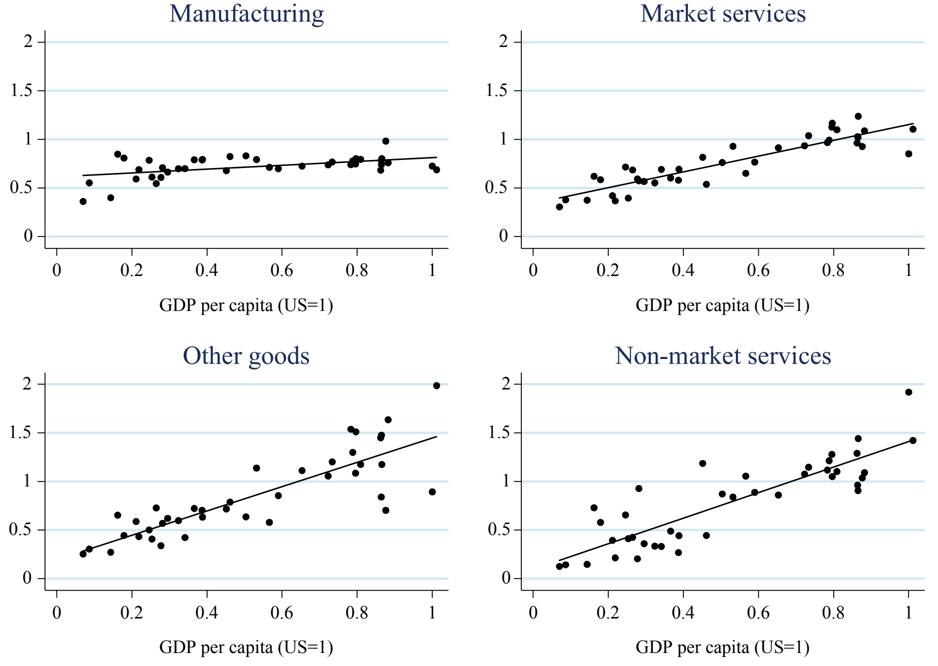

Figure 3. Relative Price of Manufacturing, Other Goods, Market Services and Non-Market Services, and GDP Per Capita, 2005

Note: See Figure 2.

TABLE 2

Industry Prices and Income Levels for Different Industry Groups

	(1)	(2)	(3)	(4)
GDP per capita (US = 1)	0.356***	0.211***	0.394***	
	(0.0528)	(0.0737)	(0.0411)	
Services dummy · GDP per capita		0.306***		
		(0.0564)		
Manufacturing industries dummy · GDP per capita			–0.236***	–0.246***
			(0.0820)	(0.0852)
Market services dummy · GDP per capita			0.0485	0.0414
			(0.0406)	(0.0400)
Non-market services dummy · GDP per capita			0.351***	0.346***
			(0.0563)	(0.0586)
Observations	1,432	1,432	1,432	1,432
Adjusted R-squared	0.241	0.272	0.289	0.347
Country dummies	no	no	no	yes
Industry dummies	yes	yes	yes	yes

Notes: Robust standard errors, clustered by country, in parentheses.
***p < 0.01, **p < 0.05, *p < 0.1.
Dependent variable in all regressions is the log of industry gross output prices. Results in column (2) correspond to equation (20); results in column (3) correspond to equation (21). In column (4), GDP per capita is omitted because country dummies are included.

services industries increase faster with rising GDP per capita than goods industries. Column (3) shows that this is entirely due to rising prices in non-market services: β_5 from equation (21) is larger than β_2 from equation (20), while β_4 is insignificant and close to zero. At the same time, output prices of manufacturing industries rise by significantly less as income increases. Column (4) adds country dummies, leaving the results almost unchanged.[17]

As a further analysis, we test whether an industry's labor share in value added is related to prices as income increases. In the original HBS argument, services are the stagnant sector, so they are not able to increase their labor productivity with rising productivity in the tradable sector. As a result, wage increases translate to services price increases relative to tradables. In Bhagwati's (1984) model technical change does not need to be biased to generate this result, but is due to differences in the labor-intensity of the production process. In this argument, capital accumulation increases with average income and drives up wages relative to rental prices, so labor-intensive industries show increasing relative prices.

We analyze this through the following regression:

$$\log(p_{ij}) = \beta_0 + \beta_1 \log(Y_j) + \beta_2 \alpha_{ij} + \beta_3 \log(Y_j) \cdot \alpha_{ij} + \varepsilon_{ij}. \tag{22}$$

Here, α_{ij} is the share of labor compensation in value added in industry i in country j. For countries in the WIOD database, there are estimates of the labor compensation of all workers, so including an estimate of the labor income of self-employed workers. For Argentina, Chile, and South Africa we make our own estimates, assuming the same average wage for the self-employed as for employees, with compensation of employees drawn from the input–output tables. If Bhagwati's (1984) argument holds, the output price of labor-intensive industries should increase more as income increases, so β_3 should be significantly positive.

Table 3 shows the result of estimating equation (22).[18] In column (1), we show that the labor share by itself has no explanatory power, but columns (2) and (3) show that the interaction term is significant and positive, as hypothesized. Coefficient β_2 is now also significant, since with the interaction term included, it shows the effect when $\log(Y_j) = 0$ for the United States. In other words, in the United States, industries with a higher labor share have significantly higher prices. The marginal effect of labor shares on price levels can also be evaluated at other levels of GDP per capita. This analysis shows that countries with a GDP per capita level of at least 80 percent of the U.S. level, of which there are ten in our dataset, show a significantly positive effect. Regardless of the marginal effects though, the positive and significant interaction term gives clear support for the Bhagwati (1984) line of reasoning that more labor-intensive

[17]These results hold through a range of robustness analyses: dropping wholesale and retail trade industries because their prices are based on the sales prices of goods; dropping finance and business services because their prices are mostly imputed based on aggregate prices; or moving other social and personal services (industry O) and private households with employed persons (industry P) to non-market services.

[18]We drop observations where the labor share is larger than one.

TABLE 3

Industry Prices, Income Levels, and the Labor Share in Value Added

	(1)	(2)	(3)	(4)
GDP per capita (US = 1)	0.356***	0.211***	0.394***	
	(0.0528)	(0.0737)	(0.0411)	
Services dummy · GDP per capita		0.306***		
		(0.0564)		
Manufacturing industries dummy · GDP per capita			–0.236***	–0.246***
			(0.0820)	(0.0852)
Market services dummy · GDP per capita			0.0485	0.0414
			(0.0406)	(0.0400)
Non-market services dummy · GDP per capita			0.351***	0.346***
			(0.0563)	(0.0586)
Observations	1,432	1,432	1,432	1,432
Adjusted R-squared	0.241	0.272	0.289	0.347
Country dummies	no	no	no	yes
Industry dummies	yes	yes	yes	yes

Notes: Robust standard errors, clustered by country, in parentheses.
***p < 0.01, **p < 0.05, *p < 0.1.
Dependent variable in all regressions is the log of industry gross output prices.
Results in column (2) correspond to equation (22).

industries show faster-rising prices with increasing income. And given that market services show considerable variation in labor shares (they vary from a low 39 percent of value added in post and telecommunications to a high 66 percent in retailing; see Appendix Table A2), one would expect that as income increases, the price changes of these industries would vary, as found in Table 2. Conversely, government, health, and education all have high labor shares (around 80 percent), which can explain the clear positive relationship from Table 2.[19]

In addition, there are statistical measurement issues that could also explain the empirical relationship we find in Table 3. We use expenditure PPPs from the ICP 2005 round to measure output prices for non-market services (education, health, and public administration). These are not genuine relative prices of output, as those cannot be directly measured,[20] but estimated based on relative prices of inputs. This input-price approach basically assumes that the productivity of inputs in these sectors is the same across countries. As labor is the major input, output PPPs in these sectors reflect wage PPPs, which may (partly) explain the positive relationship between GDP per capita and PPPs we find for this sector. If productivity is lower in poorer countries, the relationship would be less strong, but without proper output price measures this cannot be determined.[21]

[19]The outlying industry in this group is real estate which has a very small labor share in value added, due to the fact that a major share of the output of this sector is imputed as rental equivalents for owner-occupied housing.

[20]See Schreyer (2012) for a recent discussion of output measurement in non-market services.

[21]For various regions in the 2005 ICP round an adjustment for productivity differences to non-market services' PPPs was made (see Blades, 2013). For the OECD region, which comprises most countries in our dataset, this adjustment was not made.

5. Concluding Remarks

We re-examined the relative prices of services across countries using a new dataset of relative value added price levels for 35 industries across 42 countries in 2005. These relative prices are derived in an augmented GK-system building upon the work of Feenstra *et al.* (2009). We extend the GK-system within a consistent input–output framework explicitly allowing for prices of intermediate goods, alongside expenditure, and export and import prices. In the empirical implementation we draw upon a number of large price datasets. Besides data on the relative price of final consumption and investment goods, we also incorporate agricultural unit values and quality-adjusted export and import unit values. We have shown how industry output prices can be estimated by combining these price data in a consistent input–output framework. This new PPP database is available at www.ggdc.net. Developing and implementing the new methodology for estimating industry PPPs is, in our opinion, the main contribution of this paper.

We confirm that GDP prices are higher in richer countries using this data. Under the HBS line of reasoning, this is due to differences in productivity growth across industries. Manufacturing is seen as the "progressive," tradable sector where relative prices decline as income rises. In contrast, services are the "stagnant," non-tradable sector. In this paper we have shown that this distinction is too simplistic and ignores industry heterogeneity. An important new finding is that we show how the rise in the relative price of services that has been found earlier can be traced in particular to non-market services (mostly government, health, and education). Market services in contrast show price behavior that is more similar to manufacturing, where prices increase only modestly with income. This suggests that also in market services, prices rise by less than wages due to productivity increases, as found also by Jorgenson and Timmer (2011). Non-market services look more like the prototypical "stagnant" sector, where rising wages fully feed into prices. More in general, we find that the more labor-intensive industries show output prices that increase faster with rising income. Since non-market services are some of the most labor-intensive industries, this can explain our findings. We would like to stress that there is still room for improvement in the basic price data, in particular for non-market services (see, e.g. Schreyer, 2012). When such data are available, they can be easily incorporated in the estimation framework.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table A1: List of Countries, GDP and Sectoral Price Levels, 2005
Table A2: List of Industries, Sector Classification and Average Labor Share (%)