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IDE DISCUSSION PAPER No. 300

The Rise and Fall in the Price of Food, Fuel and Manufactured Goods: Interdependency between Prices and Technology Determining Comparative Advantages and Development Paths

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June 2011

Abstract

Green innovation, which enables us to extract energy from food crops, caused a food shortage in 2008. Countries suffering severe damage started to reconsider their agricultural policy with the aim of becoming more autonomous. The food price hike of the time looks like a reversal of the celebrated Singer-Prebisch thesis proposed in the 1950s. This paper examines the consequences of this trend on the comparative advantages and development strategies of developing countries. For that purpose, first, trends and short-run fluctuations in the prices of fuel and bio-energy crops are investigated. It is shown that the price series of fuels and the crops are synchronized only after the fuel extracting technology came into effect. Second, the reversal of the Singer-Prebisch thesis is underpinned by the generic form of an endogenous growth model developed by Rebelo (1991). It is shown that as an economy grows, appreciation of the non-reproducible, such as mineral resources and raw labor, over the reproducible, such as capital goods, is the norm rather than an anomaly. Third, the consequences of the food price hike and underlying capital accumulation on the development strategies of labor-abundant and low-income countries are explored. It is concluded that the impact of the food price hikes on the alteration of a development strategy is only incremental, without reinforcement from raw-labor-saving innovation. A case study of inventions by JUKI Corporation, a world-leader in the sewing machine market exemplifies the fact that, of all the major inventions the company have made, raw-labor-saving inventions have not dominated, although JUKI's machines are sold to one

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Keywords: Bio-energy, Singer-Prebisch thesis, directed technical change, development strategy
JEL classification: O13, O33, O40, Q32, Q42

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The Rise and Fall in the Price of Food, Fuel and Manufactured Goods: Interdependency between Prices and Technology Determining Comparative Advantages and Development Paths[*]

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Abstract

Green innovation, which enables us to extract energy from food crops, caused a food shortage in 2008. Countries suffering severe damage started to reconsider their agricultural policy with the aim of becoming more autonomous. The food price hike of the time looks like a reversal of the celebrated Singer-Prebisch thesis proposed in the 1950s. This paper examines the consequences of this trend on the comparative advantages and development strategies of developing countries. For that purpose, first, trends and short-run fluctuations in the prices of fuel and bio-energy crops are investigated. It is shown that the price series of fuels and the crops are synchronized only after the fuel extracting technology came into effect. Second, the reversal of the Singer-Prebisch thesis is underpinned by the generic form of an endogenous growth model developed by Rebelo (1991). It is shown that as an economy grows, appreciation of the non-reproducible, such as mineral resources and raw labor, over the reproducible, such as capital goods, is the norm rather than an anomaly. Third, the consequences of the food price hike and underlying capital accumulation on the development strategies of labor-abundant and low-income countries are explored. It is concluded that the impact of the food price hikes on the alteration of a development strategy is only incremental, without reinforcement from raw-labor-saving innovation. A case study of inventions by JUKI Corporation, a world-leader in the sewing machine market exemplifies the fact that, of all the major inventions the company have made, raw-labor-saving inventions have not dominated, although JUKI's machines are sold to one of the most raw-labor-intensive industries.

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[*] This paper was presented at the ERIA-IDE-UNIDO Expert Group Meeting "Green Economy, Sustainable Innovation, and Structural Change: Challenges and Opportunities," in Jakarta on March 7-8, 2011.

I. Introduction

An innovation may drastically change substitutability and complementarity among commodities. The recent development of technology to extract energy from some grains and plants is one example among many. Some edible crops, such as maize, sugar and rapeseed, with ethanol being extracted from them, became good substitutes for petroleum, coal and natural gas. It is notable that the additional demand for crops for energy brought about a hike in their price in 2008, as well as a hike for other crops. Net importers of grain, such as Indonesia and the Philippines, suffered from the hike and from a shortage in their grains, and some net exporters, such as India and Vietnam, imposed export restrictions to secure sufficient food for their citizens. This is completely opposite to the situation predicted by Hans Singer and Raúl Prebisch half a century ago.

This series of changes in the prices of grain has already affected the allocation of resources to some sectors. The Philippines moved towards a reduction in their dependence on imported food and an expansion of domestic production. If similar innovations are made in the future, they will inevitably change the structure of the comparative advantage of commodities among countries, and may consequently alter the development paths of developing countries (Figure 1).

This paper aims to investigate the impact of the innovation of biomass fuel on food prices and their influence on the structure of comparative advantage and the development paths of developing countries. Firstly, co-movements of the prices of mineral commodities for energy and crops for biomass fuel are examined through time series analyses. It is found that both long-term trends and short-term fluctuation between the mineral and biomass fuels have not been significantly related until recently, while the co-movements in the last five years are remarkable.

Secondly, a celebrated growth model proposed by Rebelo (1991), which is able to explain the reversal of the Singer-Prebisch thesis, is reviewed. The model indicates that the relative price of the non-reproducible, such as natural resources and raw labor force, over the reproducible, such as manufactured goods, is destined to rise as the production of the reproducible expands. According to this model, the appreciation of food and fuel prices over manufactured goods is not a transitory movement but an underlying trend.

Thirdly, the consequences of the changes in the prices of mineral and biomass fuels are discussed. The consequences may be static or dynamic, using the terminology of economics. That is, the price changes may derive static adjustment of resource allocation by sector and dynamic evolution through innovation and factor accumulation. Thus, the green innovation enabling the transformation of crops into fuel might induce further innovation that is directed by price changes.

The rest of the paper is organized as follows. The next section shows the evolution in the prices of natural and biomass fuels, which shows a reversal of the Singer-Prebisch thesis. An endogenous growth model, which underpins the trend in relative price, is given in the third section. The static and dynamic consequences of changes in the prices of mineral and biomass fuels are discussed in the fourth section. Final remarks are given at the end.

II. The reversal of the Singer - Prebisch thesis

A brief history of the rise and fall in prices

In the 1950s, most countries were yet to completely recover from the damage of World War II and colonization. Monoculture was a typical feature of the industrial structure of developing countries. Industrialization and innovation in the world developed manufactured goods, some of which were replacing primary products. A symbolic innovation is the development of chemical products such as synthetic fibers, rubber and plastic, which substituted for natural fibers, rubber, and wooden, ceramic and metal products. Seeing this, Raúl Prebisch estimated the trend in the prices of primary commodities and manufactured goods, and released a report in 1949 which stated that there was a long-term tendency in which the price of manufactured goods would appreciate in comparison with that for primary commodities (Prebisch [1962][1]). Hans Singer interpreted Prebisch's finding, which featured the role of foreign investment and innovation in strengthening the competitiveness of manufactured goods over that of primary products (Singer [1950]). This observation has been critically examined by many researchers and dubbed the "Singer-Prebisch thesis".[2]

In the 1970s, there were two oil price hikes. The first caused the appreciation of all other primary commodities in tandem. This almost coincided with a rise in concern about environmental pollution, and the scarcity of resources became a hot topic. Since then, there have been ups and downs in

[1] The paper was originally published in Spanish in a mimeographed form in 1949. It was translated into English and published by the Economic Commission for Latin America (ECLA). This is a reprint of the paper that was published in a journal of the ECLA in 1962.

[2] Although many empirical studies have tested whether a secular downward trend in relative commodity prices is observed as predicted by the Singer-Prebisch thesis, the results so far have been mixed. For example, Grilli and Yang (1988), León and Soto (1997), Zanias (2005), and Harvey et al. (2010) provide some supporting evidence, while Cuddington and Urzua (1989), Cuddington (1992), Kellard and Wohar (2006), Cuddington et al. (2007), and Ghoshray (2010) cast doubt on the thesis. It should be noted that these studies differ in terms of their model specifications (e.g. whether they choose trend-stationary or difference-stationary containing a unit root, and whether they allow for structural breaks or not), the periods they cover, and the commodities they examine.

commodity prices. One underlying trend behind the price changes was innovation directed toward scarce resources that needed to be saved. Such demand-driven innovations continue, and the most recent and influential innovations have enabled the extraction of industrial energy from food crops, such as rapeseed, maize and sugar.

Trends and fluctuations in the relative prices of primary commodities to manufactured goods

The first focus in this paper is to look into long-term trends and short-term fluctuations in the prices of groups of commodities.

Figures 2 and 3 display time series of relative prices of energy and non-energy primary commodities to manufactured goods, respectively. The price of manufactured goods has increased almost monotonically since the 1960s. Except for the periods 1981-1985 and 1995-2002, the trend looks smooth and rises continuously. Hence, the ups and downs in the relative prices are largely due to changes in the commodity prices. Both figures show that there were hikes in price in both energy and non-energy commodities against manufactured goods in the 1970s and during the first decade of the new millennium. At the same time, downward trends are apparent in the 1980s. A stark difference is that the energy price appreciated in the late 1970s, because of the second oil crisis, while the prices of non-energy commodities remained stable.

The increase in energy prices in the last decade has been steep enough for the level to exceed the peak reached in 1980, so the overall tendency of the trend slopes upward. In other words, the trend goes against the Singer-Prebisch thesis as far as the relationship of energy to manufactured goods is concerned.

Prices of Energy and Bio-Energy Crops

It is considered that an important determinant of hikes in commodity prices is the food shortage caused by the development of technology to extract industrial energy from some food crops.[3] Rapeseed is the main biodiesel food stock in Europe while maize is the main crop for bio-ethanol in the United States (IMF [2008], p. 97). Sugar is another potential food crop supplying ethanol for industrial use. Does the evolution in the price of these crops and of traditional energy reflect this recent innovation to extract industrial energy from these crops?

[3] Mitchell (2009) claims that the most important factor behind the rapid increase in food prices between 2002 and 2008 was the increase in biofuel production in the US and EU. Baffes and Haniotis (2010) review various studies, including Mitchell (2009), and conclude that the impact of biofuel production on the recent food price hike has not been very large so far.

Time series of the prices of energy commodities and these food crops provide empirical material with which to address this question.

Figure 4 displays a time series of the natural logarithm of the prices of crude oil and natural gas. There are some interesting observations. Firstly, since the mid-1970s, the movements of the two time series have been quite similar. Secondly, from the mid-1970s onward the price of crude oil tends to lead that of natural gas. Thirdly, crude oil was more volatile in the early 1970s.

Do crude oil and natural gas synchronize because they are both energy commodities? Or, do all other primary commodities tend to co-move? The answer to the last question is no. Figure 5 demonstrates that the prices of food crops which turned out to be used for energy fluctuate distinctly from that of crude oil. But what about the long-term trend and short-term fluctuations? Once the two parts are decomposed, either one might co-move well with its counterpart, crude oil.

For the investigation of the long-term trend, co-integrating relations are estimated between crude oil and the commodities mentioned above. The baseline formula for the co-integrating relations is the following[4]:

$$\ln p_t^{Oil} = \theta \ln p_t^{Other} + \varepsilon_t. \qquad (1)$$

If the error term (ε_t) is stationary in time, the relation between $\ln p_t^{Oil}$ and $\ln p_t^{Other}$ is sustainable in the long run.

Figure 4 hints that the price of crude oil and that of natural gas share a common trend, even if each series follows a random walk. Table 1 summarizes the results of exercises to estimate the co-integration relations between the price of crude oil and those of rapeseed oil and maize for 1975-2010. Irrespective of various assumptions concerning trends and intercepts for the co-integrating relations, the hypothesis that there is a co-integrating relation between the price of crude oil and that of natural gas is accepted[5]. Moreover, the estimates of the coefficient on the logarithm of the price of natural gas (θ) are all close to unity with small standard errors. These observations imply that natural gas has been a good substitute for petroleum since the mid-1970s.

The same estimation exercise indicates that there was no stationary linear relation between the price of crude oil and the prices of either rapeseed oil or maize (Table 1). This observation suggests that

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[4] As for the variation in assumptions on intercepts and time trends, see the footnote to Table 1.
[5] One reservation is that once the period is extended towards 1960, any co-integrating relations are not detected with the same set of exercises. Natural gas does not seem to have been an effective substitute for crude oil before the mid-1970s.

from a long-term perspective, rapeseed oil and maize have not been good substitutes for petroleum, in contrast to natural gas.

In the meantime, the short-term fluctuation in prices might be different. In order to examine short-term co-movement among the prices, Hodrick-Prescott (H-P) filtered series are scrutinized. The H-P filter is an operator for a time series to single out cycles at frequencies of eight years or higher. Cycles incorporated in a time series at frequencies lower than eight years are counted as "a long-term (non-linear and linear) trend" which remains after the H-P filter is applied[6].

H-P filtered log prices of crude oil and natural gas are shown in Figure 6. Generally speaking, the H-P filtered price of natural gas mimics that of crude oil well. The price of crude oil tends to lead that of natural gas and its variation is more amplified than its counterpart for the 1960s-90s.

H-P filtered prices of rapeseed oil and maize behave in totally different ways. Until very recently, the short-term fluctuation in the price of rapeseed oil is almost the opposite of that of its counterpart for crude oil. On the other hand, for 2007-10 these almost coincide (Figure 7). Similarly, the price of maize has followed that of crude oil only faintly until 2006, while the co-movements of the two for 2007-09 are impressive. This sudden change in the co-movements in price among crude oil, rapeseed oil and maize appears to reflect the innovation making rapeseed oil and maize effective substitutes as sources of energy.

The Relative Price of Energy to Capital Goods

A critical issue is whether this appreciation in fuels and food crops is a transitory or fundamental trend. A growth model that sheds light on this aspect will be introduced in the next section. Here we make some statistical observations, which will be incorporated in the model.

An important observation is that the relative price of capital goods to both energy and consumption goods has steadily declined since the end of World War II. The relative price of capital goods to energy gradually increased in the inter-war period and it exhibits a remarkable decline in the latter half of the century (Figure 9). This post-war decline in the relative price of capital goods to energy

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[6] More precisely, the H-P filter is an application of the following optimization problem to attain a non-linear trend:

$$\mathrm{Min.}_{\{y_t^g\}_{t=1}^T} \sum_{t=1}^{T} \left(y_t - y_t^g\right)^2 + \lambda \sum_{t=1}^{T-1} \left[\left(y_{t+1}^g - y_t^g\right) - \left(y_t^g - y_{t-1}^g\right)\right]^2,$$

where y_t^g and y_t^c denote long-term trends and short-term fluctuations, respectively, and $y_t = y_t^g + y_t^c$. The first term dictates a linear regression while the second term exhibits a smoothing trend. λ works as a weight balancing the two terms. Conventionally, 100 is assigned to λ for an annual series. See Hodrick and Prescott (1997), Cooley and Prescott (1995, pp. 27-29) and Stock and Watson (1999, pp. 10-14), among others.

cannot be completely attributed to continuous increases in the price of energy as shown in Figure 2, because the price of capital goods declined against consumption goods, too[7] (Figure 10). This tendency of a decline in the price of capital goods and a rise in the price of energy is explained in conjunction with Sergio Rebelo's AK model of economic growth, which is elaborated in the next section.

III. A growth model underpinning the reversal of the Singer-Prebisch thesis

A continuous rise in the price of energy and a relative decline in the price of capital goods may be consistent outcomes of the reasonable mechanism of economic growth that was depicted in a seminal paper, Rebelo (1991), known as the *AK* model in the literature of endogenous growth. The two-sector version of the *AK* model is elaborated in the paper, which is characterized by a decline in the relative price of a commodity produced with a constant-returns-to-scale technology in reproducible inputs and a rise in the relative price of non-reproducible goods and a commodity produced with diminishing-returns-to-scale technology in reproducible inputs[8]. These features are harmonious with the observations demonstrated in the previous section.

The model works as follows. There is a capital good produced with a constant returns-to-scale technology:

$$I_t = AZ_t(1 - \phi_t), \tag{2}$$

where I_t, Z_t, and A are the amounts of investment and capital stock, and the productivity parameter, respectively. Z_t is assumed to be used to produce both investment goods and consumption goods. ϕ_t denotes the percentage share of capital stock used to produce consumption goods, so that the rest, $(1 - \phi_t)$, is to be used to produce investment goods.

Capital is accumulated from investment with depreciation at the rate of δ:

$$\dot{Z}_t = I_t - \delta Z_t. \tag{3}$$

A key assumption is that consumption goods are produced with a constant-returns-to-scale

[7] The decline in the relative price of capital in the post-war period motivated research on capital-skill complementarity and directed technical change. See Hornstein et al. (2005, pp. 1308-1311) as an example.
[8] This technology may be constant-returns-to-scale in all inputs, including both the reproducible and the non-reproducible.

technology in capital stock and non-reproducible inputs, T. In other words, the technology is diminishing-returns-to-scale in reproducible inputs:

$$C_t = B(\phi_t Z_t)^{\alpha} T^{1-\alpha}, \tag{4}$$

where $0 < \alpha < 1$. Typical non-reproducible inputs are labor and land.

Assuming a time-additively separable utility function, $U = \int_0^{\infty} e^{-\rho t} \frac{C_t^{1-\sigma}}{1-\sigma} dt$, where ρ and σ are parameters signifying time preference and relative risk aversion, respectively, a rational consumer allocates resources so that the growth rate of consumption, g_{ct}, is equal to $\frac{r_t-\rho}{\sigma}$, where r_t is the interest rate in consumption goods. National income is formulated as $Y_t = C_t + p_t I_t = r_t p_t Z_t + w_t T$, where p_t is the relative price of capital goods to consumption goods and w_t is the factor price of the non-reproducible. Note that the relative price of capital goods to the non-reproducible is p_t/w_t.

In an equilibrium, the value of the marginal product of capital is equalized between the production of investment goods and consumption goods through the free movement of capital. Therefore, by differentiating the right hand sides of eqs. (2) and (4), the following static equilibrium condition is attained:

$$p_t A = \alpha B(\phi_t Z_t)^{\alpha-1} T^{1-\alpha}. \tag{5}$$

The market equilibrium growth[9] of this economy is characterized by the following relations:

$$g_p = (\alpha - 1) g_z, \tag{6}$$
$$g_c = g_w = \alpha g_z = g_p + g_z. \tag{7}$$

That is, capital goods grow by g_z which is faster than the rate of growth for consumption goods $g_c(= \alpha g_z)$. The relative price of capital to consumption goods declines by $(\alpha - 1)g_z$, and the relative price of capital to non-reproducible inputs decreases even faster, by $-g_z$.[10]

As a matter of fact, what determines the growth rate in this model is not the function of a commodity, such as investment and consumption, but whether the technology is

[9] Note that there is a steady state equilibrium in this economy and that without transition the steady state equilibrium is achieved.

[10] $g_{p/w} = g_p - g_w = -g_z$.

constant-returns-to-scale in reproducible inputs or diminishing-returns-to-scale. However, the fundamental mechanism behind the economic growth is that the output of a commodity grows more slowly if its price rises more quickly. Put differently, the price adjusts to quantitative changes so that a stable industrial structure and expenditure composition are maintained in the long run.

A consequence of this economic mechanism is that in a growing economy the reproducible grow while the non-reproducible do not (by construction). Offsetting this set of evolutions, the relative price of the reproducible to the non-reproducible declines. Moreover, if the reproducible are heterogeneous, those growing faster depreciate in terms of price over the rest. Thus, the relative price of capital goods to the non-reproducible declines faster than that between capital goods and consumption goods.

This is exactly what appears to have happened with the U.S. data for the post-war period, see Figures 9 and 10. If the above-mentioned mechanism lies behind the figures, the reversal of the Singer-Prebisch thesis is not temporary but deep-seated. This possibility must be taken seriously.

IV. Impacts on Comparative Advantages and Development Paths

Reproducible and non-reproducible factors

Suppose Rebelo's model underpins the evolution in the prices of commodities observed in section II. Then, how is the structure of comparative advantages and the development paths of low-income countries affected? In order to address this question, let us apply Rebelo's general model for the real economy of a low-income country. Table 2 summarizes the characteristics of factors of production that are available in low-income countries. The factors studied in section II were energy and capital goods, the former are non-reproducible while the latter are reproducible. The conventional concept of labor can be divided into "raw labor" and "skill". The former is nothing but man-hours devoted to production, so this is non-reproducible and its growth is bounded by the growth rate of the population. "Skill" represents all qualitative factors enhancing the human contribution to production, including physical skills, techniques, knowledge, know-how, even discipline and attitude. This portion of human inputs may be reproducible through education, training, learning-by-doing and scientific research, and can, in theory, grow unboundedly. Finally, land is another non-reproducible and bounded factor.

According to Rebelo's model, the relative price of the reproducible to the non-reproducible is likely to decline in the long run. The direction of change in the relative price among reproducible factors depends on the intrinsic potential for the growth of the commodity as reflected by its marginal productivity with respect to a composite of reproducible factors (Table 2).

Static and dynamic substitutability among factors

The evolution of relative prices in Table 2 has important implications for the structure of comparative advantages and the development paths of low-income countries. First, countries with mineral and biomass energy will heighten their degree of specialization in energy production. Second, other non-reproducible inputs, such as raw labor and land, become scarcer, so labor (land) abundant countries may derive an advantage from specializing in labor (land) intensive industries. Generally, developed countries own reproducible inputs due to their greater accumulation of physical and human capital. Thus, the original structure of comparative advantages might be strengthened by economic growth of Rebelo's type.[11]

However, this is not the end of the story. What also matters is substitutability among factors. If the substitutability between a non-reproducible factor (e.g. raw labor) and a reproducible factor (e.g. capital goods) is high, then, as the reproducible factor is reproduced and accumulates, the scarcity of the non-reproducible factor is attenuated. More simply, if there are cheap machines which are good substitutes for raw labor, the abundance of raw-labor is no longer a source of comparative advantage.

Substitutability between factors is generated dynamically, too. In particular, the evolution of relative prices among factors induces innovation in order to save factors that can demand a higher price. This is dubbed "induced innovation" or "directed technical change".[12] It is well-known that the energy price hikes in the 1970s were followed by energy-saving technical progress. Thus, demand-driven innovation may play an important role in changing the structure of comparative advantages. This is missing in Rebelo's model, where the elasticity of substitution is assumed to be constant.

Once the possibility of static and dynamic substitution between factors is taken into account, our perspective on the evolution of comparative advantages and development paths is modified. In

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[11] In fact, the authors find that some labor-abundant and low-income countries, such as Bangladesh and Cambodia, succeeded in nurturing the garment industry, a typical labor-intensive industry, and in raising wages in a sporadic manner. See Asuyama et al. (2010), Bakht et al. (2009), Fukunishi et al. (2006), and Yamagata (2006, 2009).

[12] This idea was already mentioned in Hicks (1932), and was examined either theoretically or empirically by the early "induced innovation" literature (e.g. Habbakuk, 1962; Kennedy, 1964; Samuelson, 1965; and Hayami and Ruttan, 1970). More recently, Acemoglu (2002) constructed a more sophisticated theoretical model that explains the "directed technical change" mechanism. Regarding the impact of energy prices on innovation, Newell et al. (1999) and Popp (2002) found positive associations between energy prices and energy-saving innovation. See Acemoglu (2009, chapter 15) for a survey.

addition to the endowment of non-reproducible factors, the directions and degree of innovation to make a reproducible factor more substitutable for a non-reproducible factor matter, too. For example, the accumulation of reproducible factors, which is nothing but capital accumulation, raises the capital to labor ratio and the relative wage in terms of capital (see Table 3). That is, the price of raw labor appreciates over that for capital goods. This change may induce efforts to invent new machines as a substitute for raw labor. If this is successful, the advantage that lies in abundant labor is diluted because of the proliferation of new machines. If this momentum is great enough, the Hecksher-Ohlin-like choice of strategic industries does not make sense anymore because innovation completely reorganizes the structure of any comparative advantage based on factor endowment.

Case study: Various types of inventions for the sewing machine

Is on-going innovation strong enough to nullify the static structure of comparative advantages? To address this question, the authors take a core production process in a typical labor-intensive industry for a case study. This is the sewing process in the apparel industry. Obviously, the main device used in the sewing process at present is the sewing machine. A leading firm supplying sewing machines all over the world is JUKI Corporation, a Japanese firm which was founded in 1938. Major inventions in the sewing machines made by JUKI Corporation are summarized in Table 4.

An interesting observation found in Table 4 is that there are as many skill-saving (denoted by SS) inventions as raw-labor saving inventions (RT, RW) for the sewing machine during this firm's life. This observation probably reflects the fact that skilled workers are not abundant in the countries to which JUKI exports its machines. Therefore, inventions that save skilled workers make sense.

In a nutshell, raw-labor saving inventions are not dominant enough to overturn the structure of comparative advantage based on factor endowment.

V. Concluding remarks

Has green innovation which enables the extraction of fuel from food crops dramatically changed the incentive structure for factors of production in the recent past? Is the rise in the prices of food and energy transitory, or is it based on fundamentals? If the latter is true, how does it affect the structure of comparative advantages and the development paths of low-income countries? These are three questions posed in this paper. Each of the above questions was assigned a different section (sections II-IV in order).

The answer to the first question is yes. This is obvious from the fact that the green innovation caused food shortages for some time period. The answer to the second question is based on the simple two-sector growth model formulated by Rebelo (1991). As long as reproducible commodities are reproduced steadily, the relative price of the non-reproducible rises to balance industrial structure and to maintain an equilibrium. From this viewpoint, the reversal of the Singer-Prebisch thesis is not an anomaly but the norm.

Finally, faced with a dramatic rise in food prices, while moderately labor-abundant countries have turned their resources to food production, extremely labor-abundant countries have taken over the released demand for labor-intensive products from moderately labor-abundant countries. Therefore, the modification of the development strategy for highly labor-abundant countries is incremental. In reality, however, there is another underlying force, innovation, which creates new productive inputs that substitute for other factors of production. If many sorts of new machines are invented and effectively substitute for raw labor, then the ground for comparative advantage in raw-labor intensive industries will be further diminished. The case study of the inventions in sewing machines for the garment industry shows that the actual direction of inventions is not monotonic because multiple factors of production (in particular, skilled and low-skilled workers, and various types of machines and equipment) are all involved in a factory.

Market forces raise the value of the non-reproducible, i.e. natural resources and raw-labor, evenly, as the reproducible accumulate. Green innovations may play a role in reorganizing the structure of comparative advantages. However, not many inventions seem to be great enough for a low-income country to switch their development strategy.

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Table 1. Number of Co-integrating Relations between the Price of Crude Oil and that of Other Fuels (1975-2010)

Model	1	2	3	4	5
Trend in Original Series	No	No	Linear	Linear	Quadratic
Intercepts in C. E.	No	Yes	Yes	Yes	Yes
Trends in C. E.	No	No	No	Yes	Yes
Natural Gas					
Trace Test	1	1	1	1	1
Maximum Eigenvalue Test	1	1	1	1	1
Coefficient: θ	0.992	1.130	1.130	1.155	1.155
Standard error	0.006	0.038	0.038	0.050	0.050
Rapeseed Oil					
Trace Test	0	0	0	0	0
Maximum Eigenvalue Test	0	0	0	0	0
Coefficient: θ	0.894	1.926	1.926	2.387	2.365
Standard error	0.030	0.314	0.320	0.423	0.429
Maize					
Trace Test	0	0	1	0	0
Maximum Eigenvalue Test	0	0	1	0	0
Coefficient: θ	0.966	4.485	4.466	4.172	4.191
Standard error	0.046	0.941	0.952	0.889	0.907

Notes: C. E. stands for "cointegrating equation". A cointegrating equation is formulated as a linear combination of the logged price of crude oil and that of the price of its counterpart commodity, plus intercepts and trends, if any. The cointegrating vector, $\beta^{'} = (1 \quad -\theta)$, forms a linear combination as $\beta^{'} y_{t-1} = (1 \quad -\theta)\begin{pmatrix} \ln p_{t-1}^{Oil} \\ \ln p_{t-1}^{Other} \end{pmatrix}$. The Trace Test and Maximum Eigenvalue Test provide the number of cointegrating relations, of which the maximum is the number of the original series, which is two in this case. The models #1-#5 are as follows:

Model 1: $\Pi y_{t-1} = \alpha\beta' y_{t-1}$

Model 2: $\Pi y_{t-1} = \alpha(\beta' y_{t-1} + \rho_0)$

Model 3: $\Pi y_{t-1} = \alpha(\beta' y_{t-1} + \rho_0) + \alpha^{inv}\gamma_0$

Model 4: $\Pi y_{t-1} = \alpha(\beta' y_{t-1} + \rho_0 + \rho_1 t) + \alpha^{inv}\gamma_0$

Model 5: $\Pi y_{t-1} = \alpha(\beta' y_{t-1} + \rho_0 + \rho_1 t) + \alpha^{inv}(\gamma_0 + \gamma_1 t)$

The vector representation is $\Delta y_t = \Pi y_{t-1} + \Gamma\Delta y_{t-1} + \epsilon_t$, and a one year lag is assumed for the log difference term.

Table 2. Differences in Characteristics by Factor

	Energy	Capital goods	Raw labor (Man-hour)	Skill	Land (Area)
Reproducibility / Unbounded growth	No	Yes	No	Yes	No
Relative price to capital goods	Rise	-	Rise	?	Rise

Table 3.
Events Encountered by Labor Abundant and Low-Income Countries and Their Consequences

	Bio-fuel Development	Capital Accumulation
Underlying Event	Green innovation enabling the extraction of fuel from crops	Accumulation of reproducible factors
Initial impact	Rise in the price of land	Rise in the capital to labor ratio
Repercussion on the Relative Price of Raw Labor	Decline in the relative price of raw labor to land	Rise in the relative price of raw labor to capital goods
Secondary impact	-	Directed technical change to save raw labor
Comparative Advantage in Labor-intensive Industries	Dichotomized Lost: moderately labor-abundant countries Kept: highly labor-abundant countries	Weakened
Recommended Development Strategy	Conventional market-oriented (endowment-based) strategy	(no guideline)

Table 4. Major inventions on the sewing machine made by JUKI Corporation

Machine type	Technology	Year of introduction	Details of technology	Major expected effects
Lockstitch sewing machines and sewing machines in general	One-needle, straight stitch	1953	The most standard sewing machine which stitches straight seams by lockstitch.	SS, RT, QC
	Automatic thread trimmer	1969	Automatically cuts thread at the end of a sewing cycle.	RT
	Bottom and variable top-feed	1979	Responds flexibly to various kinds of material. Ensures sewing with higher precision and quality by separating the bottom of the adjusting feed mechanism from the top.	SS, QC
	Bird's nest prevention	1992	Prevents "bird's nests" (thread tangling up on the underside of the material at the beginning of sewing) by keeping the needle thread clamped.	QC
	Bobbin thread automatic feeder	1996	Changes the bobbin thread automatically.	RT
	Dry-head	1996	Eliminates oil stains from the frame by reducing the amount of oil needed. This reduces the work involved in removing the stain and re-stitching.	RT, QC
	Direct-drive motor	1999	Saves electricity and mitigates operator fatigue by reducing vibration and noise.	RE, ENV
	High sewing speed	-	Increases the speed of stitching. The maximum stitching speed is 8,500 rotations per minute, which is even faster than that of a sports car's engine (JUKI's website).	RT
	White machine surface	-	Makes the surface of the sewing machine white, and thus improves the brightness of the needle drop point. This is better for operators' eyes.	ENV
Special sewing machines	Bartack	1958	A sewing machine which makes special stitches that prevent open seams in areas such as pocket openings.	SS, RT, QC
	Buttonholing	1961	A sewing machine which stitches buttonholes.	SS, RT, QC
	Chainstitch, button sewing	1962	A sewing machine which stitches a button using a chain stitch.	SS, RT, QC
	Overlock	1964	A sewing machine which stitches the edges of material so that they do not fray.	SS, RT, QC
	Lockstitch, button sewing	1979	A sewing machine which stitches a button using a lockstitch, which is superior to a chain stitch in terms of preventing raveling.	SS, RT, QC
	Computer-controlled buttonholing	1999	By making buttonholing computer-controlled, less time is needed for making changes to the specifications.	SS, RT, QC
Automatic machines	Buttonholing indexer	1968	A machine which feeds materials (e.g. fabrics) automatically and executes multiple buttonholes successively. Many machines can be operated by a single operator.	SS, RW, RT, QC
	Automatic serging machine	1973	A machine which automatically cuts the edges of the material and sews them so that they do not fray. A sensor prevents any mistakes in cutting.	SS, RW, RT, QC, RWT
	Edge control seamer	1976	A machine which enables the accurate joining of materials, which was done by a skilled operator, and sews them automatically.	SS, RW, RT, QC
	Automatic welting machine (automatic pocket sewing)	1979	A machine which automatically sews pockets with welts and flaps on suits, jackets and pants.	SS, RW, RT, QC
	Automatic pocket setter	1991	A machine which automates a series of pocket-attaching processes, including folding, sewing, and bartacking a pocket's openings.	SS, RW, RT, QC
	Computer-controlled operation panel	-	Reduces the time for specification changes through a panel that is easy to operate.	SS, RW, RT
Attachments (e.g. folder, hemmer, binder, needle plate, feed dog, presser feet)		-	A folder, hemmer, and binder replace manual tasks such as folding or binding fabrics. A gauge set including a needle plate, feed dog, and presser feet, helps operators sew smoothly and accurately.	SS, RW, RT, QC

Notes: Year of introduction indicates when JUKI introduced the model with the technology cited onto the market. The major expected effects are SS: substitution of skilled labor with a "machine + unskilled labor"; RW: reduction of the number of workers necessary for the production process; RT: reduction in processing time; QC: quality stabilization and improvement; RWT: reduction in waste; ENV: improvement in the working environment; and RE: reduction in the amount of electricity used.

Source: Asuyama (2009). Compiled from JUKI (2008), JUKI's website, Ishikawa (1994), and Yasuda (2004).

Figure 1. Motivation

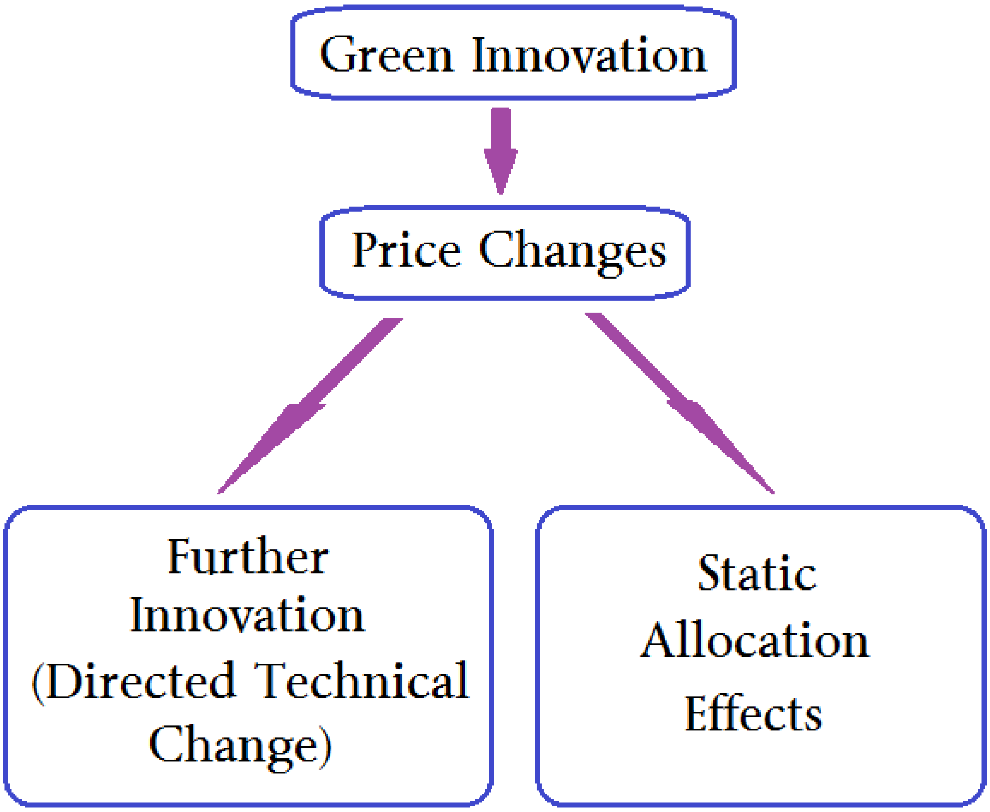
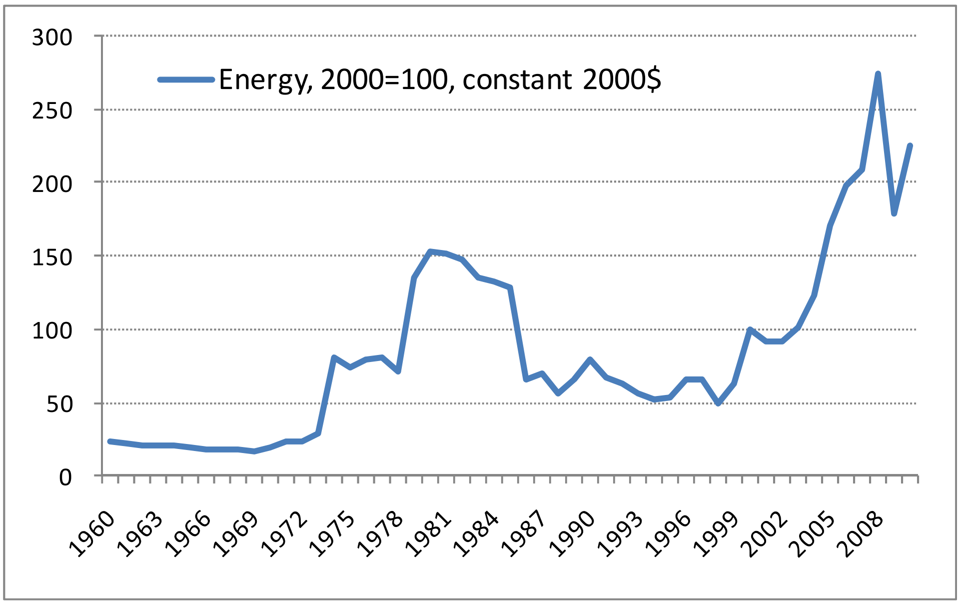
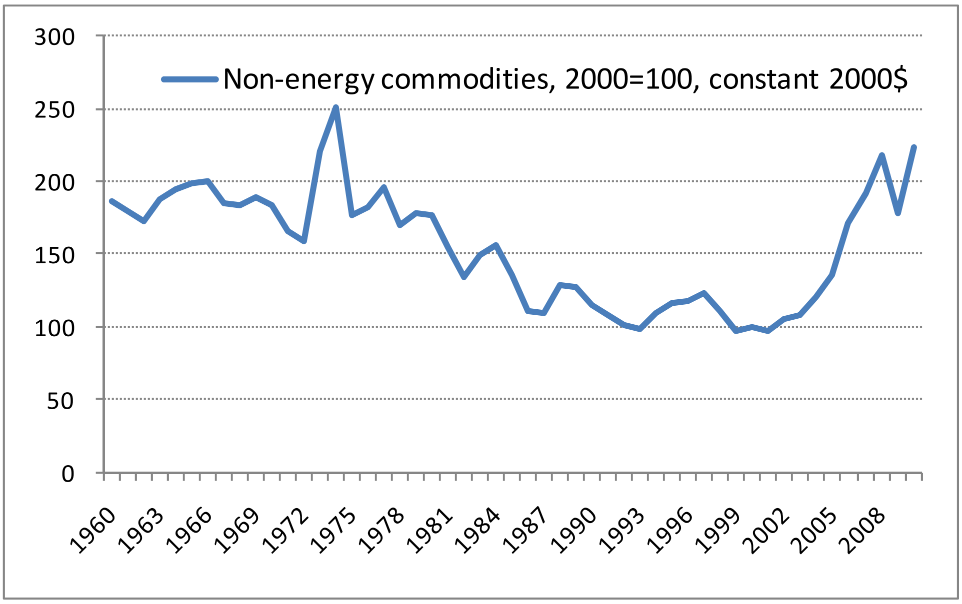


Figure 2. The Relative Price of Energy to Manufactured Goods



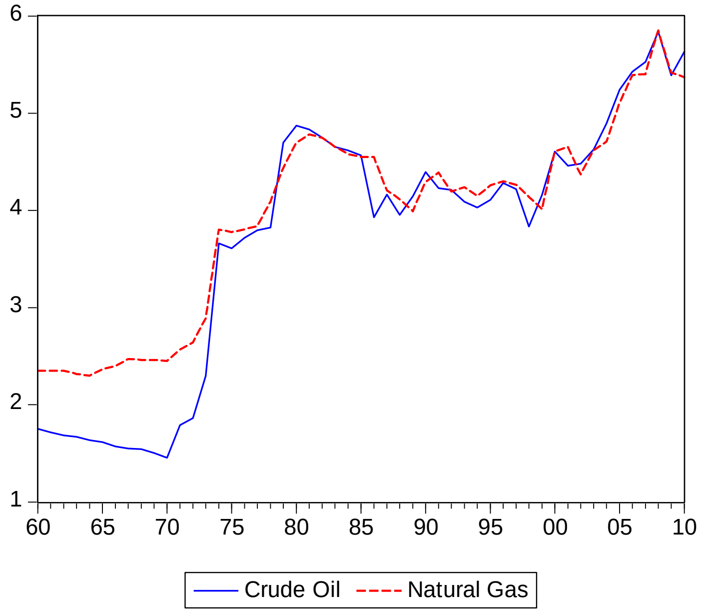
Source: World Bank, Global Economic Monitor database (accessed on Jan. 13, 2011).
Note: The numeraire indicator is the Manufacture's Unit Value Index.

Figure 3. The Relative Price of Non-Energy Primary Commodities to Manufactured Goods



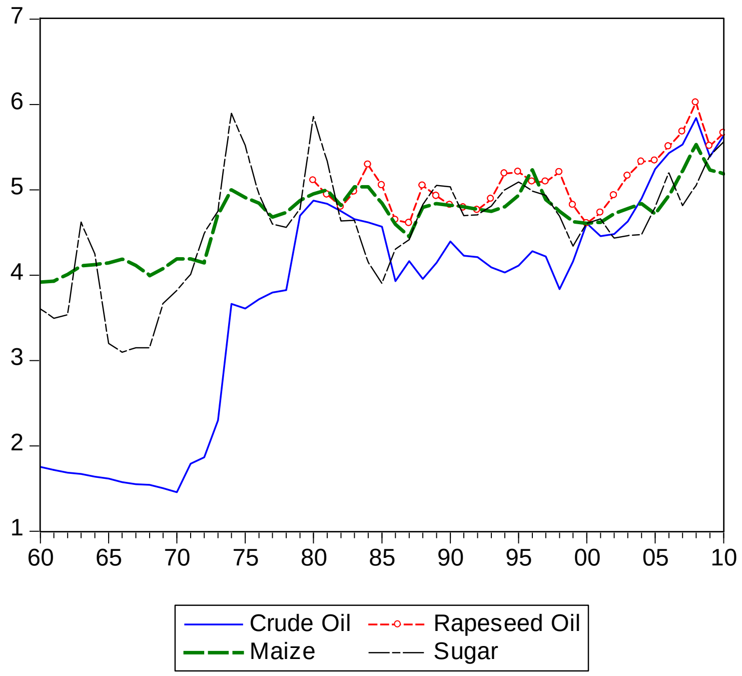
Source: The same as Figure 2.
Note: The same as Figure 2.

Figure 4. Prices of Crude Oil and Natural Gas (logarithm)



Source: World Bank, Global Economic Monitor database.
Note: Both series are indices set at 100 in the year 2000.

Figure 5. Prices of Crude Oil, Rapeseed Oil, Maize and Sugar (logarithm)



Source: World Bank, Global Economic Monitor database. IMF, Primary Commodity Prices.
Note: The same as Figure 4.

Figure 6. H-P Filtered Fluctuation in the Log Prices of Crude Oil and Natural Gas

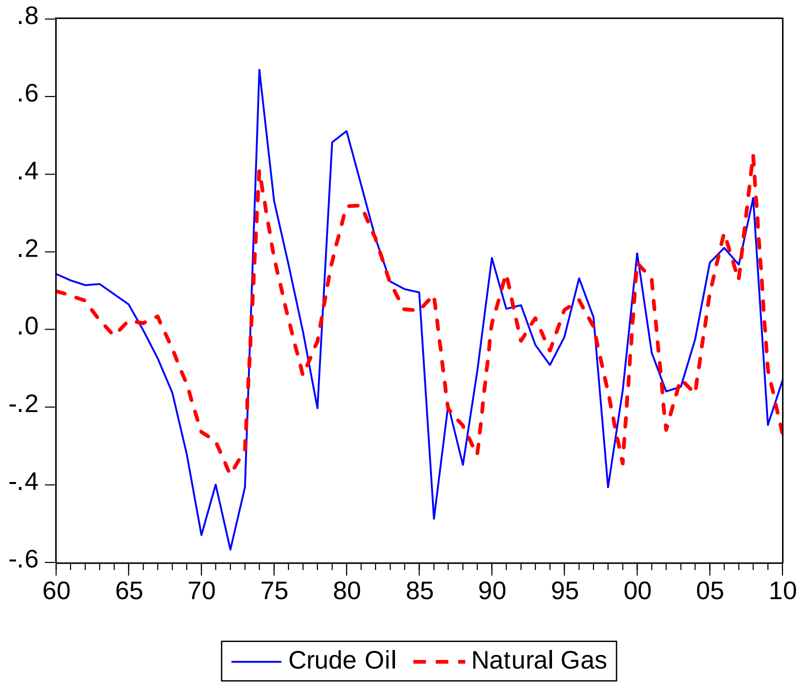


Figure 7. H-P Filtered Fluctuation in the Log Prices of Crude Oil and Rapeseed Oil

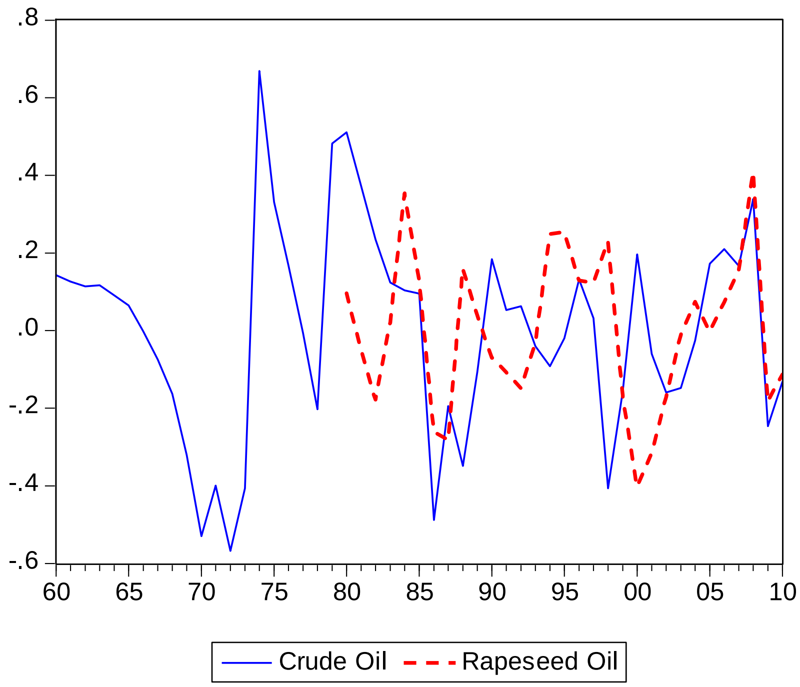


Figure 8. H-P Filtered Fluctuation in the Log Prices of Crude Oil and Maize

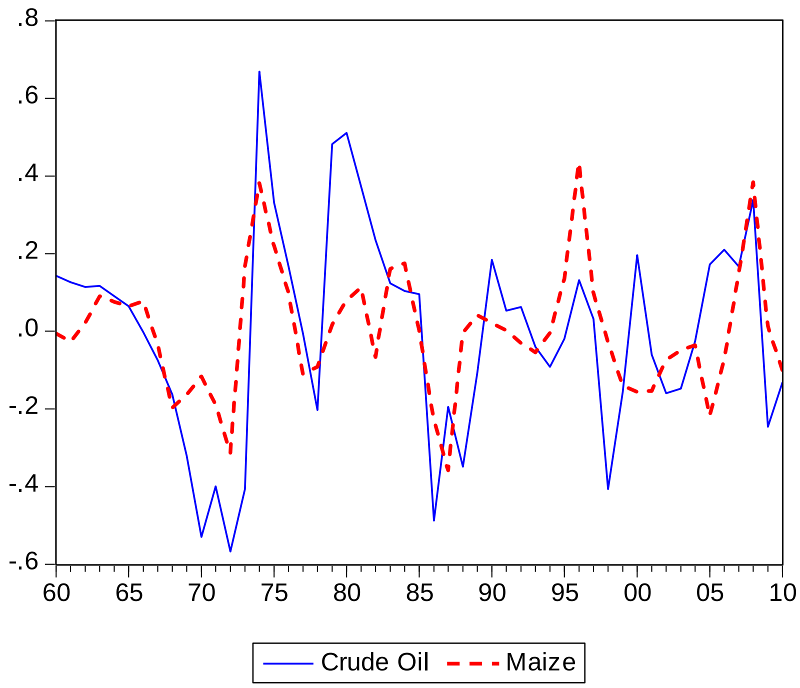
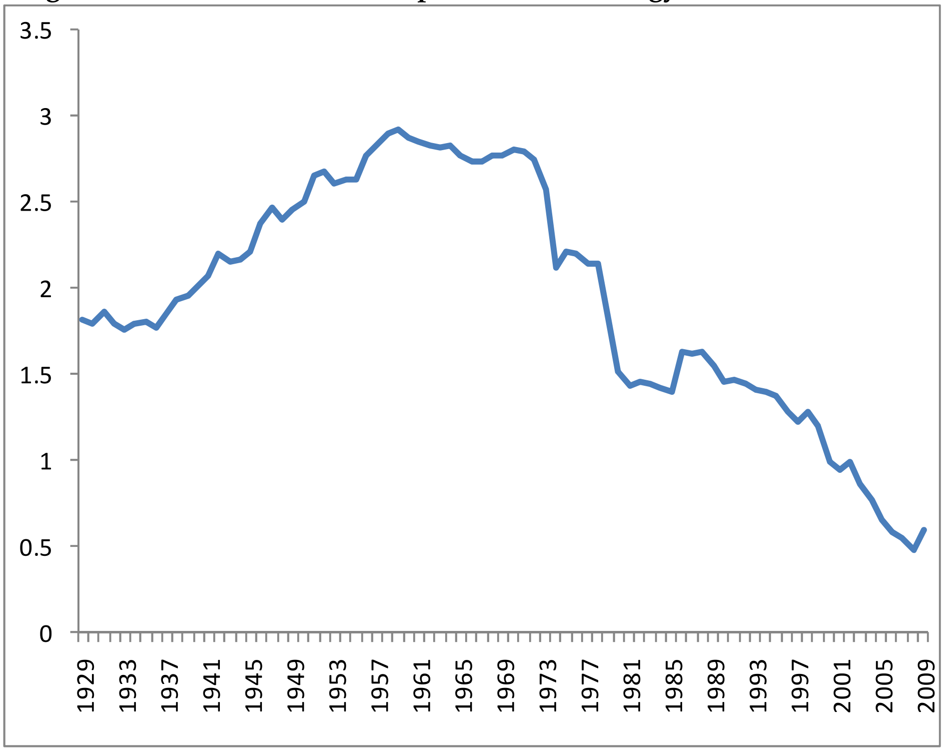
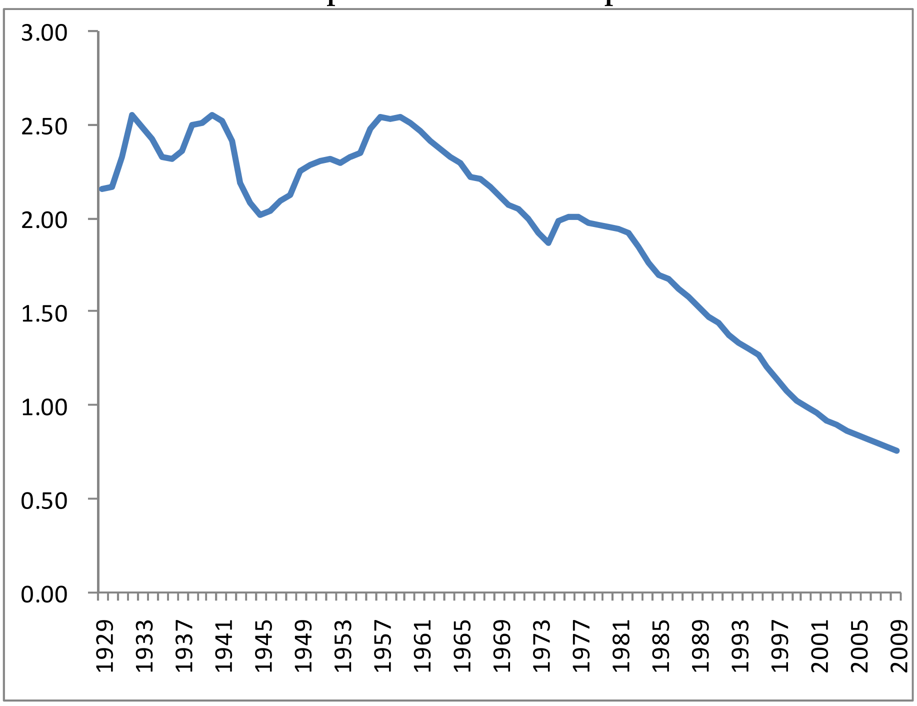


Figure 9. The Relative Price of Capital Goods to Energy in the United States



Source: Bureau of Economic Analysis, United States, NIPA tables (http://www.bea.gov/national/nipaweb /SelectTable.asp?Selected=N).

Figure 10. The Relative Price of Capital Goods to Consumption Goods in the United States



Source: The same as Figure 9.