Innovation, Real Primary Commodity Prices and Business Cycles

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Abstract Schumpeter emphasizes the role of innovation in explaining long-run economic development. This contrasts to the emphasis on scarcity in classical and neoclassical models. Our research shows the fruitfulness of Schumpeter's approach in explaining movements in real prices of primary commodities since 1650. In models that emphasize resource scarcity, rising real prices of these products are identified as limiting growth. However, in examining the historical data we find a dominance of negative price trends across individual commodities, particularly when allowing for long-run cyclical behavior. We then provide examples to show how innovations for particular commodities have contributed to the negative price trends. Overall, innovation has meant that increased supplies of primary commodities have been available at reduced real prices, thereby providing a positive contribution to growth. Of course, as Schumpeter suggests, the development process associated with innovation is uneven, so price movements are heterogeneous across long-run cycles and commodities.

1 Introduction

Our objective in this paper is to develop and apply a framework for understanding the impact of innovation on the long-run movement in the real prices of primary commodities, namely the products of land and other natural resources, specifically

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agriculture and mining products. By real price we mean the price of these products relative to other prices, especially the prices of manufactured products. By long run we mean over the course of multiple business cycles, including the long wave or Kondratieff cycle that runs for over half a century per cycle. We apply the framework to data for real prices of primary commodities that cover a period of up to more than three centuries.

Our framework is developed from Schumpeter's theory of economic development and the business cycle. Here, innovation is the force released by capitalist organization of the economy, driving progress through a process of discontinuous change. The influence of innovation is reflected in prices having a wave-like motion over time, with prices rising and then falling by an even larger amount before partially recovering over the course of the Kondratieff cycle.

We follow Rostow (1980) in extending Schumpeter's analysis of Kondratieff cycles by considering the influence of gestation lags that slow adjustment in the production of primary commodities in addition to the impact of technological breakthroughs. Primary commodities have a special role in the process of development, as they are the basic raw materials for production of finished consumer and producer goods. Any tendency for primary commodity prices to rise in the prosperity phase of a cycle enhances the incentives for exploration, enhanced recovery technology and development of substitute products or more efficient use in further production. As Schumpeter (1939) notes history is replete with examples of commodity price rises followed by opening of new production provinces, use of innovative technology to extend mine life and development of synthetic substitutes, all of which encourage prices to fall back towards long-run norms. Rostow systematizes this response of productive capacity for primary commodities thereby generating a distinctive pattern of movement for commodity prices over the Kondratieff cycle.

In addition to the analyses of Schumpeter and Rostow, we draw on the work of Prebisch (1950) and Singer (1950) regarding trend in the terms of trade between primary producers and manufacturers in the long run. Particularly important is the suggestion that the terms of trade are influenced by different degrees of market power for primary producers and manufacturers, as well as by different labor market conditions in industrialized versus developing countries. Prebisch and Singer argue that these differences in market structure along with different rates of technological change contribute to a declining trend in the price of primary commodities relative to the price of manufactured goods.

Our analysis leads to an expectation of a long-run downward trend for the real (or relative) prices of primary commodities along with a distinctive cyclical pattern, rising in the upswing of the Kondratieff cycle and declining by a larger amount in the downswing. This characterization of price movements applies in general, but is subject to disturbance by history. For the aggregate of all commodities this is reflected in larger historical events, such as wars, population migrations and financial crises, albeit with recognition that these events may have roots in the ongoing process of economic development. For individual commodities the application of the general characterization occurs against the specific technological breakthroughs in the production and consumption of that commodity.

In the next section we discuss the opposing impacts on productivity in primary production arising from natural resource constraints and technological innovation. We then review evidence on long-run trends for real primary commodity prices, both for aggregate real commodity price indexes and for real prices of individual commodities over long periods, extending back in some cases to 1650. In the third section we examine the data on an aggregate index of real primary commodity prices to identify Kondratieff cycles as suggested by Rostow's analysis of lags in the supply response of commodity production. In Sect. 4, we examine similarities and differences in the trend in the real price series across commodities and over different cycles. The final section contains our conclusions and a discussion of the implications for the future course of real commodity prices.

2 The Long-Run Trend in the Real Prices of Primary Commodities

Natural resources have long been recognized in economics as posing a limit to economic growth. In the classical economic analysis of limits to the amount of arable land by Ricardo (1911) this is reflected in declining marginal productivity of labor in the production of agricultural commodities as the economy grows. Further analysis of nonrenewable resources by Hotelling (1931) suggests that there will be declining marginal productivity over time for all variable inputs in the production of mining commodities, even without growth in the level of output. Yet, real wages have risen strongly in both agriculture and mining in advanced countries, implying equivalent rises in the marginal productivity of labor according to the marginal productivity theory of wages.

Schumpeter puts innovation at the center of the analysis of long-run economic development. In *Business Cycles*, Schumpeter (1939, pp. 237–240) notes the contribution of entrepreneurial innovations to the rise in output per acre in English agriculture over the period from 1500 to 1780. This was also a period of rural depopulation associated with enclosures (one of the entrepreneurial innovations identified by Schumpeter). The resulting rise in output per worker contradicted the dire predictions of classical economists and provided plentiful and cheap food for the manufacturing labor force required for the beginnings of the Industrial Revolution.

Schumpeter is clear that innovations in primary production continued beyond the early years of the Industrial Revolution. He notes innovations in English, German and American agriculture that vastly expanded production. While prices followed an erratic path due to the effects of variable harvests, wars and protectionism (op. cit., pp. 266–270), he cites a consistent pattern in the example of the expansion of areas of wheat cultivation in the United States, 'Each process of this kind spells an increase in production and, at the same time, prosperity in the new and depression in the old' (op. cit., p. 270). This is a nice example of the process of creative destruction that is more commonly applied to innovation in manufacturing.

Innovation and the expansion of primary production is in part a reaction to high demand and rising prices. However, the drive to innovate continues even when demand abates, shifting from a focus on capacity expansion to one of cost reduction.[1] Historically, the net result has been a long-run improvement in productive capability that has more than offset the force of the natural limits emphasized by classical and neoclassical approaches to natural resource pricing. The improvements have been so strong that the real prices of primary products have generally fallen.

Real price measures deflate the nominal price of a good measured in a particular currency by a measure of the general price level in the same currency, removing the influence of generic factors that affect prices of all goods. The resulting measure is meant to reflect factors that are specific to the individual good or group of goods. A falling trend in the real price for a primary commodity suggests that the innovations in the production and consumption of the commodity are more than sufficient to offset any effect of the finite limits to the natural resource.

Harvey et al. (2010) examine whether there are long-run trends in the prices of 25 primary commodities. The series for eight of the primary commodities (beef, coal, gold, lamb, lead, sugar, wheat and wool) go back to 1650, while the other series go back at least as far as 1900 (bananas and jute). They find evidence of a long-run downward trend in the real price of eight commodities (aluminum, coffee, jute, silver, sugar, tea, wool and zinc) without allowing for structural breaks. They also find evidence of a long-run downtrend including structural breaks for a further three commodities (hides, tobacco and wheat). No evidence of a statistically significant long-run trend, either up or down, is found for any of the other fourteen commodities.

The findings of Harvey et al. support the hypothesis of a declining long-run trend in real commodity prices as put forward in the seminal work of Raul Prebisch (1950) and Hans Singer (1950). Most of the empirical literature dealing with the Prebisch-Singer hypothesis has focused on aggregated indexes of primary commodity prices.[2] For comparison with this literature, we illustrate the phenomenon of declining real commodities prices in Fig. 1, which shows the time path since 1650 of the natural logarithm of the simple average of the real price index for the 25 commodities examined by Harvey et. al.[3] There is clearly downward movement over the full period, but many episodes of rising prices, including some substantial price spikes. This suggests there are complex dynamics at play rather than a steady

[1] Tilton and Landsberg (1999) provide an illuminating discussion of the response of US copper producers to declining copper prices from the 1970s through the 1990s. Output and productivity first declined and then rose substantially as the real price of copper fell by more than 50 %.

[2] A recent overview of this literature that also contains a discussion of volatility in commodity prices is Nissanke (2010a).

[3] We thank Jakob Madsen for supplying the data used in Harvey et al. (2010). We have extended the data series from 2005 to 2008 by chain linking, with the primary commodity index linked to the IMF all commodities world price index series and the manufacturing price series linked to the OECD total manufacturing price index series. We use the logarithm of the price index so that equal proportionate changes in price show as movements of equal distance along the vertical index, thereby reducing the potential distortion caused by very comparisons over a large range of prices.

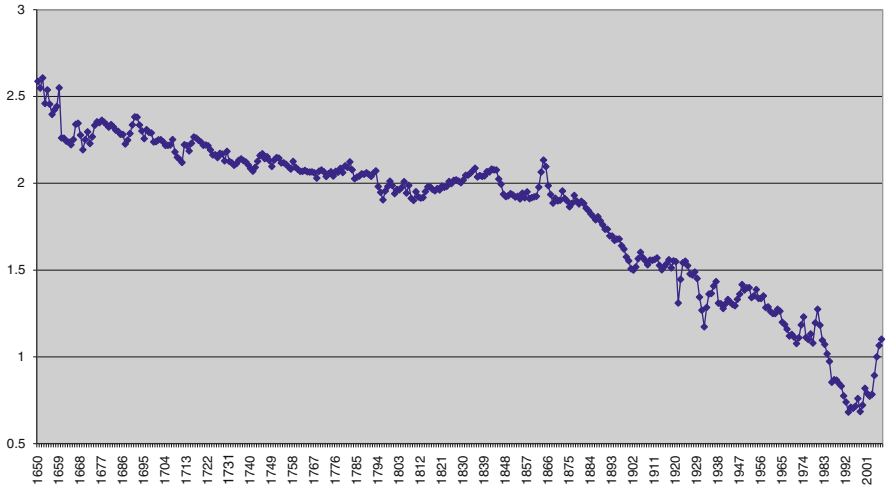

Fig. 1 Logarithm of aggregate index of real commodity prices, 1650–2008 (2005=1)

down (or up) movement over the full period. The dynamics of commodity prices are the subject of the next section of the paper.

3 Kondratieff Cycles in Real Prices of Primary Commodities

In *Business Cycles*, Schumpeter (1939) argues that innovation does not have smooth impact on the pace of economic life. Rather, it causes disturbances that lead to uneven development of the economy. Yet, he suggests a degree of regularity to this process involving cyclical fluctuations of various lengths. His stylized representation of cycles (see Schumpeter 1939, Chap. 5, Chart 1) has three overlapping cycles, a Kitchin cycle lasting slightly more than 3 years, a Juglar cycle of about 9 and a quarter years and a Kondratieff cycle of 55 and a half years. The cycles are shown as overlapping in that each Kondratieff cycle contains six Juglars and each Juglar contains three Kitchins.

Schumpeter's argument that major innovations lead to alternating long periods of expansion and decline in economic activity has been adopted in a number of works dealing with the history of capitalism, for example, Mensch (1979), Tylecote (1992) and Freeman and Louçã (2001). However, Schumpeter's characterization of regular cycles has been discarded in favor of a pattern with irregular amplitude and duration. The terminology of a long wave is used in place of the Kondratieff cycle, with the long wave having the duration of something like a half century.

The key variable in Schumpeter's characterization of the cycle is the price level rather than the level of output that features in most discussions of the business cycle. This reflects Schumpeter's emphasis on innovation as leading to structural change and uneven development. The price level rises during the upswing of a cycle and falls during the downswing. These cyclical swings in prices obscure the working of innovation on the trend in particular goods or groups of goods. This is

particularly true for primary commodities, which dominate listings of goods with "sensitive prices" that Schumpeter (1939, p. 525) recognizes 'will display cycles in prices both relatively promptly and relatively strongly'. Thus, the movement over time in prices of primary products, even when deflated by a measure of the price level, will depend on general price cycles as well as any influences of innovation.

A further complication in examining the impact of natural resource scarcity and innovation on primary commodity prices is feedback between scarcity and innovation. While nature may constrain expansion of capacity in primary production, impediments to growth are also opportunities for profitable innovation. Scarcity, as measured by high prices, presents clear opportunities for opening up new sources of supply, improved production technology and economizing in use. Schumpeter (1939, pp. 430–432) discusses as an example the development of rubber plantations, particularly in Asia, to augment the supply of "wild" rubber from Brazil after the surge in demand for tires following the innovation of mass produced motor cars. Under capitalism the dictum "necessity is the mother of invention", can be aptly rephrased as "profitability is the mother of innovation".

Rostow (1980, Chapter 2) formalizes the process of delayed expansion of natural resource production capacity, incorporating long lags in feedback from prices to expanded capacity. Rostow's model includes two sectors, one producing industrial goods and the other producing basic commodities. Natural resources in the form of land only enter into the production of basic commodities. In contrast to neoclassical models, where land is assumed to be fixed in quantity forever, Rostow assumes that amount of land can be augmented. However, the augmentation occurs with a substantial lag behind growth in labor and physical capital, taking up to three decades to match the growth rate of labor and physical capital. Simulations of the model generate a growth cycle of some 50 years, with the relative price of the basic commodity and the rent of land rising in the early decades of the cycle and then falling back towards the original levels.

Augmentation of natural resources in Rostow's model is meant to capture the pattern observed in his historical work (see Rostow 1978). Rostow argues that spurts in industrial production following on major technological innovations drive up the relative price of basic commodities as supplies are inelastic in the short run. He identifies three types of lags that slow the augmentation of the natural resource in response to an increase in relative price. Recognition lags occur because it takes time for commodity producers to become convinced that the higher prices are not temporary. Gestation lags occur because large scale infrastructure, such as rail links or pipelines, is often necessary to open up new production provinces. Finally, exploitation lags occur because it takes time to reach full potential as the number of production units expand to take advantage of the infrastructure.

Rostow's simulations are based on parameter values calibrated to match his characterization of the stylized facts of economic history. In a related two-good model, we (Bloch and Sapsford 2000) estimate the parameters of pricing equations for primary products and manufactured goods in world markets using annual data for the period from 1948 to 1993. Primary commodities in this model take the place of Rostow's basic commodities, while manufactured goods take the place of industrial goods. However, there are important differences in the structure of our model and that of Rostow.

Rostow assumes competitive market clearing in product markets for both industrial goods and basic commodities. We also treat primary commodity prices as determined by competitive market clearing, but manufactured goods are sold under conditions of imperfect competition with price equal to unit cost times one plus a gross profit margin.[4] Rostow assumes that both industrial goods and basic commodities go directly into final consumption, while we have primary commodities as inputs into the production of manufactured goods. A final important difference in structure is that Rostow has a single wage in both sectors, while we allow for different wages in the two sectors following Prebisch's (1950) arguments regarding the impact of unionization and income support programs in the industrialized countries that dominate exports of manufactures versus generally surplus labor in the developing countries that dominate exports of primary commodities.

The estimates obtained in Bloch and Sapsford (2000) imply a trend rate of decline in the price of primary commodities relative to manufactured goods of about one half percent per annum over the sample period, 1948–1993. This estimate of the trend decline in the "real" price of primary commodities is determined based on the observed average rates of change for the exogenous variables in the model, which are an increase in manufacturing output of about 5 % per annum and the average rate of increase in the manufacturing gross profit margin of about one third of a percent per annum.[5] Importantly, the results indicate that real primary commodities prices tend to increase relative to trend during periods of substantially above average growth in manufacturing output and fall relative to trend during periods of average or slower than average growth in manufacturing output. These results are consistent with Rostow's observation that spurts of rapid growth in industrial output lead to rises in the relative price of basic commodities. Unfortunately, the shortness of the time span covered does not allow any statistical test for the type of long gestation lags suggested by Rostow.

Putting the trend aside, we expect the rhythm of "sensitive" prices to be reflected in rising real prices of primary commodities in the upswing of a Kondratieff cycle and falling real prices in the downswing. If these cyclical fluctuations dominate trend in the short run as suggested in Fig. 1, then the peak of the Kondratieff cycle should be reflected in a local maximum for real prices of primary commodities and the trough in a local minimum. The long-run downward trend also needs to be taken into account when choosing minima and maxima.[6] When this procedure is applied to the real commodity price series shown in Fig. 1, we obtain the dating of peaks

[4] This asymmetric treatment follows that in Kalecki (1971).

[5] This estimate is based on a simplified version of the model that excludes rates of growth of capital stock in the manufacturing and industrial sectors as exogenous variables. We prefer the results from the simplified model as the measures for the capital stock growth variables are imprecise and the estimated coefficients of these variables have low statistical significance when they are included in regressions.

[6] Local minima are reasonably clear against a falling trend, but local maxima are not. A later observation can be higher relative to the trend line, even though it has a lower value. For example, we choose 1954 as the peak of the cycle with troughs in 1932 and 1993, even though the real price index is lower in 1954 than in 1937.

Table 1 Peaks and troughs in real primary commodity price index, 1650–2008

Year	Peak or trough?	Index value (logarithmic units)	Change in value from preceding extreme	Annual rate of change (%)
1669	Trough	2.193		
1691	Peak	2.382	0.189	0.859
1711	Trough	2.119	−0.163	−0.815
1716	Peak	2.216	0.097	1.940
1741	Trough	2.070	−0.146	−0.584
1745	Peak	2.170	0.100	2.500
1796	Trough	1.904	−0.266	−0.522
1835	Peak	2.086	0.182	0.467
1848	Trough	1.923	−0.163	−1.254
1864	Peak	2.133	0.210	1.312
1902	Trough	1.500	−0.633	−1.666
1905	Peak	1.602	0.102	3.400
1932	Trough	1.173	−0.429	−1.589
1954	Peak	1.387	0.314	1.427
1993	Trough	0.681	−0.706	−1.810
2008	Peak	1.180	0.499	3.327

and troughs that is shown in Table 1.[7] Table 1 also shows the change in the logarithmic value between adjacent peaks and troughs along with the implied annual rate of change in percentage.

The pattern of peaks and troughs in Table 1 helps to explain why there has been so much controversy about whether there is a negative trend in real primary commodity prices. Each cyclical peak exceeds the previous trough and there is even a period in the nineteenth century when there is an increase from peak to peak and trough to trough (from the trough in 1796 to that in 1848 and from the peak in 1835 to that 1864). Otherwise there is a decrease between all adjacent peaks or troughs, especially in the twentieth century, which leads to the overall downward movement in commodity prices shown in Fig. 1. Increasing volatility over time, especially in the twentieth century, is a further complication in discerning trends in real primary commodity prices, which makes even the pronounced decline in prices from the mid nineteenth century onwards subject to doubt depending on the choice of starting and ending dates.[8]

The peaks and troughs in the aggregate primary commodity price index reflect the factors that affect each component price. Some of these are specific to the particular commodity, such as innovations in the production or use of the commodity, while other factors have more general impact, such as the growth of industrial

[7] Not all local maxima and minima are chosen as peaks and troughs, respectively. In particular, we avoid choosing closely coincident local maxima and minima as these would not fit the concept of a long cycle.

[8] The sharp upward spike shown in 2008 at the end of the series in Fig. 1 has been followed by a precipitous decline in 2009 and then almost complete recovery before another downturn.

output, manufacturing profit margins and wages in both primary production and manufacturing. Having identified turning points in terms of the aggregate index, we next turn to examining movements in prices of individual commodities over the cycles in the aggregate index.

4 Trends in Real Prices for Individual Primary Commodities

Tables 2a and 2b show the rates of price change in percent per annum for each of 25 primary commodities for each of the trough-to-trough cycles shown in Table 1.[9] The top panel shows price changes for agricultural commodities, while the bottom panel shows price changes for metal and energy commodities. Annual rates of change are used to enable comparisons across cycles of different lengths.[10]

The data in Tables 2a and 2b show clear differences in the rate of change of prices of primary commodities across both commodities and cycles. While the comparison across troughs of the cycles in real primary commodity prices is meant to remove the common cyclical component of price movements, there is still substantial variation across commodities remaining in the price change. This reinforces the fragility noted above of conclusions regarding the presence of trend in real primary commodity prices. Different commodities have different measured trend rates of change in different cycles.

Statistical analysis is used to determine whether the variation in rates of price change is consistent with a single trend rate for the whole of the period for which data are available, with or without allowing for structural breaks. As noted in the previous section, Harvey et al. (2010) are able to identify statistically significant negative price trends for eight commodities (aluminum, coffee, jute, silver, sugar, tea, wool and zinc) without allowing for a structural break and a further three commodities (hides, tobacco and wheat) after allowing for structural breaks. Further evidence of statistical significant negative price trends with or without structural breaks for the shorter period from 1900 to 2007 is provided by Sapsford et al. (2010) for six commodities (aluminum, hides, rice, rubber, sugar and wheat).

The bulk of the statistically significant negative price trends in both Harvey et al. (2010) and Sapsford et al. (2010) are for agricultural commodities. In addition, in Tables 2a and 2b the price trends for bananas are negative in both cycles for which data are available. Also, rice shows all negative price changes except for the cycles in the nineteenth century. Indeed, there are only three agricultural commodities that lack statistically significant negative price trends and have an ambiguous mix of positive and negative price trends in Tables 2a and 2b. These are beef, cocoa and lamb.

[9] As discussed in note 6 above, cyclical troughs are more readily identified than are peaks. Also, 2008 is too recent to be sure that it will remain a local maximum relative to years in the near future, particularly given the volatility of commodity prices in recent years.

[10] The annual rate of change is calculated as the change in the natural logarithm of the price index for the cycle divided by the number of years elapsed in the cycle.

Table 2a Rate of price change for agricultural commodities in percent per annum (measured trough to trough)

Period	Banana	Beef	Cocoa	Coffee	Cotton	Hides	Jute	Lamb	Rice	Sugar	Tea	Tobacco	Wheat	Wool
1669–1711		−0.694						−0.824		−0.781			−0.714	−1.756
1711–1741		0.339		−0.416	−0.835			0.307	−0.440	0.017	−0.548		0.293	0.170
1741–1796		−0.112		−0.442	0.980			−0.206	−0.408	−0.196	−1.085	0.364	−0.044	−0.044
1796–1848		1.333		−0.179	−0.139			0.656	0.466	−0.072	0.206	1.202	0.164	1.103
1848–1902		1.155	1.196	−0.562	−0.323	0.030		−0.171	0.202	−1.870	−1.267	0.883	−0.634	0.405
1902–1932	−0.390	0.110	−1.826	0.347	−1.225	−1.710	−1.351	2.242	−2.456	−2.318	−1.887	0.216	−0.188	−0.435
1932–1993	−1.540	−0.600	−0.549	−2.160	−2.687	−1.610	−4.384	0.359	−1.876	−1.574	−2.370	−0.789	−1.013	−3.045

Table 2b Rate of price change for metal and energy commodities in percent per annum (measured trough to trough)

Period	Aluminium	Coal	Copper	Gold	Lead	Nickel	Oil	Pig iron	Silver	Tin	Zinc
1669–1711		−0.486		−0.734	−1.228						
1711–1741		0.238		0.170	0.392				0.197		
1741–1796		−0.188		−0.563	−0.388			−1.388	−0.593		
1796–1848		1.683		1.799	2.397			1.308	1.786		
1848–1902		3.111	1.287	2.500	3.514	−1.033		1.940	1.915	0.694	
1902–1932	−0.297	0.494	0.937	0.109	−2.373	0.327	2.799	−1.866	−0.155	−0.380	−0.545
1932–1993	−0.571	−1.110	0.656	0.820	−2.614	−0.353	2.124	0.053	0.931	−1.311	−0.120

Innovations in production play a major role in increasing output and driving down costs for agricultural commodities. Wheat farming provides a good illustration. Rostow (1978) details the impact on wheat production of the expansion of areas of cultivation from the mid nineteenth century through the early twentieth century, first with opening of the American Middle West and Great Plains to wheat production following the westward expansion of rail links, then with expansion in Canada, Australia and Russia.[11] More recently, the Green Revolution has substantially lifted yields and allowed extension of production to previously unviable locations.

As shown in Tables 2a and 2b, the real price of wheat dropped by an average of 0.634 % per annum from 1848 to 1902 and by 1.013 % per annum from 1932 to 1993. Interestingly, the first decline was among the largest for any agricultural commodity over the same period, while the second decline was around the median level of agricultural commodities in the same period. The expansion in wheat farming area was clearly specific to wheat, while the Green Revolution affected the agricultural sector as a whole.

There is little doubt that innovation has significantly impacted on the real price of wheat since 1848, given that the massive real price decrease has occurred in spite of any limits imposed by nature on the very large increases in production over the period. How much is specifically attributable to the two major innovations identified above is arguable, for there have been numerous other innovations occurring over the years, including the mechanization of harvesting and the opening of new production areas in South America and Asia. There are also the confounding influences, such as wars (the real price of wheat rose by close to 100 % from 1913 to 1917 and by almost 200 % between 1941 and 1947), the aggregate business cycle on "sensitive" prices in general (the real wheat price rose by almost 100% in the commodity boom from 1972 to 1974 and by about the same percentage in the recent boom of 2006–2008) and of weather or pests affecting crop yields. Nonetheless, the experience of radical real price decrease in the period since the middle of the nineteenth century stands in sharp contrast to the experience of the prior two centuries when the real wheat price fluctuated widely but without a discernible trend.

Technological change has affected prices of agricultural commodities on the demand side as well as the supply side. Particularly notable has been the effect of the development of synthetic substitutes. Synthetic fibers substantially reduced demand for cotton, hides, jute and wool over the course of the twentieth century and this is reflected in Tables 2a and 2b in relatively steep trend declines in prices for these commodities over the trough-to-trough cycle from 1932 to 1993. It is also reflected in the statistically significant negative trend for rubber over 1900–2007 in the study by Sapsford et al. (2010).

Innovations in institutions as well as technology have impacted on real prices of agricultural commodities. In the previous section we note the negative impact on real primary commodity prices of market power in manufacturing, in both product

[11] See especially Rostow (1978) pp. 147–149 and pp. 167–177.

and labor markets, in increasing manufacturing prices (the denominator of the real price of all primary commodities is an index of manufacturing prices). More specific to agricultural commodities have been moves towards agricultural protectionism in the industrialized countries. Particularly damaging have been subsidy programs that have led to the dumping of surplus production on world markets.[12]

The dominance of negative price trends for agricultural commodities in Tables 2a and 2b contrasts with a mixed picture for metals and energy. Harvey et al. (2010) find statistically significant negative price trends for only two of the metal and energy commodities (aluminum and zinc), while Sapsford et al. (2010) find such evidence for only one metal (aluminum). Gold prices in Tables 2a and 2b are shown as rising over all cycles since 1796, while oil prices are shown as rising for both cycles for which data are available.[13]

Some of the technological and institutional innovations affecting agricultural commodities have also influenced real prices of metals and energy commodities. In particular increased market power in manufacturing product and labor markets have had a negative impact by increasing the denominator of the real price measures. However, there have been other influences that help to explain the lesser frequency of negative price trends for metals and energy commodities as compared to agricultural commodities.

One factor pushing up metal and energy prices is depletion. Topp et al. (2008) document the impact of depletion across mining (metals and energy) industries in Australia over the past three decades. They estimate that depletion reduced measured multi-factor productivity growth in Australian mining by about two and a half percent per annum. Declining productivity pushes up costs, which makes mining unprofitable unless prices rise or there are compensating reductions in other costs. Topp et al. estimate that cost decreases associated with improvements in technology and new discoveries amounted to about two and a half percent per annum, almost exactly offsetting the increased costs due to declining resource quality.

Innovations in institutions have also had positive impact on the real prices of some metal and energy commodities. The obvious example is the influence of the Organization of Petroleum Exporting Countries (OPEC) on oil prices since the 1970s. There has also been considerably increased concentration of production on a global scale in many segments of metals mining and processing, particularly aluminum, copper, iron ore and nickel. Of course the process of concentration as an element of creative destruction might have at least a temporary depressing effect on prices rather than the increasing effect associated with monopoly in static equilibrium.[14]

[12] See Nissanke (2010b) for an extensive discussion of the impact of government policies on prices of primary commodities.

[13] For both gold and oil the absence of a statistically significant positive trend in real price can be attributed to falling prices in early years for which data are available. Real gold prices fell in the three cycles from 1669 to 1796, while real oil prices fell in the years from 1859 (the first year in the oil price series) to 1902.

[14] For a discussion of the compression of profit margins in the concentration phase of the dynamic process of competition see Bloch (2000).

5 Conclusion

Innovation has arguably been the dominant force in determining the path of real prices for primary commodities over the past three and a half centuries. The influence of innovation has been sufficient to result in negative trends in real prices for numerous individual commodities and for aggregate indexes of commodities. The negative trends have occurred in spite of massive increases in output with growth in the world economy, defying the predictions of classical and neoclassical economics that scarcity associated with natural limits would lead to rising real prices of primary commodities.

Models of growth that emphasize natural resource scarcity as a constraint on growth divert attention from the key role of innovations in determining the course of prices and quantities of primary commodities. While there is a dominant tendency for real primary commodity prices to decline, the outcomes vary across time and across commodities. We provide examples of the role of innovations in both technology and institutions in driving trends over particular periods for particular commodities. Further, the innovations are not simply the result of historical accident, but reflect concerted entrepreneurial efforts of individuals and organizations to achieve scientific advance, to advance public policy objectives and, especially, to earn profits. Schumpeter correctly identified the need to build such entrepreneurial activity into the analysis of long-run growth. The spirit of his contribution suggests that it is profitability rather than necessity that is the mother of innovation under capitalism.

Properly incorporating entrepreneurial activity and endogenous innovation into the analysis of primary commodities in the process of long-run growth requires a broad perspective. First, the scope of innovations considered needs to extend beyond the technology of producing primary commodities. Innovations in technology of using primary commodities are also important, as has been shown by the impact of the development of synthetic materials and moves to increase energy efficiency. Second, innovations in the distribution and marketing of primary commodities have had a major impact on the real price of individual commodities in the past and are likely to continue to do so in the future. Finally, innovations in the technology and market organization of manufacturing are also important as manufacturing prices constitute the denominator of the real price measures for primary commodities. While increased market power in manufacturing has had a profound negative impact on the real prices of primary commodities in the past, future innovations could reverse this trend.

One clear insight from Schumpeter's (1939) analysis in *Business Cycles* is that innovations impart a cyclical character to long-run growth, particularly in terms of long cycles of the type identified by Kondratieff. We find a pattern of cycles lasting

between three and six decades in real primary commodity prices over the past three and a half centuries. We date the last cyclical trough as occurring in 1993 and the peak as occurring in 2008.[15]

If our dating is correct, the world economy has entered into the downswing of a long cycle. Judging from the behavior of real primary commodity prices in past cycles, this should leave the aggregate of real primary commodity prices well below 1993 levels.[16] This prediction provides a sharp contrast to the view prevailing in neoclassical economics that natural resource scarcity leads to increasing real prices for natural resource products over time. Of course, with technological change being exogenous to the process of economic growth in neoclassical models, any observed behavior can be ascribed ex post to the observed course of technological change. The great virtue of Schumpeter's approach is that it brings technological change within the analysis of economic development and growth, albeit without the false precision of neoclassical optimizing models that depend on the assumption that the future is knowable or, at least, that the expected future value of economic variables can be calculated accurately.

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[15] In this context, it is important to remember that the downswing in Schumpeter's analysis refers to downward pressure on prices and is consistent with substantial output expansion. Indeed, the last downswing in real commodity prices that began in 1937 included at least three decades of robust output expansion.

[16] As noted by an anonymous referee this prediction is fragile, being dependent on the judgment that 2008 is indeed a cyclical peak as well as on the continuation of a long-run downward trend in primary commodity prices. The dramatic declines of most primary commodity prices in 2009 from their 2008 highs represent a large movement that fits the prediction, but the subsequent rebound suggests the downward path will be far from steady. Clearly, there is still a substantial distance left to cover in terms of both time and the decline in the level of real prices.

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