Reconciling High Food Prices with Engel and Prebisch-Singer

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ABSTRACT: *During the past decade, food prices experienced the longest and broadest boom since World War II. Income growth in emerging economies has been often cited as a key driver of the boom. Indeed, low and middle income countries grew at 6.4 percent per annum during 2004-13, the highest of any 10-year period since 1960—China and India grew nearly 10 percent during this period. Based on a reduced form price determination model and annual data since 1960, this paper shows that income has a negative and highly significant effect on real food commodity prices. This finding is consistent with and Engel's Law and Kindleberger's thesis, the predecessor of the Prebisch-Singer hypothesis. Moreover, it is shown that income's negative impact on real prices operates through the manufacture price channel (the deflator), thus weakening the view that income growth exerted upward pressure on food prices. Other key drivers include (in order of importance) the role of energy costs, physical stocks, and monetary conditions.*

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1. Introduction

During the past decade, commodity prices experienced the longest and broadest post-World War II boom. Indeed, after declining for nearly three decades, world prices of food commodities doubled in less than a decade. The boom took place at a time when emerging economies experienced unprecedented growth as well. Low and middle income countries grew at an annual average of 6.4 percent during 2004-13, the highest of any 10-year period since 1960. China and India, two countries that account for more than one third of world's population, grew nearly 10 percent per annum during this period.

Income growth in emerging economies has been often cited as a key driver of past decade's food price increases. Krugman (2008), for example, argued that the upward pressure on grain prices is due to the growing number of people in emerging economies, especially China, who are becoming wealthy enough to emulate Western diets. Likewise, Wolf (2008) concluded that strong income growth by China, India, and other emerging economies, which boosted demand for food commodities, was the key factor behind the post-2007 increases in food prices. Similarly, the June 2009 issue of *National Geographic* noted that demand for grains has increased because people in countries like China and India have prospered and moved up the food ladder. Other authors have mentioned income growth as well (see, for example, Roberts and Schlenker 2013 and Hochman et al. 2011).

The above views reflect a widely held belief that income-driven demand growth leads to price increases in food commodities, especially during the recent boom. However, historically the views on the relationship between income growth, food consumption, and food prices were not so uniform. More than one and a half century ago, Engel (1857) observed that poor families spend a greater proportion of their total expenditure on food, thus leading to the so-called Engel's Law of less than unitary income elasticity of food commodities. Several decades later, Kindleberger (1943, p. 349) argued that "[t]he terms of trade [ToT] move against agricultural and raw material countries as the world's standard of living increases (except in time of war) and as Engel's Law of consumption operates. The elasticity of demand for wheat, cotton, sugar, coffee, and bananas is low with respect to income." Because the income-food price relationship is bounded by Engel's Law and likely declines in ToT, any conclusion on its validity or strength should be based on empirical verification.

Kindleberger's thesis was empirically verified by Prebisch (1950) and Singer (1950) as well as by Kindleberger (1958) himself. By many accounts, the declining ToT views along with empirical verification (later coined as the Prebisch-Singer hypothesis) formed the intellectual foundation on which the industrialization policies of the 1960s and 1970s were based upon, that is heavy taxation of primary commodity sectors in favor of manufacture products, especially in low income countries.

This paper shows that income has a negative and highly significant effect on ToT for food commodities, a result which is consistent with the Prebisch-Singer hypothesis. The paper also shows that income's impact on ToT operates mainly through the manufacture price channel. These results weaken the view that income growth by emerging economies has played a key role during the past decade's run up of food prices. The results are also consistent with the lower bound of Engel's Law. Other key findings include the importance of energy costs, physical stocks, and (less so) monetary conditions.

The rest of the paper proceeds as follows. The next section discusses the views on the relationship between income and commodity prices, beginning with Engel's Law, Kindleberger's thesis, and Prebisch-Singer hypothesis; it also reviews the literature of the latter. Section 3 introduces a model testing the Prebisch-Singer hypothesis by controlling for the key sectoral and macroeconomic fundamentals affecting food prices. Section 4 discusses the results on the Prebisch-Singer hypothesis and Engel's Law, it checks robustness with respect to various measures of income, and also discusses the role of the remaining fundamentals. The last section concludes and discusses policy relevant issues.

2. From Engel to Kindleberger and Prebisch-Singer

Based on expenditures of 153 Belgian families in 1853, Engel (1857) noted that "[t]he poorer a family, the greater the proportion of its total expenditure that must be devoted to the provision of food" and later concluded that "… the wealthier a nation, the smaller the proportion of food to total expenditure." (Quoted in Stigler 1954, p. 98). Following Engel's observation, at least three competing views attempted to explain and forecast the long term behavior of the terms-of-trade faced by developing countries (Rostow 1950, Kindleberger 1958). First, a supply-side view predicted that primary commodity prices will increase faster than manufacture prices due to resource constraints of the former and technological improvements of the later—to a certain extent, this view was consistent with a Malthusian path. A second view assumed that ToT will follow investment cycles. Investment expansion will induce supply response in manufacture goods, leading to lower prices, thus increasing the ToT. Conversely, investment contraction would lead to declining ToT. Proponents of a third view argued that ToT will follow a downward path because income growth leads to smaller demand increases in primary commodities than manufacture products, an outcome which is consistent with Engel's Law.

While no dominant view emerged until the Second World War, the negative income-ToT relationship became the prevailing position after the War. A turning point was Kindleberger's (1943) argument that "[i]f the agricultural and raw material countries of the world want to share the increase in the world's productivity, including that in their own products, they must join in the transfer of resources from agriculture, pastoral pursuits, and mining to industry." Other authors, however, warned against such policies. For example, Johnson (1947) argued that the agricultural sector required few interventions. Friedman (1954) disputed the benefits of managing commodity income variability. Johnson and Mellor (1961) severely criticized the pro-urban policies prevalent in many developing countries. Despite such warnings, Kindleberger's views dominated the post-war policy agenda and set the stage for the post-war industrialization policies in developing countries.[1]

The long term behavior of ToT received renewed attention, beginning in the late 1980s. At least three reasons account for such attention. First, after the boom of the early 1970s, most commodity prices experienced large declines, subsequently stabilizing at much lower levels (see figure 1 for the ToT of the three key indices and figure 2 for the nominal agriculture and manufacture indices). Therefore, the Prebisch-Singer hypothesis began fitting the data well. These declines are in sharp contrast to the increases during the two decades following the war where food prices spiked on fears of a prolonged conflict in the Korean peninsula (Korean War) while metal prices experienced sustained boom because of Europe's reconstruction and Japanese expansion. Second, numerous authors began questioning the bias against primary commodity sectors. For example, Bauer (1976) and Lal (1985) severely criticized pricing policies and marketing arrangements in commodity-dependent developing countries. Bates (1981) argued that in order for rural communities to prosper, most developing government policies concerning markets would need to change. The tide turned against industrialization policies following the publication of two World Bank reports: The 1985 *World Development Report* (World Bank 1995), which focused on the problems associated with policy interventions in agricultural commodity markets, and the detailed assessment of distortions affecting primary commodity sectors of developing countries by Krueger, Schiff and Valdès (1992). Third, research on long term behavior of ToT was further aided by two influential papers. On the econometric side, Engle and Granger (1987) introduced improved testing procedures that enabled researchers to distinguish between meaningful long term relationships and spurious correlations. On the data side, Grilli and Yang (1988) compiled a data base of 24 internationally-traded primary commodity prices since 1900 that was utilized (and updated) by numerous authors.

More than 30 papers published in academic journals have examined the

[1] Kindleberger's influence on world economic affairs should not be surprising. In addition to being a leading architect of the Marshall Plan, he voiced an early opinion on the nature of post-war development lending operations: "If time permitted, it might be stimulating to analyze a number of knotty aspects of an international development loan operation: how would productivity be defined in order to qualify for a loan from *the international development authority or whatever institution was created to perform that function*?" (Kindleberger 1943, p. 353, emphasis added). The Bretton Woods institutions (International Monetary Fund and the World Bank) became operational two years later.

Prebisch-Singer hypothesis since the mid-1980s (see Appendix A for a detailed review).[2] Taken together, the results from this research are mixed—about half of the studies find support of the hypothesis. This should not be surprising. Not only the ratios of the three main price indices (agriculture, metals, and energy) against manufacture prices have followed different paths throughout the sample period, but also, depending on the period chosen, one could arrive at different conclusions even for the same index.

3. Modeling Food Price Trends

The negative relationship between ToT and income is a straightforward result of a 2-sector model. That is, if one sector's—food—income elasticity is less than unity, the other sector's income elasticity—manufacture—must be greater than unity. Therefore, from an empirical perspective, the ToT-income relationship can be represented as follows:

$$\log\left(\frac{P_t^i}{P_t^M}\right) = \beta_0 + \beta_1 \log(Y_t) + \varepsilon_t, \tag{1}$$

where P_t^i and P_t^M denote manufacture and food prices, respectively while Y_t represents income. Kindleberger's thesis implies that $\beta_1 < 0$.

Interestingly, almost all of the literature on the Prebisch-Singer hypothesis examined the long term behavior of ToT as a function of time, a simplified version of which can be written as,

$$\log\left(\frac{P_t^i}{P_t^M}\right) = \alpha_0 + \alpha_1 t + \varepsilon_t, \tag{2}$$

where t denotes time trend.[3] Equation (2) requires that $\alpha_1 < 0$. This paper extends the literature on the Prebisch-Singer hypothesis in the following ways. First, it tests the hypothesis on the on the basis of (1), as originally envisaged by Kindleberger, rather than (2), which is the common practice in the literature. Second, in addition to income, it accounts for the key sectoral and macroeconomic fundamentals that are expected to influence commodity prices. Third, it examines whether the income effect on ToT operates through primary commodity prices, manufacturing prices or both, thus shedding light on Engel's Law.

First, we rewrite (2) as follows:

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[2] Although Prebisch (1950), Singer (1950), and Kindleberger (1958) arrived at similar conclusions, Kindleberger repeatedly emphasized that the declining ToT is a reflection of low income elasticity as opposed to Prebisch and Singer who attributed it to monopolistic practices by developed countries.

[3] Equation (2) should be viewed as an indicative test on the Prebisch-Singer hypothesis. Most empirical studies have applied testing procedures that allow for non-linear trends, include structural breaks, use alternative measures of deflators (e.g., total export price index or general price index), to name a few.

$$\log\left(\frac{P_t^i}{P_t^M}\right) = \beta_0 + \beta_1 \log(Y_t) + F[\bullet] + \varepsilon_t, \tag{3}$$

where $F[\bullet]$ denotes the sectoral and macroeconomic fundamentals. Equation (3) can be viewed as a reduced-form price-determination model, a result of equating aggregate demand and supply of a commodity, and subsequently expressing the equilibrium price as a function of quantifiable fundamentals. The theoretical underpinnings of the model are outlined in Turnovsky (1983), Stein (1986), Holtham (1988), and Deaton and Laroque (1992). Empirical applications include Gilbert (1989) who looked at the effect of developing countries' debt on commodity prices; Pindyck and Rotemberg (1990), who examined comovement among various commodity prices; Reinhart (1991) and Borensztein and Reinhart (1994) who analysed the factors behind the weakness of commodity prices during the late 1980s and early 1990s; Frankel and Rose (2010) who analyzed the effects of various macroeconomic variables on agricultural and mineral commodities; Baffes and Dennis (2013) who analyzed the key drivers of the post-2004 food price increases; Baffes and Savescu (2014) who examined the long term determinants of metal prices.

Expression $F[\bullet]$ is approximated by two sectoral fundamentals (energy prices and stock-to-use ratios) and two macroeconomic indicators (exchange rates and interest rates). Thus, (3) becomes:

$$\log\left(\frac{P_t^i}{P_t^M}\right) = \beta_0 + \beta_1 \log(Y_t) + \beta_2 \log(R_t) + \beta_3 \log(X_t) + \beta_4 \log\left(S_{t-1}^i\right) + \beta_5 \log(P_t^E) + \varepsilon_t. \tag{4}$$

P_t^i is the nominal price of commodity i (i = maize, soybeans, wheat, rice, palm oil, and cotton) and P_t^M represents a price index of manufacturing goods. Y_t denotes income, R_t denotes the interest rate, X_t is the US$ exchange rate, S_t^i denotes the stock-to-use ratio of commodity i, and P_t^E is the price of crude oil. The β_is are parameters to be estimated and ε_t is the error term, the properties of which will be discussed later. Note that if $\beta_i = 0, i = 2, \dots, 5$, then (4) collapses to (1).

The interpretation of the parameters in equation (4) is straightforward. Income growth is expected to have a negative impact on the ToT, if the Prebisch-Singer hypothesis holds. Low interest rates will have a negative effect on ToT as well because they reduce the cost of holding inventories, in turn leading to higher inventories and hence stronger demand. The depreciation of the U.S. dollar is expected to positively affect commodity prices since it strengthens the demand and limits the supply from non-U.S. dollar consumers and producers. Low physical stocks relative to consumption (typically associated with tight markets) lead to higher prices and *vice versa*. Last, higher energy prices, a factor of production, are expected to be associated with higher commodity prices.[4] Hence, the expected signs of the parameter estimates (noted as superscripts) are: β_1^-, β_2^-, β_3^-, β_4^-, β_5^+.

For the second objective, that is, identifying the channel through which income affects ToT, we relax the homogeneity assumption of manufacturing prices and re-parameterize (4) as follows:

$$\log(P_t^i) = \beta_0 + \beta_1 \log(Y_t) + \beta_2 \log(R_t) + \beta_3 \log(X_t) + \beta_4 \log(S_{t-1}^i) + \beta_5 \log(P_t^E) + \beta_6 \log(P_t^M) + \varepsilon_t. \quad (5)$$

Equation (5) is equivalent to (4) if $\beta_6 = 1$. The reparameterization implies that some of the parameter estimates in (5) will have a different interpretation than (4). First, $0 < \beta_1 < 1$, consistent with Engel's Law. Second, $\beta_6 < 1$, if in fact manufacture prices increase faster than agricultural prices, as the Prebisch-Singer hypothesis would require. Third, the parameter estimate of the exchange rate should be larger in (5) than in (4).

4. Data, Estimation, and Results

The above model was applied to five food commodities, maize, soybeans, wheat, rice, and palm oil. The inclusion of cotton was motivated by the desire to a account for as much of world's arable land as possible. World prices were taken from the World Bank's database and represent annual (calendar) averages, expressed in U.S. dollar per metric ton (mt), except crude oil which is expressed in US dollars per barrel. Given that the study's key objective was to identify the effect of income on food prices, 12 alternative income measures were used: GDP measured at PPP and market prices for three aggregation levels (world, low and middle income country, and the sum of China and India) both in global and per capita terms (figure 3 depicts per capita income in PPP terms for the three aggregations used here). Real interest rate was the 3-month US Treasury Bill, adjusted by the US CPI. Exchange rate was the US dollar Real Effective Exchange Rate against a broad basket of currencies. More details on the data and sources can be found in Appendices 2 and 3.

Prior to estimating the model, the stationarity properties of all variables were examined by applying unit root tests to levels without and with trend as well as first differences. Two tests were used, the DF-GLS (modified Dickey-Fuller) and the PP (Phillips-Perron). Results are reported in table 1a (prices, ToT, stock-to-use ratios, and the two macroeconomic indicators) and table 1b (various measures of income). Stationarity with and without trend is rejected (in favor of difference stationarity) for price series

[4] Agriculture is an energy intensive sector. Baffes (2013) noted that the direct energy component of agriculture is four to five times higher than manufacturing sectors—the calculation was based on the input-output values of the GTAP database.

regardless of whether they are expressed in nominal or ToT form.[5] With the exception of wheat (and less so soybeans), difference stationarity is confirmed for the S/U ratio and the two macroeconomic indicators. Similar results hold for the various measures of income.[6] Thus, on the basis of unit root statistics, the performance of the models should be judged by the stationarity properties of the error term, in addition to conventional measures.

Setting the Stage

We begin with a univariate regression for the ToT of the six commodities against income, which is the simplest way to test the Prebisch-Singer hypothesis. The results (reported in the upper panel of table 2) show that the parameter estimate of income was negative and significantly different from zero at the 1 percent level in all six cases, with the estimates ranging from -0.26 for wheat to -0.48 for cotton. Such result is consistent with the Prebisch-Singer hypothesis. Moreover, with the exception of cotton, evidence in favor of cointegration is weak, implying that income alone does not explain commodity price trends. The lower panel of table 2 reports results of the price ToT on time trend. Again, the results are remarkably similar to those of income: Negative parameter estimate of trend with the highest and lowest for cotton and wheat, respectively along with very weak evidence of trend stationarity, with the exception of cotton. These results, point to the following conclusions:

- *However, the evidence on food commodities is in favor of the Prebisch-Singer hypothesis.*
- *However, on the basis of the explanatory power (R-square) and stationarity statistics, income or time trend alone cannot adequately explain commodity price movements.*

Apart from the individual price ToT, we run the same regression for six commodity price indices: food (which contain the food prices used in the model), raw materials, beverages, energy, industrial metals, and precious metals. The results (reported in

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[5] Beyond their importance for the subsequent econometric analysis, rejection of stationarity and trend stationarity of both nominal prices and ToT, implies that comovement between nominal food and manufacture prices (with unity cointegration parameter) is rejected as well, another (albeit much stricter) test for the Prebisch-Singer hypothesis. Even more importantly, nonstationarity of prices highlights the practical difficulties with price stabilization mechanisms. Consider, for example, that the ToT for agriculture has fluctuated between a high of 149 in 1974 (2010 = 100) and a low of 61 in 2001. More interestingly, the path has crossed its mean, 92, only four times, three of which occurred during 1981-85. Thus, for a long term price stabilization mechanism to work, a policy maker would have to "tax" the sector during 1960-1981 and "subsidize" it during 1985-2008. These, admittedly simplistic, calculations point to the impossibility of devising meaningful price stabilization mechanisms.

[6] Of the 36 tests for stationarity for levels with trend and another 36 for levels with trend, the null of no unit root was rejected in only 3 cases at the 5 percent level of significance. Similarly, of the 36 unit root tests in first differences, in only 4 cases stationarity was rejected at the 5 percent level (all 4 were for DF-GLS for India & China GDP). Thus, only seven out of 108 cases (6.5 percent) are not consistent with difference stationarity, remarkably close to the 5 percent level of significant.

the upper panel of table 3) give a mixed picture. The effect of income on the food, beverage, and (less so) raw materials index ToT is negative and significantly different from zero. It is virtually zero for metals and large, but positive and highly significant for energy and precious metals. Furthermore, the unit root statistics indicate very weak evidence of cointegration between commodity indices ToT and income. The lower panel of table 3 reports univariate regression results on a time trend with remarkably similar results.

The Role of Income

Table 4 reports parameter estimates consistent with equation (4). For efficiency gains, the model was estimated as a system of seemingly unrelated regressions (SUR). The models performed in a satisfactory manner. For example, 23 out of 30 parameter estimates (excluding the β_0) were significantly different from zero at the 5 percent level. Furthermore, more than two thirds of price variability is explained by the fundamentals and, with the single exception of the DF-GLS statistics for rice, the error term is stationary in all models. In all cases income had a negative and significantly different from zero parameter estimate (at the 1 percent level). The estimates range within a remarkably tight band, from -0.52 for soybeans and rice (*t-statistic* = -5.19 & -5.50) to -0.71 for cotton (*t-statistic* = -7.62).

In addition to the income measure reported in table 4 (world GDP evaluated at Purchasing Power Parity), equation (4) was re-estimated by using the 12 income measures discussed earlier, again using SUR. Parameter estimates are reported in table 5 (to conserve space, only the income parameter estimate is reported.) The parameter estimate of income was negative and significantly different from zero at the 1 percent level for all 12 income measures and 6 commodity prices. Three key conclusions emerge from these results:

- *Results reported in table 4 and 5 confirm the Prebisch-Singer hypothesis for food commodity prices—consistent with the univariate model.*
- *The univariate models underestimate the negative impact of income of ToT by almost half.*
- *The unit root-free error terms imply that fundamentals adequately explain the behavior of ToT.*
- *These results hold regardless of the measure of income used.*

Yet, it is not clear whether income's negative impact on ToT operates through nominal commodity prices, P_t^i, manufacture prices, P_t^M, or both. To identify the transmission channel, we estimate equation (5), results are of which are reported in table 6. On the basis of the explanatory power and stationarity statistics, the nominal price model appears to have performed much better than the ToT model.[7] The *R*-square aver-

[7] The superior performance of (5) should not be surprising because of the relaxation of the homogeneity restriction imposed on the parameter estimate of P_t^M. In fact, Houthakker (1975) argued in favor of relaxing such restriction on the deflator because, in addition to improving the model's performance, the impact of fundamentals on nominal prices can be assessed in a direct fashion.

aged 0.83, up from 0.67 in the ToT model while 10 out of 12 unit root tests confirmed stationarity of the error term at the 1 percent level of significance—as before, exception is the DF-GLS test for rice.

In no case income had a positive effect on nominal prices; for the five food commodity prices, the parameter estimate was not significantly different from zero while for cotton the estimate was negative and significant at the 5 percent level. As in the ToT case the model was replicated with all 12 measures of income (results are reported in table 7). Again, with the exception of cotton where in 7 cases the parameter estimate of income was negative and significantly different from zero at the 5 percent level, income appears to have no effect on nominal prices. These results point to the following conclusions.

- *Income exerted no effect on nominal prices (with the single exception of cotton where the effect was negative), a result which is consistent with Engel's Law.*
- *Thus, the negative effect of income on ToT derived earlier is transmitted through manufacture, not primary, commodity prices.*
- *The parameter estimate of the manufacture prices is far less than unity in three cases (maize, wheat, cotton) and zero in the remaining cases, implying that the homogeneity condition is a very restrictive assumption. This is also evident by the explanatory power and improved cointegration statistics of the nominal price model.*

Although these results are in sharp contrast to what has been assumed or reported in the literature, they should not come as surprise. If income had a strong positive effect on food prices, that should have showed up on consumption patterns. Yet, evidence that grain consumption by emerging economies has experienced growth rates that are either high by historical standards or comparable to their income growth rates is, at best, weak. Alexandratos (2008, p. 673) concluded that China's and India's combined average annual increment in grain consumption was lower in 2002-08 than in 1995-2001. In a similar vein, FAO (2008, p. 12) noted that:

> China and India have usually been cited as the main contributors to this sudden change [in cereal prices] because of the size of their populations and the high rates of economic growth they have achieved. However, since 1980, the imports of cereals in these two countries have been trending down, on average by 4 percent per year, from an average of 14.4 million tonnes in the early 1980s to 6.3 million tonnes over the past three years. Moreover, mainland China has been a net exporter of cereals since the late-1990s, with one exception in the 2004-05 season. Similarly, India has been a net importer of these commodities only once, in the 2006-07 season, since the beginning of the twenty-first century.

Numerous other studies have reported similar findings, including Alexandratos and Bruinsma (2012), Sarris (2010), Baffes and Haniotis (2010), FAO (2009), and Lustig (2008). In fact, Deaton and Drèze (2008), based on household survey data in India found that, despite growing incomes, there has been a downward trend in calorie intake since the early 1990s. They added that although the reasons behind this trend are not clear, one likely explanation may be that calorie requirements have declined as a result of better health and lower physical activity levels.

The Role of Sectoral Fundamentals

The discussion thus far focused on income. Yet, as evidenced by the models, it is the remaining fundamentals that play a key role in the food price determination process. As expected the stock-to-use ratio estimates are negative and highly significant, ranging from a high of -0.43 for maize to a low of -0.17 for soybeans. The nominal price model (table 6) gave similar estimates, except rice, whose estimate was not significantly different from zero. The stock-to-use ratio elasticities estimates for the three grains reported here are remarkably similar to findings reported elsewhere. For example, Bobenrieth, Wright, and Zeng (2012) estimated correlation coefficients between stock-to-use ratios and real de-trended prices for wheat, maize, and rice of -0.40, -0.50, and -0.17, respectively (compared to -0.42, -0.43, and -0.32 from the ToT model or -0.26, -0.40, -0.21 from the nominal price model.)[8] Similarly, FAO (2008, p. 6, figure 3) reported correlation coefficients between the cereals price index and various measures of stock-to-use ratios ranging from -0.47 and -0.65.

The estimate of the oil price elasticity was different from zero in all six regressions in both specifications—the only parameter estimate significantly different from zero at the 5 percent level across the two versions of the 6 models. The oil elasticity averaged 0.20 in the ToT model and 0.31 in the nominal price model, implying that a doubling in oil prices would lead to a 20 to 30 percent increase in food prices. In both models the lowest estimate was for cotton (0.15, *t-statistic* = 2.91 and 0.23, *t-statistic* = 4.46) and the highest was for palm oil (0.34, *t-statistic* = 4.70 and 0.43, *t-statistic* = 5.75).

The strong relationship between energy and non-energy prices has been established long before the post-2004 price boom. Gilbert (1989), for example, using quarterly data between 1965 and 1986, estimated transmission elasticity from energy to non-energy commodities of 0.12 and from energy to food commodities of 0.25. Hanson et al. (1993) based on a General Equilibrium Model found a significant effect of oil price changes to agricultural producer prices in the United States. Borensztein and Reinhart (1994), using quarterly data from 1970 to 1992, estimated transmission elasticity to non-

[8] The low and not significantly different from zero for rice (nominal price model) most likely reflects policy distortions, including the substantial quantities of rice stocks that are either handled by state trading enterprises or heavily influenced by government policies (Alavi and others 2012). Indeed, Anderson and others (2009, p. 489, table 12.11) estimated that during 2000-04, rice exhibited the highest level of distortion (43 percent) compared to wheat (4 percent) and maize (3 percent), as measured by the trade restrictiveness index. Martin and Anderson (2012, p. 426) found that restrictive trade policies during the 2006-08 price spike may explain as much as 45 percent of the increase in the international rice price.

energy commodities of 0.11. A strong relationship between energy and non-energy prices was found by Chaudhuri (2001) as well. Baffes (2007), using annual data from 1960 to 2005 estimated elasticities of 0.16 and 0.18 for non-energy and food commodities, respectively. In a similar model that included the recent boom, Baffes (2010) reported somewhat higher elasticities. Moss et al. (2010) found that U.S. agriculture's energy demand is more sensitive to price changes than any other input.

Yet not all studies concur with a strong oil/non-oil price relationship. Saghaian (2010) established strong correlation among oil and other commodity prices (including food) but the evidence for a causal link from oil to other commodities was mixed. Gilbert (2010) found a correlation between the oil price and food prices both in terms of levels and changes, but also noted that it is the result of common causation and not of a direct causal link. Zhang et al. (2010) found no direct long-run relationship between fuel and agricultural commodity prices and only a limited short-run relationship. Reboredo (2012) concluded that the prices of maize, wheat, and soybeans are not driven by oil price fluctuations. Baffes (2013) noted that, in the presence of biofuels, the mixed evidence on the energy/non-energy price relationship should not be surprising. To see this, consider an exogenous shock which pushes crude oil prices up, in turn, lowering fuel consumption. Under a mandated ethanol/gasoline mixture ethanol and maize prices will decline, *ceteris paribus*, leading to a negative relationship between food and oil prices (De Gorter and Just 2008). The mixed evidence on the energy/non-energy price link may also reflect the frequency of the data used in various models. Indeed, Zilberman et al (2013) noted that higher frequency (and hence "noisier") data are typically associated with weaker correlations. The results on the effects of sectoral fundamentals on food prices point to the following conclusions.

- *Crude oil is the most important driver to food prices. An average elasticity of 0.25 implies that the 200 percent increase in energy costs during the past decade could explain more than half of the food price increases.*
- *While crop conditions, as reflected by the stock-to-use ratios, had significant effect on food prices (the elasticity estimate was almost twice as high compared to crude oil), the actual effect is much smaller because the stock-to-use ratios changed much less during the boom period.*

The Role of Macroeconomic Indicators

Results of the effect of the exchange rate on food prices are mixed but they are highly consistent with expectations. The parameter estimates from the nominal price model (table 6), which are all significantly different from zero, indicate that exchange rates matter a lot, especially in rice whose estimate is twice as high compared to other prices (-2.13, *t-statistic* = -4.10). The large parameter estimate for rice is consistent with initial expectations given that the United States does not play any significant role in that market. These results are line with earlier literature. See, for example, Lamm (1980), Gardner (1981), and Baffes and Dennis (2013) for agriculture and Gilbert (1989), Baffes (1997), and Akram (2009) for metals. Estimates from the ToT model, however, indicate a considerably weaker effect of exchange rate (except rice.) Again, this outcome is expected since ToT is a currency-free unit.

Last, the results on the effect of interest rates on the ToT are mixed. Wheat had a positive and significantly different from zero parameter estimates for soybeans, palm oil, and cotton, the estimate was negative and significant, and zero for maize. Again, the mixed nature of the interest rate results is consistent with the literature on the subject. Gilbert (1989) based on an error-correction model (1965Q1–1986Q2) concluded that high interest rates have a negative impact on the metal price index, though with considerable lags. Baffes (1997), who used a reduced form price model for five metals (1971Q1–1988Q4) estimated mostly negative but not significantly different from zero elasticities. Akram (2009), based on a VAR model (1990Q1–2007Q4), concluded that commodity prices (including metals) increase significantly in response to reduction in real interest rates. Anzuini et al. (2010), who applied a VAR on monthly data for 1970–2009, did establish that easy monetary policy is associated with higher commodity prices but also noted that the impact is modest. Frankel and Rose (2010) based on annual data for a number of commodities found little support that easy monetary policy and low real interest rates are an important source of upward pressure on real commodity prices. Last, the 2013 Spillover Report (IMF, 2013) estimated that under a smooth growth-driven normalization of monetary policy, a 100 basis points increase in short term interest rates by the US Federal Reserve will lead to a 7% and 5% increase in energy and non-energy commodity prices (under other scenarios, however, commodity prices would decline). Based on the nominal price model, however, even this mixed evidence of the real exchange rate weakens further, implying that, as it was the case with income, the interest rate effect operates through the manufacture, not the primary commodity, price channel. The results on the effects of macroeconomic fundamentals can be summarized as follows.

- *The US dollar depreciation positively affects nominal food prices, as expected; with a single exception of rice, there is no exchange rate effect on the ToT, since the latter is currency-free unit.*
- *The effect of interest rate on the ToT is small and mixed. There is no interest rate impact on nominal prices, however, implying that even the limited impact, operates through manufacture prices.*

5. Summary and Conclusion

This paper reconciled the Prebisch-Singer hypothesis—which states that the ratio of primary commodity prices over manufacture prices declines as income increases—with the recently held view that income growth by emerging economies has been a key driver of the food price increases during the past 10 years. In particular, the paper extended the literature on the Prebisch-Singer hypothesis in three ways. First, it tested the hypothesis by examining the effect of income on the ToT, as originally envisaged by

Kindleberger, rather than relating ToT with time, which is the common practice in the literature. Second, in addition to income, the model accounted for the key sectoral and macroeconomic fundamentals that are expected to influence commodity prices. Third, the model examined whether the income effect on ToT operates through primary commodity prices, manufacturing prices or both.

The paper employed a reduced-form price determination model and applied it to 1960-2013 annual data for five food commodities (maize, soybeans, wheat, rice, palm oil) and cotton. It concluded that income has a negative and highly significant effect on real agricultural commodity prices. This finding is consistent with and Engel's Law and Kindleberger's thesis, the predecessor of the Prebisch-Singer hypothesis. Moreover, it is shown that income's negative impact on real prices operates through the manufacturing price channel (the deflator), thus, weakening the view that income growth by emerging economies has played a major role during the past decade's run up in food prices. Other key drivers include (in order of importance) the role of energy costs, physical stocks, and monetary conditions.

On the methodological side, the literature review showed that the research on the Prebisch-Singer hypothesis reflects mostly concerns of primary commodity prices not manufacturing prices. Yet, this paper showed that the negative impact of income (and interest rates) operates mostly through the manufacturing price channel, not the primary commodity price channel.

Table 1a: Stationarity Properties of Prices, Sectoral and Macroeconomic Fundamentals

	Log-levels without trend		Log-levels with trend		First differences of logs	
	DF-GLS	PP	DF-GLS	PP	DF-GLS	PP
Nominal prices						
Maize	0.37	-1.13	-2.62	-2.29	-6.23***	-6.25***
Soybeans	0.48	-1.29	-1.59	-2.28	-5.62***	-6.76***
Wheat	-0.16	-1.25	-3.24*	-2.54	-6.06***	-5.51***
Rice	-0.78	-2.12	-3.37**	-2.80	-6.17***	-5.53***
Palm oil	-0.67	-1.75	-2.28	-2.80	-8.77***	-6.96***
Cotton	-0.41	-1.90	-2.30	-2.43	-7.01***	-8.10***
Crude oil	0.04	-0.82	-1.78	-1.81	-4.43***	-6.66***
Manufacture	-0.06	-1.48	-1.41	-0.98	-3.56***	-4.04***
Ratio of nominal to manufacture prices (ToT)						
Maize	-1.85	-1.68	-2.13	-1.52	-6.11***	-6.50***
Soybeans	-1.25	-1.62	-1.17	-1.67	-5.45***	-7.67***
Wheat	-2.18	-2.08	-2.70	-2.04	-6.15***	-6.04***
Rice	-1.56	-1.98	-2.93	-2.39	-6.30***	-5.91***
Palm oil	-1.18	-2.24	-1.29	-2.49	-9.20***	-7.48***
Cotton	-0.91	-1.94	-3.17**	-3.64**	-7.95***	-9.43***
Crude oil	-0.35	-0.89	-1.80	-1.99	-4.67***	-7.39***
Stock-to-Use ratios						
Maize	-1.75	-2.13	-2.04	-2.13	-4.72***	-7.40***
Soybeans	0.32	-3.32**	-3.82***	-4.01***	-6.29***	-7.04***
Wheat	-3.14***	-3.98***	-3.92***	-3.95***	-3.53***	-8.31***
Rice	-0.51	-2.36	-0.95	-1.35	-2.21	-6.01***
Palm oil	-0.78	-2.83*	-1.63	-3.11	-5.23***	-11.19***
Cotton	-2.54	-2.21	-3.25**	-2.62	-3.22***	-6.75***
Macroeconomic variables						
Exchange rate	-2.88	-2.24	-3.17**	-2.46	-4.04***	-4.49***
Interest rate	-2.45	-2.69*	-2.51	-2.78	-5.87***	-8.00***

Notes: All variables (except interest rate) are expressed in logarithms. DF-GLS = modified Dickey-Fuller, PP = Phillips-Perron (both statistics for unit roots). Significance level of stationarity: * = 10 percent, ** = 5 percent, *** = 1 percent.

Table 1b: Stationarity Properties of Income

	Log-levels without trend		Log-levels with trend		First differences of logs	
	DF-GLS	PP	DF-GLS	PP	DF-GLS	PP
GDP measured at Purchasing Power Parity (PPP), total						
World	0.34	-2.13**	-1.37	-2.68	-4.39***	-4.37***
Low & Middle Income	0.08	0.35	-2.27	-1.25	-2.44**	-3.73***
China & India	0.11	4.51	-0.26	-2.77	-1.11	-6.31***
GDP measured at Purchasing Power Parity (PPP), per capita						
World	1.04	-1.72	-1.55	-2.59	-4.33***	-4.76***
Low & Middle Income	0.94	1.06	-2.26	-0.47	-2.98***	-3.07**
China & India	0.71	5.13	-0.69	-1.12	-1.27	-4.91***
GDP measured at Market Prices, constant US$ 2010, total						
World	0.54	-4.30***	-1.10	-3.02	-4.23***	-4.23***
Low & Middle Income	0.08	0.01	-1.89	-1.46	-2.71***	-3.67***
China & India	0.26	3.97	-0.36	-3.18*	-1.04	-6.79***
GDP measured at Market Prices, constant US$ 2010, per capita						
World	0.94	-3.20**	-1.33	-3.27**	-4.15***	-4.92***
Low & Middle Income	0.81	0.68	-2.19	-0.82	-3.39**	-3.20***
China & India	0.80	4.65	-0.41	-1.31	-1.98**	-4.93***
GDP measured at Market Prices, nominal, total						
World	0.36	-1.96	-1.26	-0.97	-4.08***	-4.24***
Low & Middle Income	0.71	0.43	-2.05	-1.56	-3.28***	-4.36***
China & India	0.92	3.50	-0.57	-0.55	-1.87*	-5.40***
GDP measured at Market Prices, nominal, per capita						
World	0.45	-1.83	-1.41	-1.24	-4.34***	-4.32***
Low & Middle Income	0.87	0.46	-1.91	-1.39	-3.65***	-4.27***
China & India	1.34	3.30	-0.51	0.18	-2.64***	-4.97***

Notes: All variables are expressed in logarithms. DF-GLS = modified Dickey-Fuller, PP = Phillips-Perron (both statistics for unit roots). Significance level of stationarity: * = 10 percent, ** = 5 percent, *** = 1 percent.

Table 2: Univariate Regressions of ToT on Income and Trend, Individual Prices

	Maize	Soybeans	Wheat	Rice	Palm oil	Cotton
Equation (1)						
Income	-0.33***	-0.29***	-0.26***	-0.42***	-0.39***	-0.48***
	(4.66)	(4.54)	(4.13)	(5.04)	(4.65)	(8.77)
R-square	0.29	0.28	0.25	0.33	0.29	0.60
DF-GLS	-1.70*	-1.87*	-2.17**	-2.21**	-1.27	-3.45***
PP	-1.73	-1.89	-2.09	-2.33	-2.61*	-3.47**
Equation (2)						
Trend	-1.16***	-1.05***	-0.92***	-1.50***	-1.38***	-1.72***
	(4.72)	(4.74)	(4.19)	(5.25)	(4.68)	(9.48)
R-square	0.30	0.30	0.25	0.33	0.30	0.63
DF-GLS	-1.68*	-1.87*	-2.14**	-2.26**	-1.25	-3.69***
PP	-1.64	-1.82	-2.05	-2.30	-2.59	-3.62***

Notes: The dependent variable is the logarithm of the nominal commodity price divided by the manufacture price index. Income is world GDP measured at PPP. The parameter estimate of the time trend has been multiplied by 100 and thus it should be interpreted as annual percentage change. Constant terms are not reported. Because of data unavailability, the regressions for soybeans and palm oil begin in 1965. DF-GLS = modified Dickey-Fuller, PP = Phillips-Perron (both statistics for unit roots). Absolute *t*-statistics in parentheses, * = 10 percent, ** = 5 percent, *** = 1 percent.

Table 3: Univariate Regressions of ToT on Income and Trend, Price Indices

	Food	Raw Materials	Beverages	Energy	Metals	Precious Metals
Equation (1)						
Income	-0.27***	-0.10**	-0.38***	1.29***	-0.00	0.75***
	(4.53)	(2.63)	(4.89)	(11.22)	(0.01)	(8.48)
R-square	0.28	0.12	0.32	0.71	0.00	0.58
DF-GLS	-0.89	-1.26	-2.26**	-1.84*	-1.94*	-2.23**
PP	-1.56	-1.73*	-2.41	-2.09	-1.89	-1.78
Equation (2)						
Trend	-0.94***	-0.29**	-1.41***	-4.33***	0.01	2.51***
	(4.67)	(2.19)	(5.40)	(10.21)	(0.04)	(7.79)
R-square	0.30	0.08	0.36	0.67	0.00	0.54
DF-GLS	-1.88	-2.75*	-2.32**	-1.81**	-1.94*	-2.16*
PP	-1.49	-1.89	-2.47	-1.91	-1.89	-1.72

Notes: The dependent variable is the logarithm of the nominal commodity the nominal price index divided by the manufacture price index. Income is world GDP measured at PPP. The parameter estimate of the time trend has been multiplied by 100 and thus it should be interpreted as annual percentage change. Constant terms are not reported. DF-GLS = modified Dickey-Fuller, PP = Phillips-Perron (both statistics for unit roots). Absolute *t*-statistics in parentheses, * = 10 percent, ** = 5 percent, *** = 1 percent.

Table 4: Parameter Estimates from Seemingly Unrelated Regressions, ToT Model, Equation (4)

	Maize	Soybeans	Wheat	Rice	Palm oil	Cotton
Constant	14.70***	12.60***	11.90***	20.60***	16.40***	11.40***
	(6.73)	(4.56)	(4.70)	(6.95)	(4.81)	(4.32)
Income	-0.60***	-0.52***	-0.52***	-0.65***	-0.70***	-0.71***
	(7.85)	(5.19)	(5.90)	(5.58)	(5.78)	(7.62)
Stock-to-Use ratio (lag)	-0.43***	-0.17***	-0.42***	-0.32***	-0.35***	-0.41***
	(6.83)	(3.00)	(4.44)	(3.75)	(3.46)	(4.31)
Real oil price	0.19***	0.18***	0.16**	0.17***	0.34***	0.15***
	(4.62)	(3.40)	(3.33)	(3.04)	(4.70)	(2.91)
Real exchange rate	-0.46	-0.31	-0.05	-1.41***	-0.20	-0.21
	(1.49)	(0.81)	(0.15)	(3.44)	(0.41)	(0.56)
Real interest rate	-0.01	-0.05***	0.04***	-0.03*	-0.05**	-0.03**
	(0.50)	(3.21)	(3.20)	(1.66)	(2.42)	(2.23)
R-square	0.75	0.60	0.61	0.73	0.61	0.71
DF-GLS	-2.72***	-2.95***	-3.48***	-1.57	-2.31**	-2.46**
PP	-3.01**	-3.32**	-3.21**	-3.95***	-4.08***	-3.61***

Notes: The dependent variable is the logarithm of the nominal price divided by the manufacturing price index. Interest rate is the 3-month T-bill rate adjusted by inflation. Income is world GDP measured at PPP. Because of data unavailability, the regressions for soybeans and palm oil begin in 1965. DF-GLS = modified Dickey-Fuller, PP = Phillips-Perron (both statistics for unit roots). Absolute *t*-statistics in parentheses, * = 10 percent, ** = 5 percent, *** = 1 percent.

Table 5: Sensitivity Analysis to the Choice of Income, ToT Model, Equation (4)

	Maize	Soybeans	Wheat	Rice	Palm oil	Cotton
GDP measured at Purchasing Power Parity (PPP), total						
World	-0.60***	-0.52***	-0.52***	-0.65***	-0.70***	-0.71***
Low & Middle Income	-0.41***	-0.34***	-0.35***	-0.45***	-0.48***	-0.51***
China & India	-0.22***	-0.18***	-0.18***	-0.23***	-0.25***	-0.28***
GDP measured at Purchasing Power Parity (PPP), per capita						
World	-1.16***	-0.93***	-0.98***	-1.23***	-1.34***	-1.39***
Low & Middle Income	-0.63***	-0.46***	-0.51***	-0.68***	-0.73***	-0.80***
China & India	-0.25***	-0.20***	-0.20***	-0.26***	-0.30***	-0.33***
GDP measured at Market Prices, constant US$ 2010, total						
World	-0.64***	-0.56***	-0.56***	-0.70***	-0.74***	-0.75***
Low & Middle Income	-0.43***	-0.36***	-0.37***	-0.47***	-0.50***	-0.52***
China & India	-0.21***	-0.17***	-0.17***	-0.22***	-0.24***	-0.27***
GDP measured at Market Prices, constant US$ 2010, per capita						
World	-1.34***	-1.12***	-1.15***	-1.42***	-1.54***	-1.57***
Low & Middle Income	-0.68***	-0.50***	-0.56***	-0.73***	-0.78***	-0.84***
China & India	-0.24***	-0.19***	-0.19***	-0.25***	-0.28***	-0.31***

Notes: Only the income parameter estimates are reported in this table. The parameter estimates of the first row are the ones reported in the "Income" row of table 4. * = 10 percent, ** = 5 percent, *** = 1 percent.

Table 6: Parameter Estimates from Seemingly Unrelated Regressions, Nominal Price Model, Equation (5)

	Maize	Soybeans	Wheat	Rice	Palm oil	Cotton
Constant	11.90***	9.94***	9.48***	19.20***	14.30***	9.61***
	(5.17)	(4.73)	(4.60)	(6.49)	(4.18)	(3.76)
Income	-0.10	0.11	0.02	-0.25	-0.20	-0.32**
	(0.66)	(0.87)	(0.14)	(1.30)	(0.89)	(2.11)
Stock-to-Use ratio (lag)	-0.26***	-0.14***	-0.40***	-0.21	-0.24*	-0.43***
	(2.93)	(3.28)	(4.88)	(1.28)	(1.72)	(4.45)
Real oil price	0.31***	0.33***	0.29**	0.29***	0.43***	0.23***
	(6.08)	(7.18)	(6.35)	(3.32)	(5.75)	(4.46)
Real exchange rate	-1.21***	-1.33***	-0.93***	-2.13***	-1.05*	-0.81**
	(3.38)	(-4.06)	(2.83)	(4.10)	(1.77)	(2.12)
Real interest rate	0.02	0.01	0.00	0.00	-0.01	0.00
	(1.27)	(0.37)	(0.13)	(0.20)	(0.23)	(0.02)
Manufacture prices	0.30*	0.16	0.28**	0.36	0.31	0.49***
	(1.67)	(1.20)	(2.18)	(1.13)	(1.07)	(3.14)
R-square	0.86	0.88	0.90	0.78	0.74	0.81
DF-GLS	-3.27***	-3.62***	-5.37***	-1.62	-3.45***	-2.26*
PP	-3.84***	-4.70***	-4.06***	-4.10***	-4.23***	-3.74***

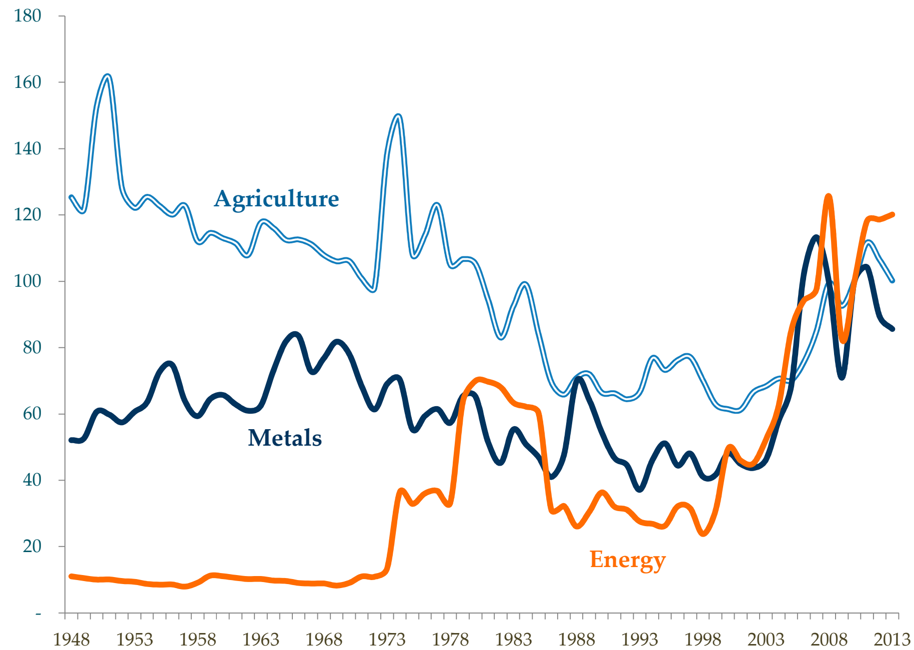
Notes: The dependent variable is the logarithm of the nominal price while the price of manufacture goods is one of the independent variables. Interest rate is the 3-month T-bill rate adjusted by inflation. Income is world GDP measured at PPP. Because of data unavailability, the regressions for soybeans and palm oil begin in 1965. DF-GLS = modified Dickey-Fuller, PP = Phillips-Perron (both statistics for unit roots). Absolute *t*-statistics in parentheses, * = 10 percent, ** = 5 percent, *** = 1 percent.

Table 7: Sensitivity Analysis to the Choice of Income, Nominal Price Model, Equation (5)

	Maize	Soybeans	Wheat	Rice	Palm oil	Cotton
GDP measured at Purchasing Power Parity (PPP), total						
World	-0.10	0.11	0.02	-0.25	-0.20	-0.32**
Low & Middle Income	-0.00	0.09	0.03	-0.15	-0.08	-0.19*
China & India	-0.01	0.02	0.01	-0.09	-0.05	-0.12**
GDP measured at Purchasing Power Parity (PPP), per capita						
World	-0.14	0.30	0.06	-0.40	-0.33	-0.55*
Low & Middle Income	0.05	0.18	0.07	-0.20	-0.06	-0.25
China & India	-0.00	0.03	0.01	-0.10	-0.05	-0.14**
GDP measured at Market Prices, constant US$ 2010, total						
World	-0.16	0.09	0.01	-0.28	-0.24	-0.37**
Low & Middle Income	-0.00	0.09	0.03	-0.16	-0.08	-0.19*
China & India	-0.01	0.02	0.01	-0.08	-0.05	-0.11**
GDP measured at Market Prices, constant US$ 2010, per capita						
World	-0.36	0.29	0.03	-0.49	-0.46	-0.70**
Low & Middle Income	0.06	0.21	0.08	-0.21	-0.05	-0.25
China & India	-0.00	0.03	0.01	-0.09	-0.05	-0.13**

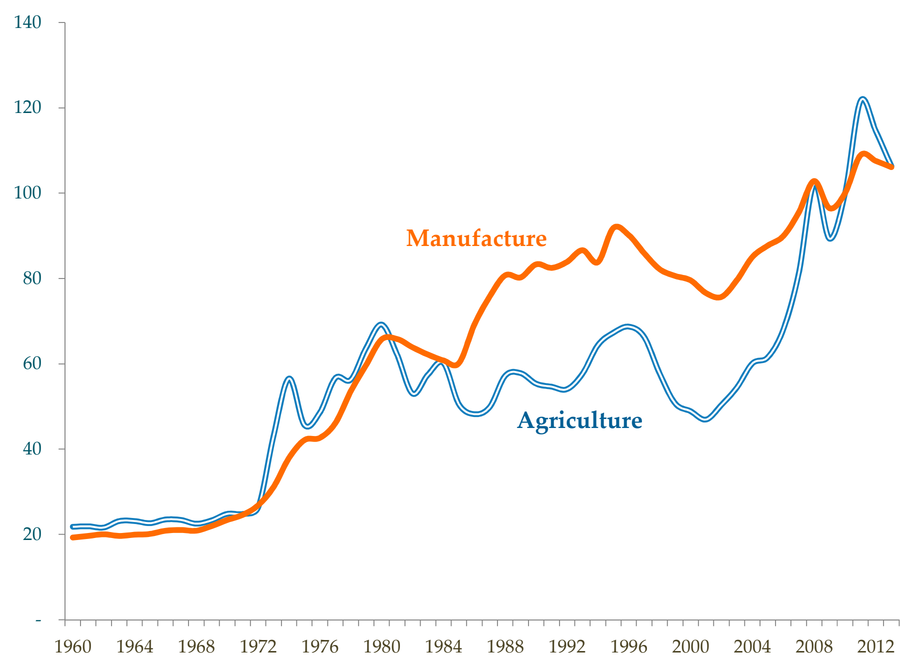
Notes: Only the income parameter estimates are reported in this table. The parameter estimates of the first row are the ones reported in the "Income" row of table 6. * = 10 percent, ** = 5 percent, *** = 1 percent.

Figure 1
Commodity Prices (MUV-deflated, 2010 = 100)



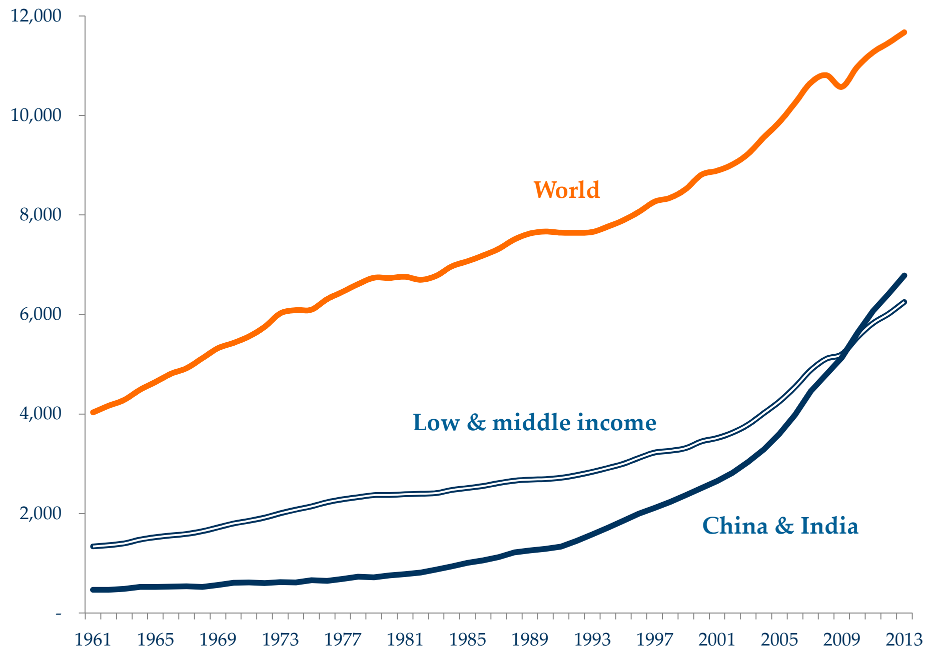
Source: World Bank.

Figure 2
Agriculture and Manufacture Prices (Nominal, 2010 = 100)



Source: World Bank

Figure 3
Per Capita Income measured at PPP



Source: World Bank

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Appendix A: Summary of Empirical Research the Prebisch-Singer Hypothesis

AUTHOR(S)	DATA	METHOD	MAIN CONCLUSION
Engel (1857)	Budget expenditures of 153 Belgian families, 1853	Non-parametric analysis	Poor families spend a greater the proportion of their total income for food.
Kindleberger (1943)	No data used	No model employed	As income grows, the terms of trade move against primary commodity producing countries.
Prebisch (1950)		Non-parametric analysis	
Singer (1950)		Non-parametric analysis	
Kindleberger (1958)	Unit vale indices, country specific, 1872-1952	Non-parametric analysis	The Tot moved against underdeveloped and in favor of developed countries
Morgan (1959)		Non-parametric analysis	
Spraos (1980)	Various indices of primary commodities, 1871-1970	Tested for a trend	A significant downward trend up to WWII; no trend after WWII.
Sapsford (1985)	Index of primary commodities, 1900-1982	Tested for trend with a structural break in 1950; correcting for serial correlation	Downward trend on post-WWII data of the non-energy index, with a once-for-all upward shift in 1950.
Thirlwall and Bergevin (1985)	Primary commodities and index, developed and developing countries, 1954-1982	Tested for a trend	Either constant or deteriorating trends in disaggregated commodity price indice.
Grilli and Yang (1988)	Index and various sub-indices of primary commodities, 1900–1983 (G-Y index)	Tested for a trend	Negative trends in the relative prices of all primary commodities.
Cuddington and Urzua (1989)	G-Y index, 1900-1983	Tested for trend using TS and DS with structural breaks	Little evidence of negative trend after accounting for a structural break.
Helg (1991)	G-Y index, 1900-1988	Tested for a trend by controlling for structural breaks	Significant downward trend of the G-Y index since the post 1920 period.
Powell (1991)	G-Y index	Cointegration analysis between non-oil index and MUV, accounted for jumps in the data	Marginally in favor of stepwise declines (1921, 1938, and 1975) than a continuous downward trend.
Sarkar and Singer (1991)	Country-specific, 1965-1985	Tested for a trend	Mixed evidence: Negative trend in some countries and positive in others.
Ardeni and Wright (1992)	Primary commodity prices and index, 1954-1982	Tested for a trend, developed vs. less-developed countries	Either constant or deteriorating trends in disaggregated commodity price indices on the post-war period.

Boughton (1991)	Price ratio of primary commodities to manufactures, 1854-1990	Tested for trend, error-correction model	Evidence of declining trend.
Cuddington (1992)	26 individual commodity price, 1900-1983	Tested for trend using unit roots nonparametric approach	Mixed evidence: No trend for 16 prices, 5 negative trends, and 5 positive trends.
Sapsford, Sarkar, and Singer (1992)	Lewis CTT series and G-Y index, 1870-1938	Tested for a trend	A tendency of a declining trend in the terms of trade of primary commodities.
Bleaney and Greenaway (1993)	G-Y index, 1900-1991	Tested for unit root allowing for structural breaks	May have been a long-run downward trend, but this trend is a slow one.
Lipsey (1994)	Various measures of manufacturing export prices, 1953-1991	Non-parametric analysis	The MUV overstates the long-run rise in manufactured goods prices by as much as one percent per annum.
Leon and Soto (1997)	G-Y index, several sub-indices, and 24 commodity prices, 1900-1992	Tested for unit root allowing for structural breaks using nonparametric methods	Support of the P-S hypothesis: 17 of 24 prices have negative long-run trends, three are trendless, and four have positive trends.
Bloch and Sapsford (2000)	Post-World War II price and wage data	Structural model of price and wage determination	Support of the P-S hypothesis, except in periods of rapid manufacturing growth.
Cashin and McDermott (2002)	Economist's commodity price index, 1862-1999	Tested for trends, volatility and duration of booms and slumps	Downward trend of about 1% per year; no presence of structural break.
Blattman, Hwang, and Williamson (2003)	Data for 35 countries, 1870-1938	Panel data regression	Secular terms of trade growth had a positive impact on growth performance.
Kim, Pfaffenzeller, Rayner, and Newbold (2003)	G-Y index, sub-indices, and individual commodities	Tested for trend with nonparametric method	Relative commodity prices behave like unit root processes and only 5 of the 24 commodity prices have negative trend.
Persson and Terasvirta (2003)	G-Y index, 1900-1995	ESTAR non-linear model, testing for trend	Rejected the P-S hypothesis.
Toye and Toye (2003)	No data or model used	Literature review	
Bunzel and Vogelsang (2005)	G-Y index, 1900-1995	Univariate deterministic trend model to test for a trend	Statistically significant downward trend.
Newbold, Pfaffenzeller, and Rayner (2005)	G-Y index and with 24 prices, MUV-deflated, 1900-2002	Tested for trends using ARIMA model	The G-Y does not provide an adequate representation of commodity price behavior, weak support for the P-S when individual prices are used.
Zanias (2005)	G-Y index, 1900-1995	Tested for trend allowing for a unit root and structural breaks	No deterministic or stochastic trend but two major negative structural breaks.
Kellard and Wohar (2006)	G-Y index and 24 commodity prices, 1900-1998	Unit root test allowing for structural breaks, testing for trend	Limited support for the P-S hypothesis.

Molick, Faria, Albuquerque, and Leon-Ledesma (2008)	US PPI data, 1947-1999	Tested for trend allowing for a unit root and structural breaks	The internal terms of trade of the US economy declined.
Balagtas and Holt (2009)	G-Y index and 24 individual prices, 1900-2003	Tested for linear unit root against STARs model	Limited support for the P-S hypothesis.
Harvey, Kellard, Madsen, and Wohar (2010)	25 prices, 1650-2005	Assess trend function and the existence of structural breaks	Mixed evidence: Long-run decline for 11 prices, zero-trend for remaining ones.
Ghoshray (2011)	G-Y index and 24 individual commodity prices, 1900-2003	Unit root tests allowing for up to two structural breaks	Half of the prices are difference stationary, the rest are trend stationary subject to structural breaks.
Fernandez (2012)	G-Y index deflated by HPIM, MUV, PPI, and CPI, 1900-2003	Tested for trend, allowing for structural breaks	Annual data more likely to support P-S when deflating by US CPI than MUV.
Arezki, Hadri, Kurozumi, and Rao (2012)	Nine prices deflated by the US CPI	Stationarity tests accounting for cross-sectional dependence and a structural break, panel data	All real commodity prices exhibit significant negative trend except oil.
Erten and Ocampo (2013)	1865-2010	Tested for super-cycles in commodity prices	A step-wise deterioration of real prices, which supports P–S hypothesis.
Yamada and Yoon (2013)	G-Y index and 9 sub-indices, 1900-2010	Testing for piecewise linear trends	Most commodities exhibited negatively sloped trends during some sub-periods.
Arezki, Hadri, Loungani, Rao (2014)	25 prices deflated by a manufacturing value-added price index, 1650-2010	Panel stationarity allowing for multiple structural breaks	Mixed evidence, majority of series have negative trends. Most series are stationary after allowing for endogenously determined structural breaks.

Notes: G-Y = Grilli-Young index of primary commodity prices, ToT = terms of trade, MUV = Manufacture Unit Value, CPI = Consumer Price Index, PPI, Producer Price Index, P-S = Prebisch-Singer.

Appendix B: Data Description

World prices were taken from the World Bank's database and represent annual (calendar) averages, expressed in U.S. dollar per metric ton (mt), except crude oil which is expressed in US dollars per barrel. The description of commodity prices is as follows: ***maize*** (United States), no. 2, yellow, f.o.b. (free on board) U.S. Gulf ports; ***rice*** (Thailand), 5 percent broken, white rice, milled, indicative price based on weekly surveys of export transactions, government standard, f.o.b. Bangkok; ***wheat*** (United States), no. 1, hard red winter, ordinary protein, export price delivered at the U.S. Gulf port for prompt or 30 days shipment; s***oybeans*** (United States), c.i.f. (cost, insurance, freight) Rotterdam; ***palm oil*** (Malaysia), 5 percent bulk, c.i.f. N. W. Europe; ***cotton*** (Cotton Outlook "Cotlook A index"), middling 1-3/32 inch, traded in Far East, C/F beginning 2006; previously Northern Europe, c.i.f.; and ***crude oil***, average price of Brent, Dubai and West Texas Intermediate, equally weighed. Finally, the manufacture unit value (MUV) was used as a proxy of manufacturing prices. The MUV is a US dollar trade weighted index of manufactures exported from 15 economies (Brazil, Canada, China, Germany, France, India, Italy, Japan, Mexico, the Republic of Korea, South Africa, Spain, Thailand, the United Kingdom, and the United States). More details on the prices along with the MUV can be found at the World Bank's Commodity Price Database.

The ***stocks-to-use ratio*** was calculated as the ratio of end-of-season stocks to total consumption taken from the U.S. Department of Agriculture's Production, Supply, and Distribution Online. The ***exchange rate*** measure was the broad index of the U.S. real foreign exchange value of the dollar. The 3-month US Treasury bill was used as ***interest rate*** proxy, taken from the U.S. Federal Reserve's Selected Interest Rates database. It was adjusted by the U.S. CPI to convert it to real terms. Last, the various measures of ***GDP*** were taken from the World Bank's World Development Indicators database.

Appendix C: Data Sources

Prices: http://worldbank.org/prospects/commodities

Income: http://data.worldbank.org/indicator

Stock-to-use ratios: www.fas.usda.gov/psdonline

Interest rate: www.federalreserve.gov/releases/h15/data.htm

Exchange rate: http://research.stlouisfed.org/fred2/series/TWEXB