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Dynamics of Structural Transformation

An Empirical Characterization in the Case of China, Malaysia, and Ghana

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ABSTRACT

The paper develops a metric of structural transformation that can account for the production of new varieties of goods embodying advancements in technological know-how and design. Our measure captures the dynamics of an economy's transformation and can be viewed as an extension of Hausmann and Klinger's static measure. We apply our measure to four-digit-level SITC trade data of China, Malaysia, and Ghana over the period 1962–2000. The results show that two important factors characterize the rapid transformation of the Chinese economy: the high proximity of its export basket to three main industrial clusters—capital goods, consumer durable goods, and intermediate inputs—and the increase in the values of the new goods belonging to those three clusters. Malaysia exhibits a similar but more modest pattern. In contrast, the structure of the Ghanaian economy appears unchanged over the entire 1962–2000 period. That economy is dominated by primary goods clusters, and the values of the goods in those clusters have remained relatively low. We also discuss qualitatively the role of policies and institutions in spurring transformation in the three countries.

Keywords: **structural transformation, discovery, technological change**

JEL Codes: F19, O14, O33, O40

1. INTRODUCTION

Wealthy countries are not only recognized for producing more output per worker than poor countries, they also produce a larger number of evolving varieties of more complex products associated with higher unit value. Such products embody varieties of intermediate factors that entail advances in technological know-how and design to meet the changing wants of own households as well as those around the world. This evolutionary process characterizes a structural transformation within and across industrial sectors. Determinants of this transformation process have received increasing attention in recent years. Hausmann, Hwang, and Rodrik (2005), for example, observed that the types of goods a country produces and exports affect its long-run economic performance. Building on that work, Hausmann and Klinger (HK) (2006) focus on the determinants of structural transformation as a process in which developing countries approach those with advanced technologies and economic structures. They find the rate of structural transformation relates to the proximity of new goods to the ones a country is currently producing and the values of the new goods. The slow change in structure experienced by many lower-income countries can be explained by the specificity of their skills and assets to certain types of goods that do not facilitate the transformation toward more complex industrial products.

While HK's study provides new insights for understanding differences observed in the evolution of industry and the determinants of such differences, some important issues remain unaddressed. First, the HK study does not provide a measure of the dynamic performance of industrial clusters within individual countries. Without such information, it is difficult to inform the policy process of the experience of successful countries. Second, although HK conduct a country-specific analysis of proximity for selected developing countries, they do so only by applying the data of a single year. A single-year analysis is static and unlikely to address many important dynamic questions. These include: What are the features over time of structural transformation of those developing countries that have increased substantially their proximity to upscale or more complex products? Why have some developing countries successfully moved to produce upscale or more complex products while others continue to produce the same low-value goods year after year? Is the industrial transformation in a country an automatic process resulting from the accumulation of fundamentals or an outcome of more pragmatic policy and institutional reforms?

This paper extends the HK study and fills the aforementioned gaps by adapting HK's methodology to analyze the dynamics of structural transformation of selected countries in the context of the evolution of world trade. We use the same data set as HK, World Trade Flows from Feenstra et al. (2005), and focus on three of six countries in the HK study—China, Malaysia, and Ghana. To complement the empirical analysis, we also discuss the role of policies and institutions that appear to have spurred the transformation in the three countries.

HK measure the distance or proximity of a country's export basket to a particular good. To study the dynamics of structural transformation, we instead calculate the distance between a country's current export basket and a group of goods a country is not producing. We call this new measure the *density gravity center*. Using this measure, we find that the change in Chinese industrial structure over 1962–2000 is the result of two important factors: the high proximity of the country's export basket to three industrial clusters—capital goods, consumer durable goods, and intermediate inputs—and the high values of the new goods in these three industrial clusters. This suggests that these clusters contain goods that are relatively sophisticated or complex. A similar transformation pattern is found in Malaysia but of a relatively more modest magnitude compared with China.

Ghana stands out. Its export structure appears to be unchanged over the 39-year period (i.e., 1962–2000). Not only are this country's exports continuously dominated by non-energy primary goods, a less sophisticated industrial cluster, but also the values of individual products in this cluster have remained low. In the qualitative discussion section we further find that although the evolution of China's institutions is seen to be out of alignment with the Washington Consensus (Rodrik 2006a), its rapid transformation appears to have benefited from openness to multinational enterprises, the relatively large scale of its economy, the abundant endowment and low cost of labor, and the supply of relatively low-cost materials as intermediate inputs. The institutions developed in Malaysia inherit the features of that country's former colonial partner that facilitated its transformation much earlier than China. As a result, Malaysian industry has advanced and continues to evolve. However, initial conditions as well as structural factors have allowed China to outperform Malaysia in the transformation process. Policies and other barriers appear to have prevented an industrial transformation of the Ghanaian economy.

The forces of structural transformation are broadly discussed in the literature, including the centrality of research and development (R&D) in driving innovation and the role of policies and institutions in this process. R&D is viewed as facilitating the acquisition of the technological know-how needed to upgrade the quality of industrial products (Stokey 1988; Grossman 1989; Segerstrom, Anant, and Dinopoulos 1990; Grossman and Helpman 1989c, 1990a, 1991; Aghion and Howitt 1992), the development of new industrial products (Romer 1990; Grossman and Helpman 1989a, 1989b, 1989d, 1990a, 1990b), and/or the reduction in the cost of production (Corriveau 1988). Innovation is the result of actions taken by firms in response to market incentives that in turn are dependent upon a well-functioning market environment supported by the government. This implies that the pace of innovation is likely to be higher where policies and institutions are well designed to induce knowledge discovery. Many of these studies also provide insights into mechanisms through which poor countries can achieve a more rapid structural transformation. Openness to trade provides opportunities for domestic firms to exploit the discoveries in advanced countries. Also, a good policy environment creates conditions for domestic firms to become multinational, which allows them to take advantage of abundant and low-cost resources in other parts of the world, extend the scale of their enterprise to larger markets, and further facilitates the transfer and absorption of more advanced foreign technology.

The rest of paper is organized as follows. Section 2 revisits and summarizes the findings of the HK study. Section 3 extends the HK method by developing a new measure, the density gravity center, and applies that measure to analyze the dynamics of structural transformation of the same three countries—China, Malaysia, and Ghana— studied by HK so that we may compare the results and insights of our approach with theirs. Section 4 investigates the determinants of the dynamics of structural transformation in those countries. Section 5 discusses the role of policies and institutions in the determination of structural transformation in those countries. Section 6 concludes.

2. STRUCTURAL TRANSFORMATION AND PATTERNS OF COMPARATIVE ADVANTAGES IN THE PRODUCT SPACE—HK STUDY

The HK paper develops the concept of product space and uses it to investigate the process of structural transformation and its determinants. According to HK, the assets used in the production of currently existing goods in a country can be adapted to produce new goods. The adaptation capacity of that country depends on how close the technologies employed to produce goods in a specific period are to the technologies used to produce new goods and whether the new goods are upscale, or of higher value.

The theoretical model underpinning HK's empirical analysis is a two-period overlapping generation model of firms with each producing in each period one unit of either the existing/standard good (good 1) or the new good (good 2). The new good is more attractive since it bears a higher price compared with the standard good, that is, $P2 > P1$. It is also associated with a fixed cost C. This cost increases with the distance between the standard and new goods by the parameter δ_{12}. A positive externality exists for subsequent firms (entrants) because they do not incur the fixed cost C. Such externalities in adapting capabilities are the force that drives innovation in this model.

The empirical assessment of the HK model is achieved using the World Trade Flows data from Feenstra et al. (2005) covering the period 1962–2000. HK first construct a matrix of proximity of pairs of goods in each period, where the proximity (inverse of distance) measure is approximated by the conditional probability between two goods.[1] The proximity between two goods (say i and j) at time t is given by

$$\varphi_{i,j,t} = \min\left\lfloor P\left(x_{i,t} / x_{j,t}\right), P\left(x_{j,t} / x_{i,t}\right)\right\rfloor, \tag{1}$$

where $x_{i,t} = 1$ $\left(x_{j,t} = 1\right)$ if a country has a revealed comparative advantage (RCA)[2] in good i (good j) in period t and $x_{i,t} = 0$ $\left(x_{j,t} = 0\right)$ otherwise, $P\left(x_{i,t} / x_{j,t}\right)$ is the probability for a country to produce a good i in period t given that it is already producing a good j in the same period, and $P\left(x_{j,t} / x_{i,t}\right)$ is the probability for a country to produce a good j in period t given that it is already producing a good i in the same period. It is expressed as

$$P\left(x_{it} / x_{j,t}\right) = \frac{P\left(x_{it} \cap x_{jt}\right)}{P\left(x_{jt}\right)}, \quad P\left(x_{jt} / x_{i,t}\right) = \frac{P\left(x_{it} \cap x_{jt}\right)}{P\left(x_{it}\right)}, \tag{2}$$

where the numerator of equation (2) is the joint probability of producing both goods i and j, and the denominator is the marginal probability of producing good i or good j.

It should be clear from the preceding description that the subscripts i and j are used to designate two goods in the product space in a specific period and do not refer to a new or an old good. Also, it is important to stress that the proximity between two goods is the same regardless of the countries producing them, and it is bounded below by 0 and above by 1. A value of $\varphi_{i,j,t}$ of 1 implies that goods i and j are homogeneous, while the value of $\varphi_{i,j,t}$ of 0 implies that the two goods are heterogeneous. Between 0 and 1, goods i and j can be close to being homogeneous or heterogeneous depending on

[1] The conditional probability is computed using all countries in the data set in year *t*.

[2] The revealed comparative advantage is used in the Balassa (1965) sense, that is, a country has a RCA in good *i* if its export share in this good is greater than the world export share in this product.

whether the value of $\varphi_{i,j,t}$ is close to 1 or to 0. A path or distance-weighted number of products around a good i is then constructed such as

$$path_{i,t} = \sum_j \varphi_{i,j,t} \quad . \tag{3}$$

Using the average proximity over 1998–2000, HK make the first cut into the characteristics of product space. Fifteen products are located in the densest part of the forest, that is, the part of the forest with more sophisticated or complex products. These 15 products include 10 manufactured products, 3 machinery products, and 2 chemical products.[3] On the other hand, 15 products are located in the least dense part of the forest, including 10 unprocessed agricultural and animal goods, 3 low-tech manufactured products, and 2 chemical products.

The firms' decisions or abilities to jump to producing new products depend on the locations of the currently produced goods in the economy, the distances to the new goods, and the values of the new goods. HK build upon those three factors to test their model of structural transformation described earlier. They first construct the measure of distance as well as the prices for both standard and new goods. They next extend the measure of proximity between two products to the proximity between the current export basket, taken to represent the existing economic structure of the country, and a particular good. The measure of this proximity is termed *density*. The intuition behind this measure is that if a country produces goods that surround or are close to a particular other product, then the probability of this country to develop a RCA in that particular product in the future should be high. The density is a scaled sum of paths that lead to the good in which a country has a RCA, where the scale is the number of all paths. The value of the density of good i in country c at time t is between 0 and 1.[4] More formally, it is given by

$$density_{i,c,t} = \frac{\sum_k \varphi_{i,k,t} x_{c,k,t}}{\sum_k \varphi_{i,k,t}} \quad , \tag{4}$$

where $\varphi_{i,k,t}$ and $x_{c,k,t}$ are defined as before. Unlike the proximity measure, which is the same across countries for two specific goods, the density of a good varies across countries.

Then, HK define the prices for the standard goods as well as for the new goods by constructing two additional measures, *Expy* and *Prody*. The *Prody* measure is commodity specific and defined for good i at time t. $Prody_{i,t}$ is calculated as the weighted sum of per capita gross domestic product (GDP) of all countries exporting this good, where the weights are the countries' respective RCAs in good i. *Prody* is defined globally, that is, it is the same for all countries in the case of good *i* at time *t*. *Expy*, on the other hand, is country specific, but the same for all goods in which this particular country has a RCA. The *Expy* measure is calculated as the weighted sum of *Prody* over all goods exported by this country, where the weights are this country's share of each exporting product in the country's total exports.

With these constructed measures, HK also test the structural transformation model empirically through a cross-country regression (probit and ordinary least squares) using World Trade Flows data from 1985 to 2000. They test whether the price of a new good (*Prody*) as well as the proximity of the new product (*density*) have positive effects on the probability of developing a RCA in the product in the next period, controlling for the price of the standard good (*Expy*), and whether the country has a RCA in the product in the current period. The regression results confirm the prediction of the model. An increase of one standard deviation in the density increases the probability of exporting a new good in the next period

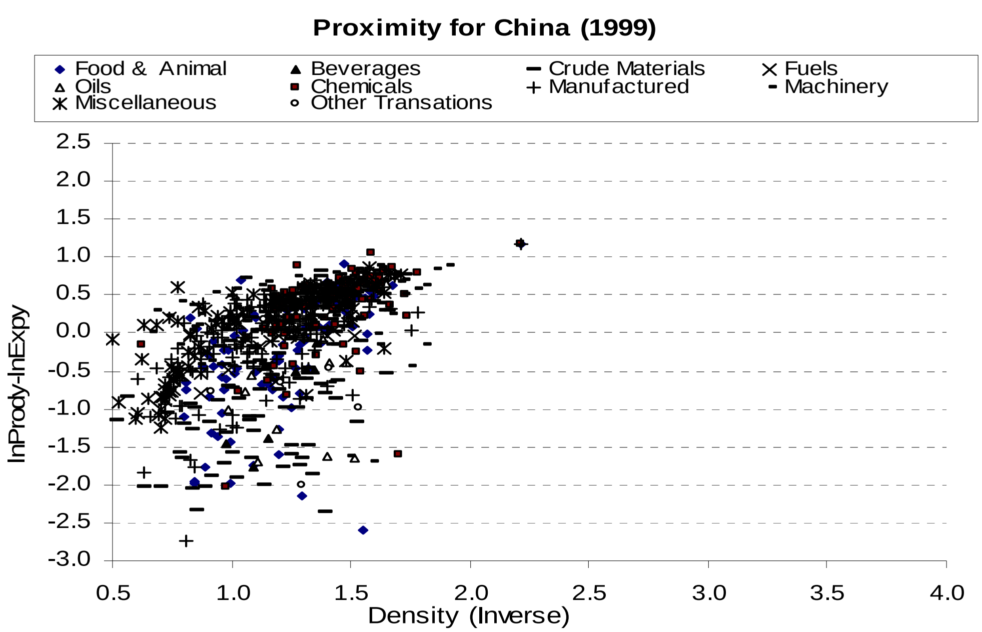
[3] One thousand and seven products are in the entire product space of the data between 1962 and 2000. This number is slightly different from the one reported in the HK study (which is 1,006). See the appendix for the description of the methodology and the discrepancies that result thereof in replicating the results of HK.

[4] As in the case of the proximity measure, the value of density can be used to determine whether a good is homogeneous or heterogeneous.

by 1.3%, while an increase of one standard deviation in *Prody* causes this probability to increase by 0.008%.

The analysis of structural transformation at the individual country level is illustrated by plotting the difference between *Prody* and *Expy* of a good against its distance[5] (inverse of density) using one-year data (1999) and for the selected three countries. HK's results for the three countries (China, Malaysia, and Ghana) are presented in Figure 1.[6] As shown, patterns of industrial structure as well as potential transformation are quite different among the three countries in 1999. Starting with China, it is obvious that the nearby goods[7] to its current export basket that represents its industrial structure in 1999 are downscale, or low-value primary goods (food and animal, crude materials [agricultural and natural resources], fuels, and beverages). But at a distance of about unit 1, more upscale or high-value products exist. These products, which include chemicals, manufactured, and machinery, represent a more sophisticated industrial structure than the 1999 structure. The 1999 structure indicates a relatively high potential for China to further change its industrial structure in the years following 1999. The same pattern can be seen for Malaysia in which upscale products in the chemicals, manufactured, and machinery clusters exist at a slightly farther distance than in China (starting at unit 1.5). For Ghana, on the other hand, a totally different pattern is observed in the figure. In fact, no product exists at a distance of approximately 1.5 from Ghana's current (1999) export basket. The goods near to its current export basket start at a distance of 1.75, and they are downscale products as exemplified by food and animal and crude materials. The close distance to the upscale products is as far as 1.8, and most of these products belong to primary industrial clusters. The upscale, high-value goods such as those in the chemicals, manufactured, and machinery clusters are far from the country's current export basket with a distance of more than 2.5. Although only one year's data are used, these results show key differences in potential for structural transformation across the three countries. However, without a different measure that can capture the process or dynamics of the transformation process over time, these figures can provide only a conjecture as to the different transformation rates across countries in the future.

Figure 1. Visual representation of proximity for selected three countries

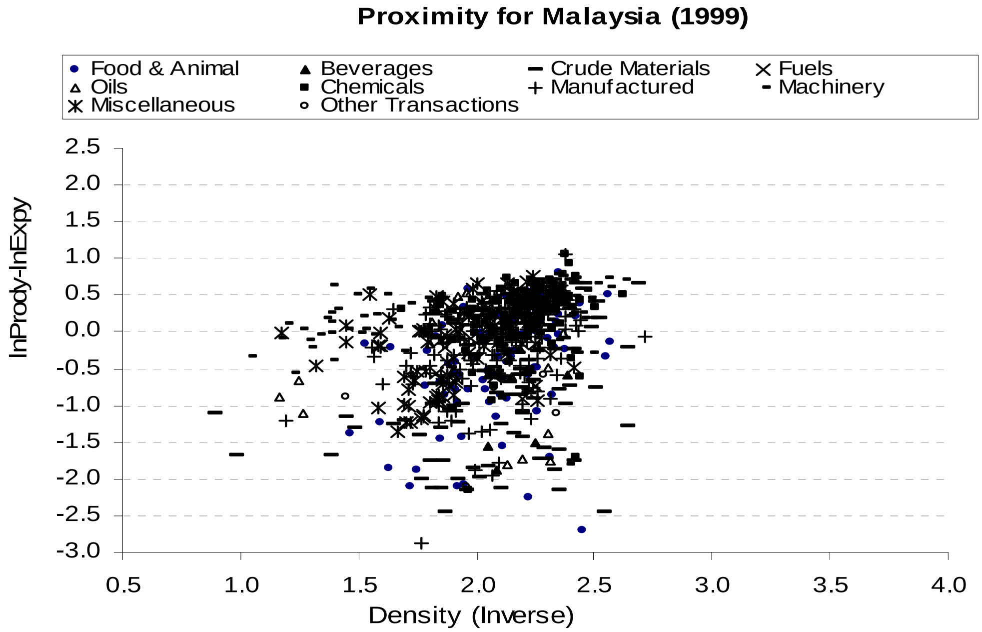


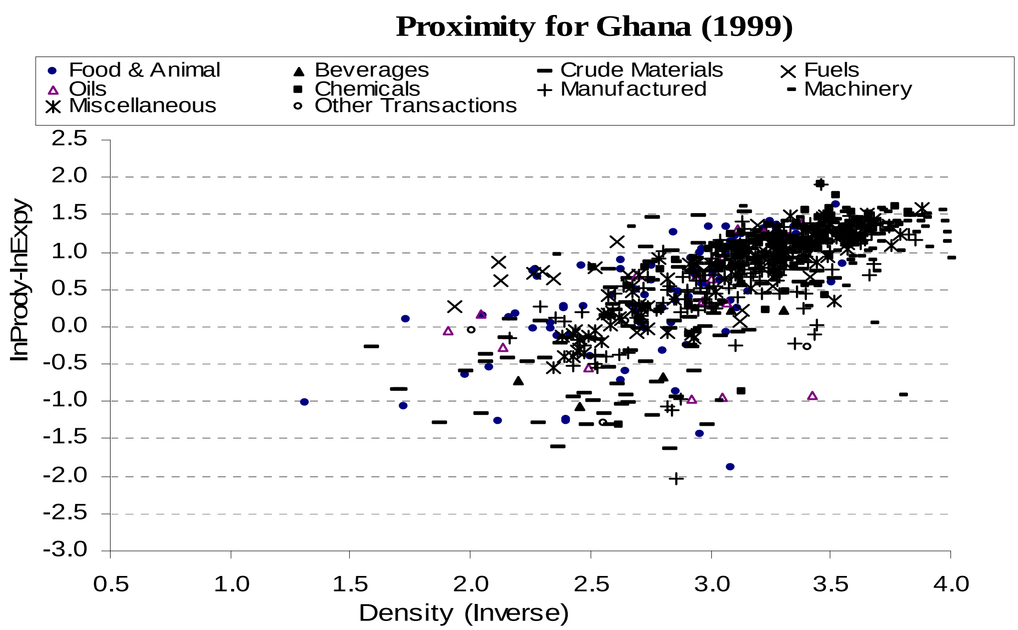
[5] The measure of the inverse of density is in log.

[6] The HK study depicts this relationship for six countries: China, Malaysia, Columbia, Venezuela, El Salvador, and Ghana.

[7] A distance (inverse of density) of a good to the existing productive capabilities can be read on the *x* axis. A nearby good is the one located at a distance relatively close to 0 compared with other goods.

Figure 1. Continued





3. DYNAMICS OF STRUCTURAL TRANSFORMATION IN CHINA, MALAYSIA, AND GHANA

The results of Section 2 show how the proximity of the current export basket to new products as well as the price differential between the current and new products determines the patterns of structural transformation. Although the results are consistent with the predictions of the model developed by HK, the analysis is for only one year (1999). A one-year analysis is rather static and may miss key factors unobservable at a specific point in time. Our contribution is to develop the methodology so the analysis can be conducted over time at the country level. Such an analysis will allow for the comparison of patterns of structural transformation across countries and time, thus helping to identify the dynamic differences in the process of transformation.

To achieve this goal, we need to develop a new measure of proximity in which the distance from the current export basket to a broader set of products can be captured. HK's measure of proximity (*density*) captures only the distance between the current export basket and a particular good. It does not, however, provide any idea about the diversity of the basket as a country develops RCAs in various sectors. Specifically, if a country's export basket includes goods that are located in diverse parts of the product space,[8] then the probability is high for that country to have its export basket surrounded by many new goods. As a result, such a country may develop RCAs in many other goods, possibly including some high-value goods, in the future, and hence achieve a more rapid structural transformation. Conversely, a country with an export basket composed of products located in a few parts of the product space may develop RCAs in a very few new products in the future. The possibility of new, upscale goods becoming part of this country's export basket is less than in comparison to the former country. The structural transformation in this country will tend to be stagnant.

The concept of comparative advantage we use in this study is broader than the one used in the Heckscher-Ohlin theory of trade. According to that theory, a comparative advantage in a specific good is endowment driven and does not admit any role for differences in technology across countries. As an implication, the structural transformation is shaped primarily by factor endowments as countries will have a tendency to move toward the production of goods intensive in factors they are abundantly endowed in. However, recent patterns of comparative advantages across countries have shown that the static aspect of comparative advantage (endowment driven) is not always justified. For instance, the East Asian countries (first and second tiers) are highly endowed in labor and natural resources but have moved lately toward the production of high-tech products, including automobiles, electronics, and other capital goods. This indicates that the comparative advantage has a dynamic aspect that goes beyond just the factor endowment. A country can develop comparative advantages over time by investing intensively in R&D, human capital, and learning by doing, and by implementing policies that allow factor endowments to play a supporting role in this process (see Grossman 1989; Costinot 2009).

We develop a measure of proximity we call the *density gravity center* (*DGC*). The density gravity center measures the distance between a country's current export basket and all goods in the product space in which the country is not present but are produced by the other countries. The value of *DGC* is high when a country has a diversified export basket surrounded by many new goods and low for a country with a less diversified export basket. The *DGC* for country *c* at time *t* is defined as a sum of densities of all goods *i* in which a country has RCAs (i.e., $x_{i,c,t} = 1$). This sum of densities is further normalized by densities of all goods regardless of whether this country has a RCA in good *i* or not. Specifically, *DGC* is given by

[8] A product space is a representation of all goods that can possibly be produced in the world.

$$DGC_{c,t} = \frac{\sum_i density_{i,c,t} x_{i,c,t}}{\sum_i density_{i,c,t}} \quad (5)$$

Before applying this measure, we first describe how it relates to the other determinants of structural transformation developed by HK. Recall that the price differential between the existing and new goods is the other important factor that drives innovation, in addition to the distance we discussed earlier. Now the question is whether the prices HK developed (*Prody* and *Expy*) are still relevant for the new measure developed here (i.e., *DGC*). Since *Expy* is country specific at time *t*, it is also suitable for the measure of the level of sophistication of the country's export basket in a particular year.[9] The *Prody*, on the other hand, is commodity specific and uniform for all countries because this measure includes all countries' RCA in commodity *i*. Given the similarity of *Prody* for a particular product across countries, we need only to find weights for individual good *i* in order to construct the *Prody* of a group of goods. We can use a global weight such as trade share of each individual good in world total trade. The difference between *Expy* for a country and *Prody* for a group of goods in the world can be used to assess whether an export basket for a country includes several new goods that are upscale or downscale with respect to the country's current export basket. If new goods are predominantly upscale, then they should translate into an increase in the value of *Expy*, and if they are downscale, they should translate into a decrease in its value.

Using the above simplification, we first analyze the relationship between *Expy* and *DGC* for a specific country. If a country's export basket is diversified and surrounded by many new goods, then the country is likely to develop RCAs in these goods. Developing RCAs in these goods should translate into an increase in the value of a country's export basket if most new goods are upscale, or a decrease in the value of its export basket if most new goods are downscale.

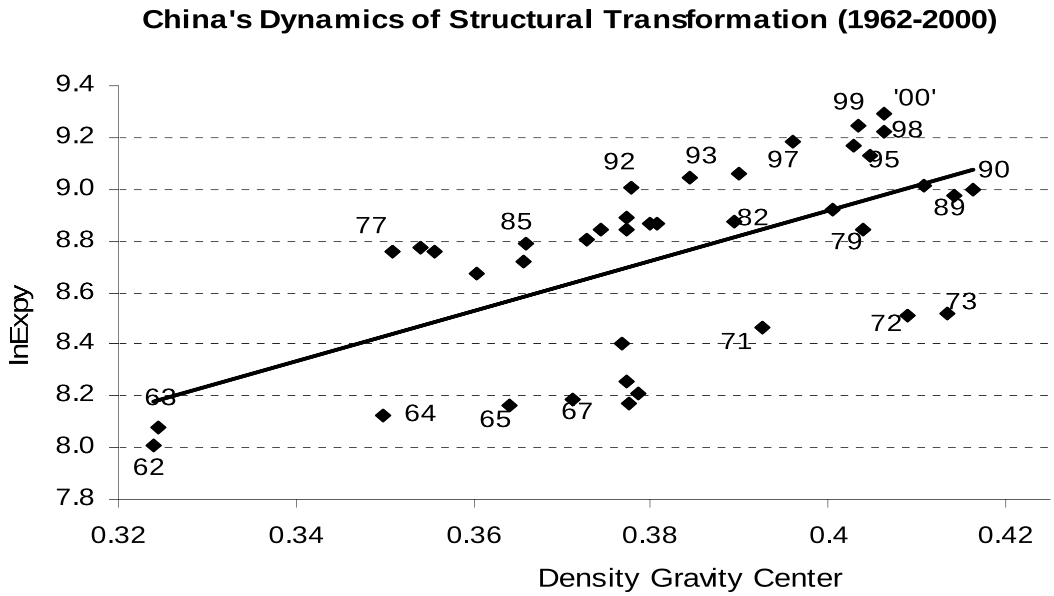
We use the same data set as in the previous section to show the relationship between *Expy* and *DGC*. We select three countries to study this relationship—China, Malaysia, and Ghana. Two reasons motivate our choice of these countries. First, the three countries were selected by HK (2006) in their static analysis of structural transformation. Choosing them in our study allows a comparison of our results with theirs. Second, we want to see whether differences in the nature as well as the patterns of comparative advantages explain differences in the structural transformation process across countries. Choosing these three countries helps find this explanation since Ghana has a production/export profile that is endowment based, while the production/export profiles of China and Malaysia are based on both endowments and R&D.

We apply the *Expy* and *DGC* measures to data of the three countries. Figure 2 depicts this relationship for China, Malaysia, and Ghana. Each point in the figure is a year-specific coordinate of the proximity of the export basket to all other goods a country is not producing/exporting (*DGC*) and the value of the export basket in the next period (*lnExpy*). A trend line reveals the general extent of transformation. A clear upward-sloping trend suggests a positive relationship between *Expy* and *DGC*, and is observed for China and Malaysia but not for Ghana. This trend indicates that the increased value of the respective country's export basket is associated with the increases in the value of *DGC*, while in the case of Ghana a flat trend indicates no relationship between those two measures. Also, the slope of the trend in the case of China is steeper than that of Malaysia, suggesting that China's industrial structure and hence export composition have changed more rapidly than that of Malaysia. Moreover, these changes are associated with larger increases in the number of new and more complex goods with higher values in the case of China compared with Malaysia. While Malaysia's export structure changed during the same period, the speed of change seems to be slower than that in China. In contrast, the commodity

[9] We will use *Expy* interchangeably as the price or the value or the level of sophistication or the level of income of a country's export basket.

composition of exports in Ghana shows no change. This implies that while Ghana may have added new goods to its export basket, those new goods are dominated by the presence of downscale goods.

Figure 2. Dynamics of structural transformation, 1962–2000



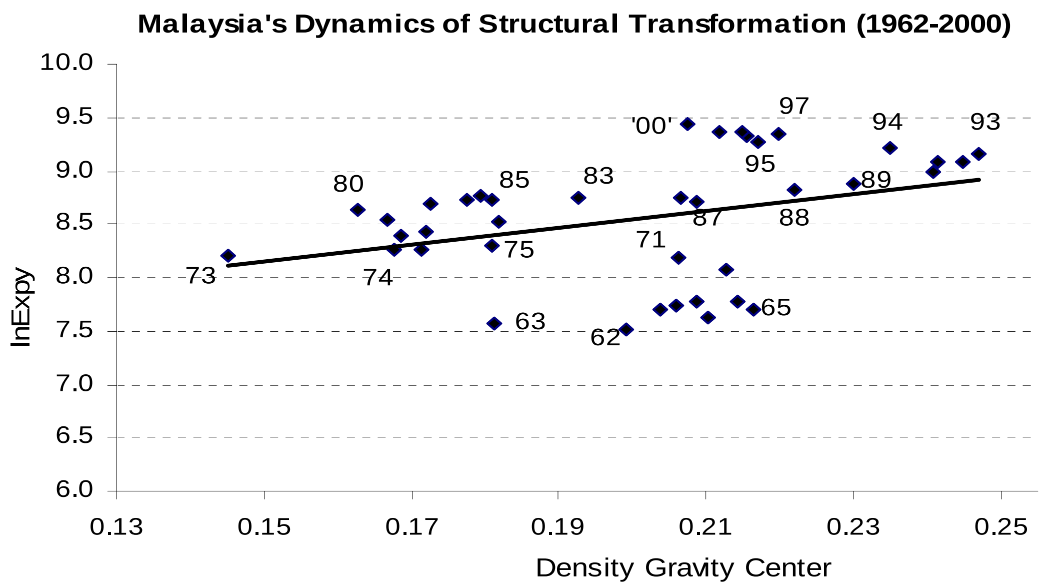
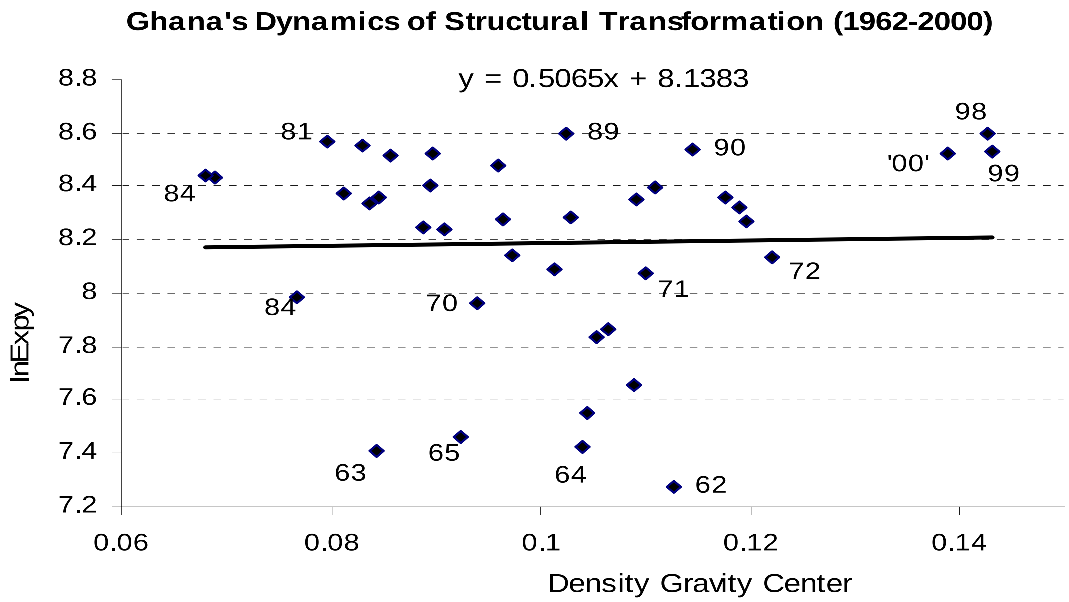


Figure 2. Continued



A simple linear trend[10] yields estimated slope values $(\hat{b})$ of 9.69, 7.69, and 0.51 for China, Malaysia, and Ghana respectively. This result confirms the significantly different magnitude of transformation for each of the three countries. This estimate can also help us assess the density elasticity of *Expy*. A 1% increase in the value of *DGC* translates into an increase in the value of *Expy* of 3.7% for China, 1.53% for Malaysia, and only 0.05% for Ghana. Indeed, these results suggest that the transformation speed has been dramatically different between China and Ghana and modestly different between China and Malaysia. In other words, the speed of structural transformation for China was 2.4 times that of Malaysia and 72.6 times that of Ghana over the period 1962–2000. These results prompt the question of whether Ghana can "catch up" to one of the other countries in this structural sense. Notice that two periods can be distinguished from China's graph: the 1960s and 1970s period (pre-reform period) and the 1980s and 1990s period (post-reform period). If we draw a trend line for the first period (below the shown trend line), we see little difference in the process of transformation between China and Malaysia. However, a trend line for the second period is steeper than the one shown, that is, a change in the estimated intercept and the slope. This is an indication that the process of transformation was accelerated during the post-reform era. Thus China's experience might reflect the potential that other countries would aspire to.

Also, these results show that China's structural transformation entailed diversification and increasing sophistication of its export basket. While the replication of the one-year HK analysis of the previous section is consistent with these results, the single-year analysis could not tell how each of the three countries has transformed its structure of exports over time, prior and after 1999.

To further assess the process of industrial transformation of the three selected countries, we include in the analysis for comparison two countries that have the most sophisticated export profiles in the world (the United States and Japan) and one country that features a very rapid transformation (Korea). In Figure 3 we include *DGC* (panel one), distance (panel two), and *Expy* (panel three) for the six countries over time. As the first panel of Figure 3 reveals, the patterns of transformation of China stand out.

[10] A linear equation, $y = a + bx$, is used here. We also tried other types of equations including logarithmic, polynomial, power, and exponential. However, the linear trend seems to fit the data better than the other ones.

Starting below the United States and Japan in 1962, China has increased the proximity of its export basket to the rest of the goods in the product space over time, undercutting Japan and getting even closer to the United States near the end of the period. Malaysia, after a stagnant period, 1962–1971, and a modest reversal period, 1971–1973, has improved its proximity from 1973 on. However, that country's *DGC* curve stayed below those of the United States, Japan, and China. On the other hand, Ghana remained at the bottom of the figure in the entire period. The graph on the distance (panel 2 of Figure 3) reinforces these conclusions. Starting at a distance of 3.09 in 1962, China reduced the distance between its export basket and the rest of the goods in the product space over time, cutting it down by 22% with respect to the ideal distance (distance = 0) and approaching the group of richer countries by year 2000. Malaysia and Ghana reduced their respective distances too, but they were still far from those of the rich countries by the end of the period. Between 1962 and 2000, Malaysia reduced its distance by 4%. The distance for Ghana remained the largest, at 7.20 from the ideal distance.

Figure 3. Dynamics of structural transformation for selected countries, 1962–2000

<u>Panel 1: *DGC* over time</u>

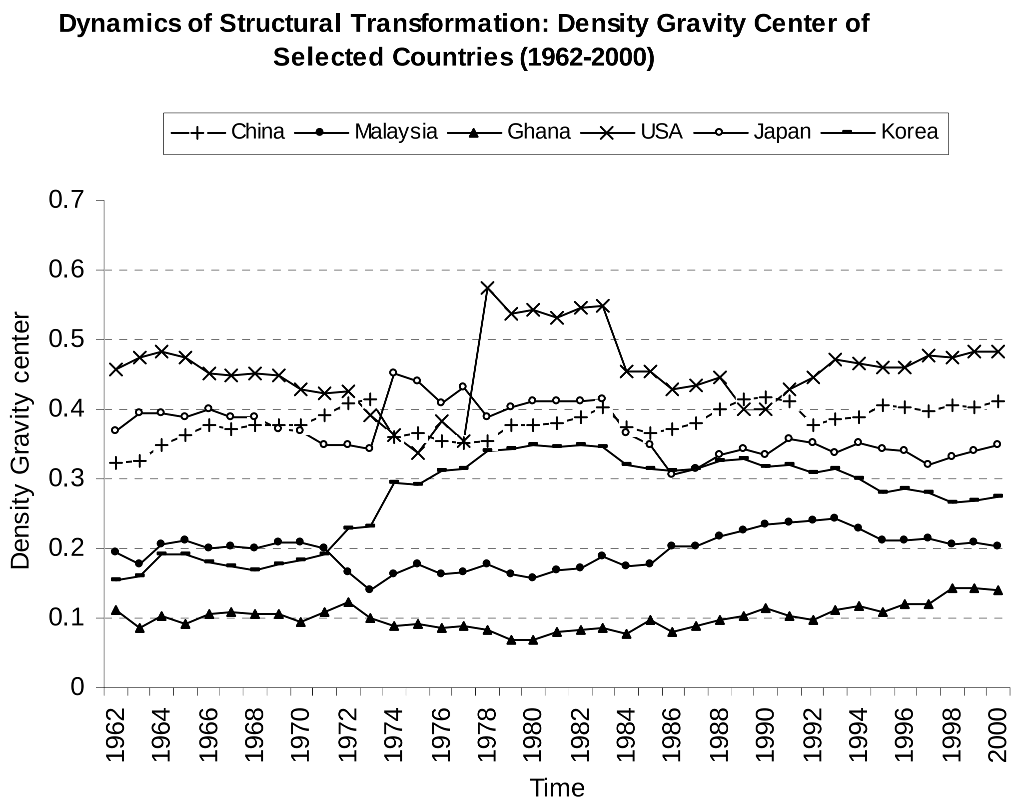
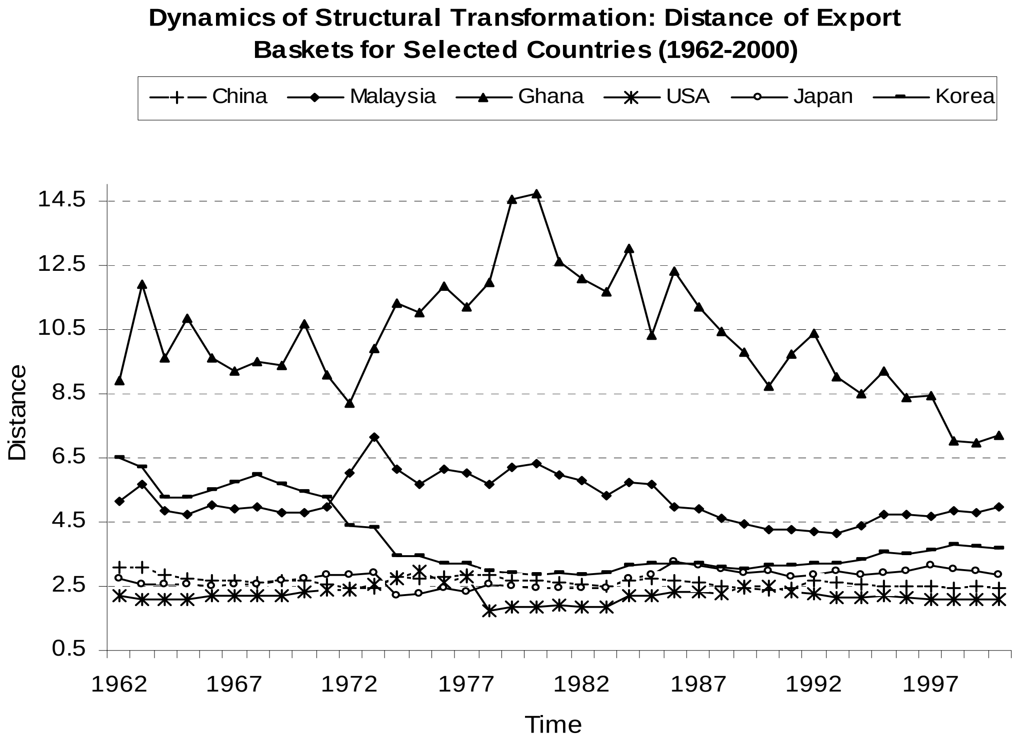
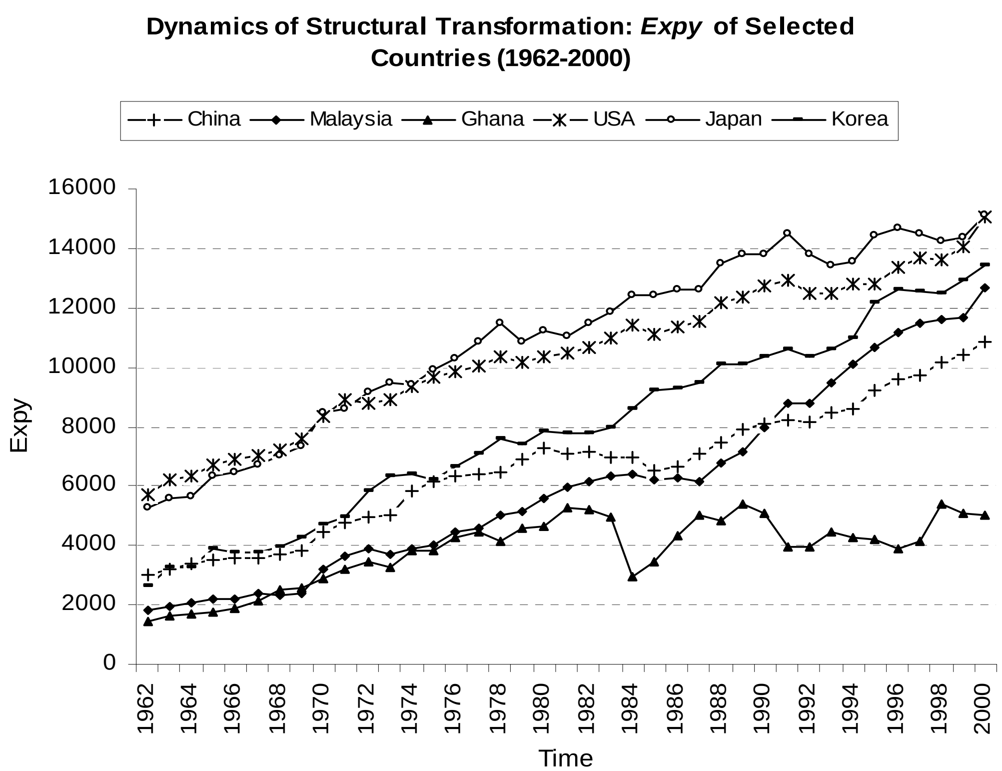


Figure 3. Continued

Panel 2: *Distance* over time



Panel 3: *Expy* over time



The intersecting or the crossing of the *DGC* lines of some advanced countries does not imply that a country (e.g., China) has reached a similar or more advanced export basket than an advanced country (Japan). Instead, this result implies that the less advanced country is likely to develop RCAs in a number of new goods in the near future that are currently in the advanced countries' export basket. The development of such new goods will accelerate the transformation of the industrial structure only if they contribute to an increase in the level of sophistication of the export basket as captured by the value of *Expy*. A look at the last panel of Figure 3 indicates that the value of China's *Expy* increased during the period under study. This suggests that the improvement in its *DGC* has translated into the development of the RCAs in more upscale goods. However, the sophistication levels of its export basket were still below those of the rich countries (the United States, Japan, and Korea) by the year 2000. Malaysia was further below the advanced countries as well as China, but undercut the latter in 1992. In contrast, Ghana is the less-performing country on the basis of the sophistication of its goods. After a relatively short period of increase in its *Expy* (1962–1977), the country displayed an episode of erratic movement in the value of its export basket that suggests a stagnation in its process of structural transformation.

4. DETERMINANTS OF THE SPEED OF STRUCTURAL TRANSFORMATION ACROSS COUNTRIES

As emphasized in Section 2 and shown in Section 3, the characteristics of the product space determine the patterns of structural transformation. The close proximity of China's current export basket to new, high-value goods has helped China transform its structure of production/export more rapidly than Malaysia and Ghana. Now we extend the analysis to assess how the proximity as well as the price differential between current and new goods influenced the speed of structural transformation across countries.

We first classify all products that could be included in the product space into six industrial clusters. These six groups of products are (1) capital goods, (2) consumer durable goods, (3) consumer nondurable goods, (4) intermediate inputs, (5) primary energy, and (6) nonenergy primary.[11]

We then measure the proximity of each cluster to new goods in the same category to assess which clusters have contributed the most to the process of structural transformation. The contribution also depends upon the values of new goods. This dependence requires a value index for each of the six clusters over time. With some modification, we construct an index similar to the *Prody* measure in HK. Specifically, instead of constructing the value (price) for a particular new good we construct a value index for a group of new goods. This is accomplished by defining the group *Prody* (*GPrody*) for a group (or cluster) of goods as the weighted sum of *Prody*s of goods in that cluster, where the weights are the world export share for each product included in that cluster scaled by the their respective total shares. The calculation is given by

$$GPRODY_{j,t} = \sum_i \left(\frac{share_{i,j,t}}{\sum_i share_{i,j,t}} PRODY_{i,j,t} \right). \qquad (6)$$

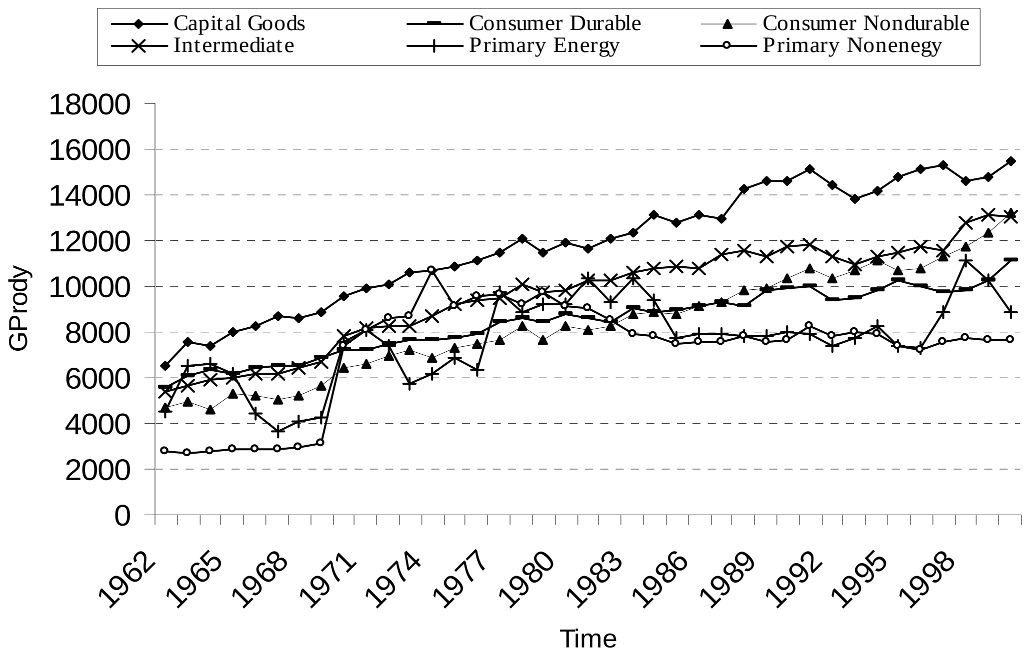
The results of *GPrody* for the six product groups appear in Figure 4. The capital goods group has the highest values of *GPrody* over the entire period 1962–2000. The gap between capital *GPrody* and the other *GPrody*s widened with time. *GPrody* for consumer durables has the second highest value between 1962 and 1971, after which the intermediate input group prevails in 1972–1990, and the consumer nondurable group since 1990. Also, this figure shows that the two primary product groups always have the lowest values in *GPrody* with a few exceptions corresponding to world primary resource shocks in the 1970s and early 1980s.

The magnitude of the *GPrody* index for each cluster has a major effect on our measure of structural transformation. The proximity of a country's export basket to the capital goods and consumer durables will affect our estimate of the speed of structural transformation, since these goods not only bear higher values but also often embody recent advancement in technological know-how and designs (which has been well studied in the endogenous innovation literature cited in the introduction). The proximity to the intermediate inputs and to some extent to consumer nondurables is also important in the transformation process. However, the proximity to the two primary product groups appears to not contribute to a country's process of transformation. This result can be explained as follows. First, primary products often bear low values of *Expy* compared with other categories and do not contribute to the

[11] These six classification groups are consistent with the United Nations classifications (see United Nations 2000). Capital goods include industrial and nonindustrial equipment and transportation engines. Consumer durable goods encompass durable and semi-durable goods and passenger vehicles. Consumer nondurable goods include food and nondurable goods used mainly for household consumption. Intermediate inputs include parts and accessories, processed products, and other products mainly used as inputs in the industrial production process. Primary energy goods are composed of energy resources such as hydrocarbons, coal, and so on. Nonenergy primary goods include mineral resources, industrial minerals, and primary agricultural goods. We prefer this classification to Leamer's commodity clusters (1984). Indeed, some of Leamer's clusters include products that are not homogeneous in terms of factor shares and capabilities required to produce them. For instance, cluster 2 (crude materials) includes unprocessed animal and agricultural products, other natural resources, fuels, processed agricultural and animal products, chemicals, and so on.

increase in the value of the export basket. Second, primary products are mostly located in the sparse part of the forest and tend not to provide technological links to the production of other more complex products. Finally, little advanced technology is embodied in such products, which constrains them from serving as a driving force of the structural evolution of a country's industry through complementarities or technological spin-offs in designing and inventing new products. Whether the presence of primary groups hinders the transformation process, as some of the primary resource literature might suggest, is worthy of further study.

Figure 4. Evolution of GPrody of different product clusters, 1962-2000

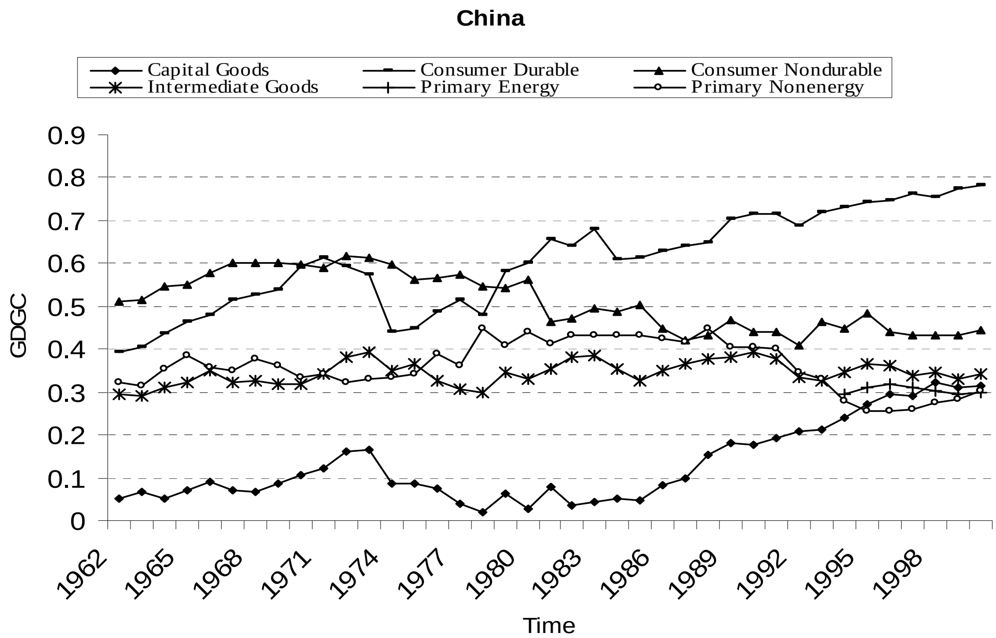


We now turn our attention to the characteristics of the product space that have influenced the speed of transformation differentially across countries by constructing the group *DGC* (*GDGC*) for each individual country. The question we address here is whether the group proximity of each industrial cluster to the new goods in this cluster has translated into the development of RCAs in new goods for an individual country. The results are reported in Figure 5 for each of the three countries.

We start the discussion for China. As shown in the first chart of Figure 5, the *GDGC* for two industrial clusters, that is, consumer nondurables and primary nonenergy, has decreased over time, from 0.50 and 0.33 in 1962 to 0.43 and 0.30 in 2000, declining by 14% for consumer nondurables and 15% for primary nonenergy. In contrast, *GDGC* for the other two clusters, capital goods and consumer durables, increased substantially in the same period. It rose from 0.05 and 0.40 in 1962 to 0.31 and 0.79 in 2000 for capital goods and consumer durables, respectively, a total of 520% and 100% increases for these two groups in this period. China also made modest improvements in the proximity to the intermediate inputs with *GDGC* rising from 0.30 to 0.34, or an increase of 13% in this period.

In comparison, Malaysia's *GDGC* paths are similar to China's, with relatively low initial values. The *GDGC* for consumer nondurables and primary nonenergy fell from 0.33 and 0.28 in 1962 to 0.28 and 0.19 in 2000, with similar degrees of decline as in the case for China (−15% and −32%, respectively). Also, similar to China, Malaysia's *GDGC* for both capital goods and consumer durables has increased, rising from 0.03 and 0.09 in 1962 to 0.33 and 0.21 in 2000, or 725% and 133% increases, respectively. The *GDGC* for intermediate inputs also rose slightly, from 0.161 to 0.164, in this period.

Figure 5. Group density gravity center (*GDGC*) of product clusters, 1962–2000



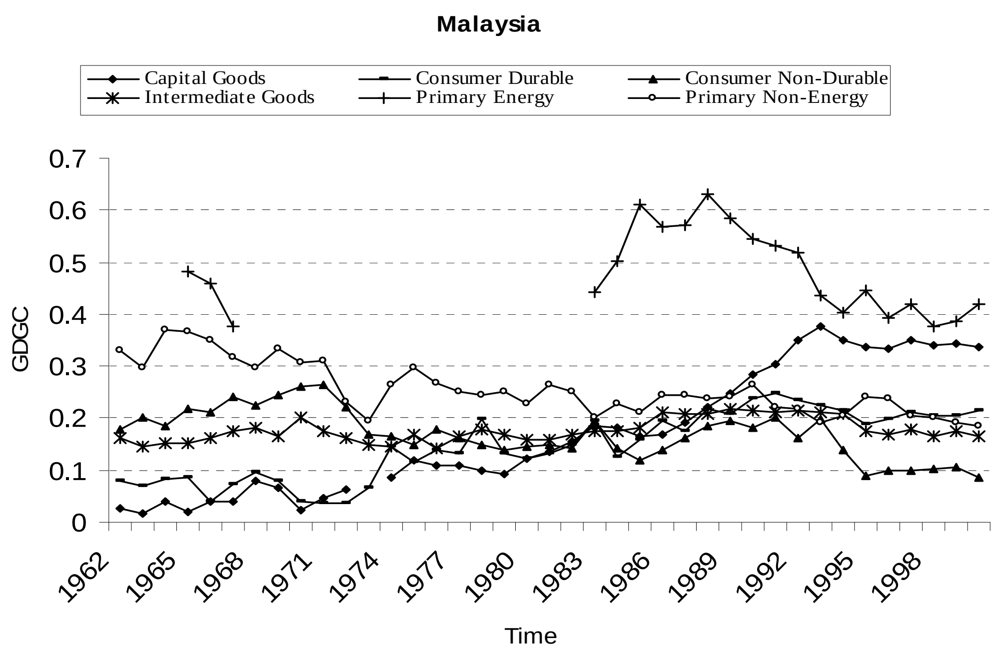
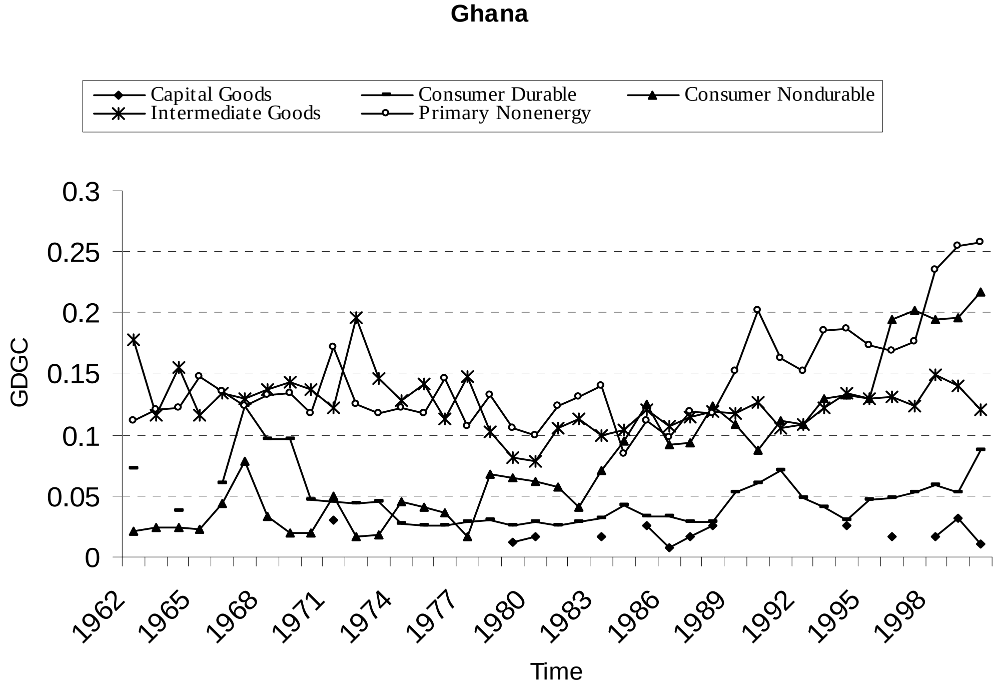


Figure 5. Continued



In contrast to China and Malaysia, Ghana's structural transformation is quite different. The only clusters in which substantial improvement is observed are consumer nondurables and nonenergy primaries with their *GDGC* rising from 0.02 and 0.11 in 1962 to 0.22 and 0.26 in 2000. The *GDGC* for the intermediate inputs, on other hand, fell to 0.12 in 2000 from 0.16 in 1962. Furthermore, the *GDGC* for consumer durables shows a stagnant pattern with a similar low value in the beginning and ending of the period (0.071), while the *GDGC* for capital goods fell to 0.011 in 2000.

Figure 5 suggests that differences in the rate of structural transformation across the three countries is associated with the proximity of each country's export basket to the upscale (more complex) goods such as capital goods and consumer durables, and to some extent to intermediate inputs. Increases in the values of *GPrody* for these three industrial clusters and the large magnitude of such increases are an indication of a relatively rapid rate of transformation. However, the initial conditions also matter. That China started with a proximity to each of the three categories higher than Malaysia in 1962 is such an indication. China also maintained its leading position for the entire period under study. The consistency of such a pattern seems to suggest that China has developed RCAs in more new goods in this transition than Malaysia and Ghana. Indeed, the cumulative number of all new goods exported in 1963–2000 was 924 for China, 529 for Malaysia, and only 245 for Ghana. Of the 924 goods that China exported, 103 were capital goods (11% of total number), 127 were consumer durables (14%), 112 were consumer nondurables (12%), 418 were intermediate inputs (45%), 163 were nonenergy primary goods (18%), and only 1 was primary energy.

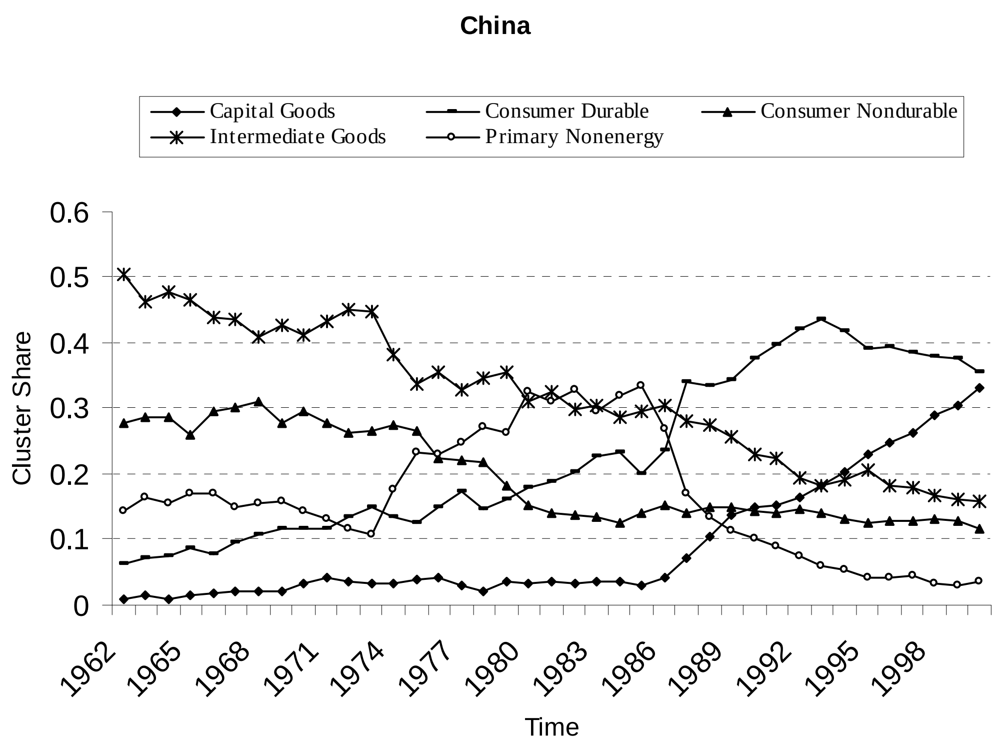
The structure of the new goods exported in Malaysia is similar to that of China, although the former is half the distance from the latter in level terms. In the case of Malaysia, the shares of clusters in the total number of new goods are 16% for capital goods, 16% for consumer durables, 13% for consumer nondurables, 35% for intermediates, and 20% for non-energy primary goods.

The structure of new goods in Ghana is different from those in China and Malaysia. Capital goods have an extremely low cluster share of 5%, followed by consumer durables with a share of 7%. While the shares for consumer nondurables (15%) and intermediates (38%) are comparable with the corresponding shares for China and Malaysia, a much larger share (34%) is observed for nonenergy primaries in Ghana.[12]

While Ghana continuously showed strength in the development of new products in the nonenergy primary cluster, products in this category had low value (low *GPrody*), which indicates that these goods did not contribute to the country's structural transformation. This comparison again raises the question of whether comparative advantage in primary good exports tends to crowd out the production of new, more complex goods.

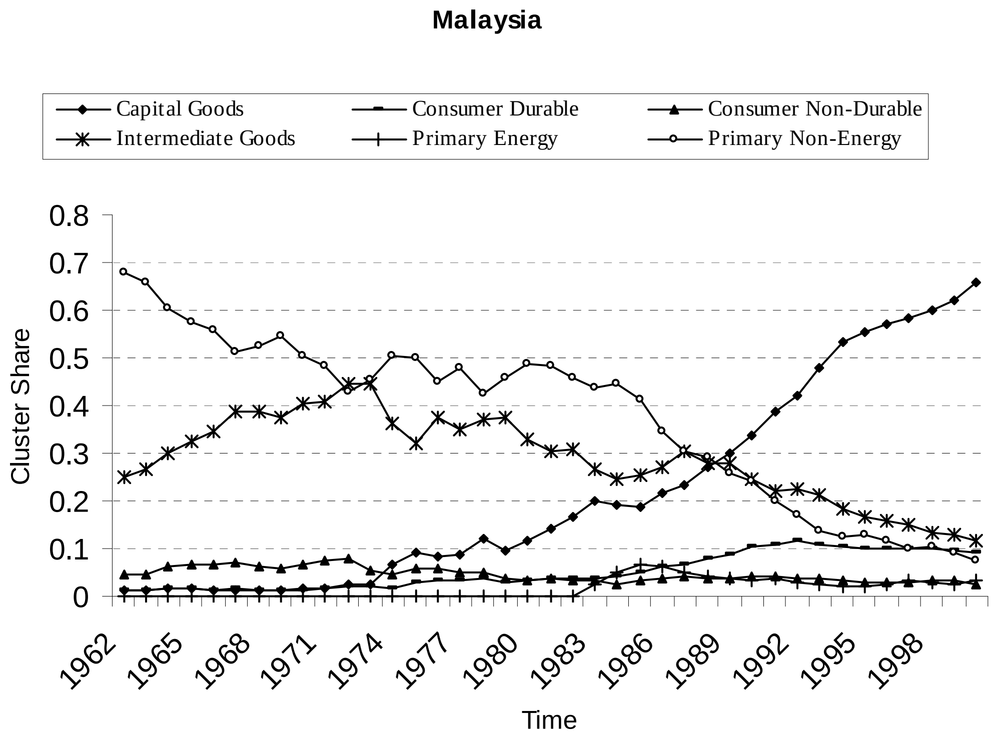
To support this argument, we depict in Figure 6 the contribution of each industrial cluster to each country's export basket represented by *Expy.* As the figure shows, in China and Malaysia the structure of exports in 2000 was significantly different from the one prevailing in 1962. The initial (in 1962) top three clusters for China were intermediate inputs (51% of *Expy*), consumer nondurables (28%), and nonenergy primaries (14%). Consumer durables and capital goods, the two more advanced clusters, had the lowest share, 6% and 1%, respectively. In China in 2000, a totally different structure is observed. The consumer durables, capital goods, and intermediate inputs became the most important three clusters with shares of 37%, 33%, and 16%, respectively, while two of the country's initial top three categories turned into the last two with shares of only 12% for consumer nondurables and 3% for nonenergy primaries.

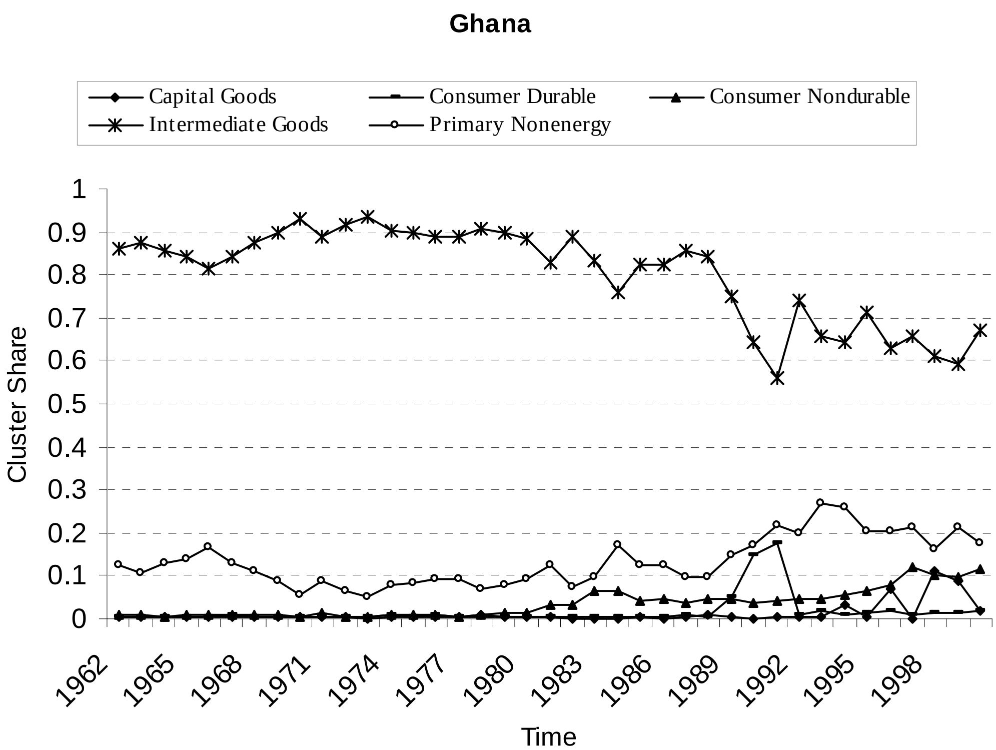
Figure 6. Contributions of product categories to country's export basket (*Expy*), 1962–2000



[12] The share for primary energy is equally small (close to zero) for all the three countries.

Figure 6. Continued





Likewise, Malaysia’s structure of exports in 2000 was totally different from its 1962 structure. Its initial structure was dominated by non-energy primaries with a share of 68%. The shares for consumer nondurables, capital goods, and consumer durables were all very small. However, by 2000, the capital goods cluster became the most important category in export structure with a share of 66%, followed by intermediate inputs (12%) and consumer durables (9.5%). In comparison, Ghana’s product/export structure in 2000 closely resembled its product/export structure of 1962. Its top two categories—non-energy primaries and intermediate inputs together—contributed 99% and 84% to the country’s total value (*Expy*) in 1962 and 2000, respectively. The only slight change was the combined contribution of the remaining three categories, increasing from 1% in 1962 to 16% in 2000.

5. INSTITUTIONAL DETERMINANTS OF STRUCTURAL DYNAMICS

Analysis conducted in the previous three sections focuses on the determinants of the structural transformation in the selected three countries based on extending measures developed by HK. The analysis has shown that the proximity of the export baskets (which represents the current economic structure) of China and Malaysia to more complex goods, such as capital goods, consumer durables, and intermediate inputs, and the higher values of the new goods in these industrial clusters have been major determinants of the patterns and rate of transformation in these two economies. Now we focus on the institutional factors associated with the transformation process. Specifically, we focus our discussion on whether the timing of policy and institutional reforms in the three countries matches with the patterns of structural transformation shown in figures 3, 5, and 6.

For background purposes, we draw upon a series of papers by Rodrik (2004, 2006a, 2006b) in which he focuses on the role of policies and institutions in driving innovation. Obviously, economic fundamentals such as initial factor endowments, macroeconomic stability, and well-functioning markets are important factors in understanding *what* a country will produce, but those factors alone appear insufficient in explaining the rate of structural transformation or, in the case of Ghana, structural stagnation. Rodrik advances the notion of the existence of information and coordination externalities that impede a "jump" to innovative activities. These externalities require government intervention through policy and institutional reforms in order to alleviate constraints to the design and investment in new products.

China

An overview of Chinese economic history over the last four decades reveals the most dramatic change in institutions and policies in recent world history. China's market-related institutions as well as policies are generally recognized as being among the most backward before the early 1980s. With a socialist regime prevailing until the early 1980s, government employed a number of direct and indirect instruments to control most economic activities, which also made the economy relatively closed to world markets. Although imports and exports did exist, as shown in the data, they were not only controlled and determined by the government, but also imports tended to be limited necessities with exports serving as a source to provide foreign exchange

The paths describing changes in China's production and export structure are shown in Figures 3, 5, and 6. They show the different patterns in both the structure and change in the structure of the economy between the two sub-periods, pre-reform and after the reform that started in the early 1980s. Moreover, the export structure in the pre-1980 period partially reflected the state-driven industrialization process under the socialist regime, which resulted in a relatively high share of intermediate goods and some capital goods in total exports (Figure 6).

The most impressive dynamics in all the figures of this paper are observed in the second sub-period for China, the period starting in the mid-1980s. At that point, China initiated reform of both its policies and institutions. Many other impressive facts of this sub-period, which are widely recognized and not presented in the previous sections, include China's persistent double-digit growth in GDP, an extraordinarily high share of GDP involved in trade,[13] a high level of foreign direct investment (FDI) inflows, and the increasing market power in the world economy. While it is difficult to list all the factors the literature has associated with China's economic evolution, we summarize the following factors that are most relevant to this study. According to Lo and Chan (1998), Kraemer and Dedrick (2001), Prasad (2004), Sutton (2004), and Rodrik (2006a), China has succeeded by taking advantage of key fundamentals in the reform period, including the relatively large size of markets for many products, abundant and low-cost labor, relatively low material costs, a relatively high level of human capital thanks

[13] Exports accounted for 37% of GDP in 2006, a share that is extraordinarily high for a large economy, when compared with 8% for the United States and 13% for India in the same year.

to the education system developed under the socialist regime, and high saving rates that link to the nature of Chinese culture. These factors together with the process of gradual policy and institutional reforms have provided incentives for enterprises to increase investments in new activities primarily guided by the market signals. And most importantly, these factors have attracted foreign investors to participate in such activities and hence to bring in new technology know-how and designs that China could exploit to foster its growth and transformation process. While the fundamentals played an important role in realizing China's miracle, almost all these factors existed before the reforms, but they alone were not sufficient to create the miracle. Without the "right" institutions and policies that opened the economy to foreign markets and multinational enterprises, the fundamentals appear, in hindsight, unable to launch the process of growth and transformation. However, the so-called "right" institutions and policies had to be tailored to China's case, and they are often not the copies of those that prevailed in the advanced economies from which China has "copied" technology know-how.

The important roles of China-specific "right" policies and institutions have attracted the attention of many. The literature documents a number of issues, including a gradual reform process that lowered economic risk associated with rapid reform; the creation of special economic zones (SEZs) in the early 1980s aimed at attracting foreign investment; the gradual and eventual increases in the number of SEZs and the adoption of policies and institutions that are more attractive for FDI such as duty-free access to imports of intermediate goods for exports from SEZs, various tax exemptions with a relatively longer period for foreign companies, gradual liberalization in labor mobility, and the determination of wages in SEZs; the eventual enforcement of contracts; the limited direct intervention of government; and the fostering of the spillovers of such new policies and institutions beyond the boundaries of SEZs to almost the entire country.

While the market forces created by the reforms are driving forces of the structural transformation, a set of safeguard measures were employed to foster technological transfers to domestic firms. Those safeguards, for example, required multinational firms to achieve certain local product content over an agreed-upon period of time. Further, the safeguards also sought to restrain the volume of multinational firms' sales in domestic markets to a certain proportion of their exports. This promoted exports and allowed domestic firms to have the time and opportunity to "copy" or adapt the technology know-how and design associated with the new products. The safeguards also forced multinational firms to enter into joint ventures with local entrepreneurs in the early stage of reform. Thus, as discussed by Rodrik (2006a), the per capita income typically associated with the type of goods that China exports is much higher than China's actual income, indicating that the skill content of China's exports is likely to be much higher than its endowment may imply. By the year 2000 (the endpoint of our data set), a majority of the world's large multinational firms were active in China either through their subsidiaries or in joint ventures, and a majority of such multinational firms' products were high-tech and destined for exports. The industries in which these firms are actively involved include mobile phones (Motorola, Nokia, TCL, Sagem, Samsung, and Siemens), personal computers (Acer, Arima, AST, Compal, Compaq, DEC, Dell, Epson, FIC, GVC, HP, Huashang, IBM, Quanta, and Toshiba), home electronics (Sony, Philips, Toshiba, TCL, Siemens, Samsung, Electrolux, LG, Mitsubishi, Sanyo, Sigma, and Toshiba Carrier), and automobiles (VW Automotive, Citroen, GM, Honda, and Daihatsu). The number of privately owned domestic firms has grown and resulted in the development of high-tech domestic industries.[14] Although China remains mainly an assembler of imported components for high-tech products that are exported with a relatively low value-added component (Koopman et al. 2008), the country has become more integrated into the global production chain that it depends on for the production and exports of other high-value and high-tech products.

[14] The government and government research institutions also play an important role in such development. For example, the leader in the PC market, Legend, is affiliated with the Chinese Academy of Sciences, the leading government research institution in China. Other large domestic PC producers are affiliated with research institutions. For example, Founder Group and Great Wall are affiliated with Beijing University and the Ministry of Electronics Industry, respectively. This affiliation allows each firm to use the results of research from the affiliated institution (see Kraemer and Dedrick 2001).

China's patterns of structural transformation analyzed in the previous sections seem consistent with its institutional and policy "transformation" discussed in literature and summarized in this section. Obviously, the policy and institutional environment created by the reforms after the mid-1980s provided incentives for both domestic and foreign enterprises to be actively involved in the development process, the consequences of which are observed in the data and analyzed in the previous sections. This match in timing and in patterns between transforming the economy and reforming the institutions provides strong support to the argument that policies and institutions have played the most important role in the extent and rate of transformation.

Malaysia

The important role of export-led industrialization in explaining the rapid transformation of many East Asian economies into the category of newly industrialized countries (NICs in both the first and second tiers) has received considerable attention in development literature. Malaysia is one such country. Starting as early as the 1960s, Malaysia adopted a series of policies and institutional arrangements aimed at promoting its most promising export sectors to become the vanguard for the country's industrialization process. Similar to developments in other East Asian countries, these reforms consisted of promoting private entrepreneurship and opening the economy to international competition through the promotion of exports while gradually reducing import restrictions (Carbaugh 2002). The early reforms also included a series of tax incentive policies initiated in the early 1970s and the creation of export zones aimed at attracting foreign investors and technology transfers to domestic firms. In 1972, Malaysia created its first free-processing zones, where multinational firms were exempted from import duty, sales and excise taxes (Rasiah 2004). By 1975, the success of these reforms featured many multinational firms and numerous joint ventures and subsidiaries and helped the country evolve from an agricultural-and-primary-resource-based economy to a producer of many capital and consumer durable goods. In the early 2000s, it was ranked the fifth most competitive economy in Asia after Singapore, Hong Kong, Japan, and China (MIDA 2005). It was also ranked the world's ninth largest personal computer producer in 1999 (Kraemer and Derrick 2001) and one of the world's top five exporters of semiconductor devices in 2000 (MIDA 2004).

In terms of the capital goods sector, Malaysia is a major producer of industrial and nonindustrial machines (heavy and precision engines) and transportation equipment (such as buses, refrigerator trucks, and so on). It has attracted multinational firms in aerospace activities (Boeing, General Electric, Honeywell Aerospace, Parker Hannifin, MTU Maintenance, Hamilton Standard, and Eurocopter) and developed an aerospace industry that assembles, maintains, and repairs light aircraft and manufactures aircraft parts and components. Tax incentives encouraged these multinational firms to extend their activities to shipbuilding (yachts, jet skis, sail- and speedboats, inboard/outboard boats, canoes, barges, trawlers, ferries, and cement carriers) and ship repair. The production of these more complex capital goods has helped transform the structure of Malaysia's industry and the composition of its exports.

The timing of institutional and policy reforms in Malaysia seems to coincide with the movements of Malaysian industry toward capital and consumer durable products described in Figure 6. This is an indication that these policies and institutions may have determined the patterns of change of the structure of Malaysian exports. Figure 6 shows that Malaysia started developing its capital goods cluster in the mid-1970s but waited until the early 1980s to foster a faster rate of expansion. By the mid-1980s, this cluster grew at a high rate, resulting in an export share of 66% in 2000. The consumer durables cluster also experienced expansion in its share of total exports. However, that expansion was not sufficient to change its share in foreign trade. Although this cluster moved from the fifth largest cluster in 1975 to the third largest cluster in 2000, its share in exports was only 10%.

The slow expansion of the consumer durables cluster can in part be attributed to structural and institutional factors that counteracted the otherwise beneficial effects of multinational firms in the economy. Among those factors are the shortage of labor as well as of skills,[15] low investment in R&D

[15] Ahmad and Sulaiman (2000) point out that Malaysia has lacked scientists and engineers as well as training programs

necessary to absorb foreign technology,[16] the high costs of inputs due to local content requirement (Kuchiki 2007), low competitiveness in international markets due to a high level of protection of some industries in this cluster,[17] and the Asian financial crisis of 1998. These factors may explain why, having begun its structural transformation in the 1960s and reached a middle-income standard of living in the 1980s, and hence prior to China's "takeoff," Malaysia has not advanced as rapidly as China in the entire period.[18]

Ghana

As the first independent country in Sub-Saharan Africa in the late 1950s, the initial conditions in Ghana were obviously very different from those either in China or in Malaysia. As a major producer and exporter of cocoa and gold during the colonial period, there were little social, economic, and institutional assets left from such history that an independent Ghana could rely on to initiate its modernization. Thus, from this point of view, a lack of fundamentals can explain the lack of transformation in Ghana, at least in the early years of the period we study. However, after many lost years between the 1960s and 1980s, Ghana started its policy and institutional reform in the late 1980s, and in the years following the reform saw sustainable economic growth with a reduction in poverty. While both the total and per capita growth rates cannot compare with those of China and Malaysia, they are high compared with the country's own history and other countries in Africa (Breisinger et al. 2008).

Although the country has experienced persistence in economic growth over the last 20 years, its economic structure has not changed appreciably in terms of the share of agricultural and manufacturing in national product or in terms of export structure (Breisinger et al. 2008). It may be unrealistic to expect a country like Ghana that faces human capital and infrastructural constraints to experience rapid structural change within a period of 20 years. However, the factors necessary for transformation but not yet in place are worth discussion. The former discussion suggests that structural transformation has been led by both domestic and foreign enterprises investing in new goods with high value that the country did not previously produce. There are certain necessary conditions to provide enterprises an incentive to be innovative and invest in new products. Such conditions include both physical infrastructure and institutional conditions. Ghana's colonial history and political and social instabilities in the first 30 years of its postcolonial history have left the country with extremely poor infrastructure, such as roads, electrification, and efficient adjudication of commercial disputes and in many other basic conditions for doing business. These together with the lack of human capital and basic skills are the result of little public investment in education and health, which has made relatively costly the supply of effective labor services to private enterprises, both domestic and foreign. Realizing such constraints in development, the government of Ghana has rapidly increased investment in all these aspects over the last 10 years. However, the growth rate in providing these necessary conditions still falls short of demand even under the current economic structure.

In terms of policy and institutional conditions, Ghana has pursued an open economic policy in the last 20 years through both policy and institutional reforms. The country has liberalized its economy and trade; privatized almost all state-owned firms; pursued the control of inflation through

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needed to achieve reverse engineering. For instance, it had an average of only 400 scientists per million population by the end of 1990s, a number far below the standard in industrialized countries, which is between 4,000 and 6,000 scientists and engineers per million. Rasiah (2004) points out that a low supply of human capital prevents the movement of firms toward higher R&D activities. Sadoi (2000), on the other hand, attributes the problem partially to the Malaysian worker attitude toward skill upgrading. He points out that a Malaysian worker pays less attention to precision and is less motivated to learn by doing than a worker of an industrialized country.

[16] According to Rasiah (2004), the R&D intensity of electronics products in Malaysia (0.088) was far below that of Taiwan (0.546) and of Korea (0.212) in 2000.

[17] Kuchiki (2007) documents tariffs on vehicles that range from 40% to 300% in 1998.

[18] For example, Malaysia was the world's ninth largest producer of PCs with a share of 2.8% in 1999, lagging four places behind China (fifth largest producer with a share of 5.5%) despite having made a technology jump to PCs earlier than China (Kraemer and Dedrick 2001).

macroeconomic stabilization; and imposed a series of policies to encourage foreign investment including tax exemptions, protection of foreign companies' intellectual property rights, guarantee of free transfer of capital, profits, and dividends abroad, and guarantees against expropriation and nationalization.

In spite of such reforms and incentive policies, Ghana has not succeeded in attracting foreign investors interested in investing and producing new goods of higher value. The cumulative value of FDI from 1994 to 2000 was only $1.32 billion (U.S. Commercial Service 2004), and most of that investment was in mining. The limited magnitude of foreign investment that is concentrated in producing a few primary products is unlikely to allow for the transfer of technology needed to transform the Ghanaian industry. That new investors are mainly interested in mining is an indicator that the country may be suffering from the natural resource curse (Auty 1993; Sachs and Warner 1995), which reduces the competitiveness of other sectors in the economy. Despite abundant natural resources (gold, timber, industrial diamond, bauxite, manganese, rubber, timber, petroleum, and so on), Ghana's mismanagement and inefficient use of such resources has failed to boost the economy through the improvement of infrastructure and investment in human capital and in R&D. It has also distorted the allocation of resources across sectors, preventing the promotion or creation of the manufacturing subsectors that have a relatively short distance to the more sophisticated and high-value goods. Without additional policies, the current industrial structure and relevant institutional factors will continue to prevent foreign investment flows into more complex activities. Thus, the initial industrial structure of Ghana is a major challenge if the country is to follow the paths of China and Malaysia. As shown in the previous sections, a light manufacturing industry (electronics and car assemblies) existed in China and Malaysia prior to policy and institutional reforms. Such light manufacturing exhibits a relatively short distance to other more sophisticated new goods, and hence firms can more easily "jump" between the trees in the relatively dense forest. That made it easier for China and Malaysia to move from their previous industrial structure to a more sophisticated one as compared with Ghana.

6. CONCLUSIONS

This paper contributes to the literature first by developing new measures to analyze the dynamics of a country's structural transformation as reflected by the changing structure and value of a country's exports in the context of the evolution of the world economy. The second contribution is to provide insights into the features and determinants of transformation of the Chinese, Malaysian, and Ghanaian economies. The new measures are an extension of those developed by Hausmann and Klinger. We find that China's relatively rapid structural transformation is determined by the high proximity of its export basket to capital goods, consumer durables, and intermediate inputs coupled with high values of new goods in these three clusters. In the 924 new products in which China has developed RCAs and exported during 1962–2000, 648 (70%) belonged to these top three industrial clusters. Many products in the three clusters embody high levels of technological know-how that tends to facilitate further movement toward more complex goods. As a result, not only has China transformed its industrial structure and developed an export profile that is skewed toward goods often associated with advanced economies, but the profile also increases China's potential to sustain this path.

Malaysia started its transformation process earlier than China and achieved industrial clusters exhibiting sophisticated export profiles that by the year 2000 also resembled those of advanced economies. In its 529 new products exported over 1962–2000, 352 (67%) belonged to the top three industrial clusters mentioned earlier. However, certain structural factors appear to have impeded a faster expansion of industries in the country's consumer durables cluster. Toward the end of the study period, Malaysia lags behind China in the advanced goods component of its export profile.

In contrast to the two former countries, the transformation of the Ghanaian economy appears far behind in new product content and increasing value. Only 245 new products appear in the country's export basket in the 39 years after 1962, of which only 13 are capital goods. Ghana's export profile and hence economic structure are dominated by agricultural and other primary products throughout the period. The relatively less technical nature of these clusters prevents the country from advancing to a product space featuring more complex products, and hence slows the evolution of its industrial structure.

This study also discusses the role policies and institutions may have played to improve the proximity of each country's existing production structure to more innovative and sophisticated activities. Drawing from existing literature, the discussion suggests that policy and institutional reforms seem to be key factors in inducing the transfer and absorption of foreign technology, allowing both China and Malaysia to advance more rapidly into the capital and consumer durable goods components of the forest. Ghana offers interesting insights in contrast to those two countries. In its case, unfavorable initial conditions and a relatively short life of transformation have not enabled the policy and institutional reforms initiated in the late 1980s and early 1990s to stimulate anywhere near a rapid transformation of the economy. Although Ghana significantly improved its investment environment to analyze the dynamics of structural transformation in China, Malaysia, and Ghana can be extended to the other developing countries in the Feenstra et al. (2005) data set. Such generalization will help classify these countries based on the nature and patterns of their comparative advantages, and hence on the similarity of their structural transformation processes. With such a classification, it may be possible to recommend to similar countries policies that facilitate a stepwise jump of private enterprises into innovative activities in order to accelerate the structural transformation process. The patterns of this transformation may differ from those exhibited by China and Malaysia, but they will at least lay the foundation for the development of RCAs in goods with high technological intensity instead of just primaries.

APPENDIX: METHODOLOGICAL NOTES

We follow the methodology described in the appendix of Hausmann and Klinger (2006, 29) to clean the 1962–2000 World Trade Flows data (Feenstra et al. 2005). In fact, we first calculate for each country and for each year the total exports in artificial products "A" and "X." Then we drop from the dataset any countries whose total exports in A and X are more than 5% of total exports. After that, we drop all products A and X from the dataset. This cleaning procedure results in a total number of commodities of 1,007, which is different from that reported in HK (2006), that is, 1,006 products.

Next, we generate the matrix of proximity for each year over the period 1962–2000. Given the difference in the total number of commodities between this study (1,007) and the HK study (1,006), we transform each matrix of proximity into a variable of proximity in order to compare their descriptive statistics. Tables A.1 and A.2 depict the descriptive statistics of the variable proximity for the year 1985 and the variable average proximity for the years 1998, 1999, and 2000 for the two studies.[19] As each of the two tables shows, the proximity is almost the same in the two studies.

Equipped with the average proximity for 1998–2000, we calculate the paths around trees and compare them to the ones reported on page 12 in HK (2006). Tables A.3 and A.5 report the 15 goods in the least dense part of the forest and the 15 goods in the densest part of the forest, respectively. From Table A.3, it is obvious that two goods in the least dense part of the forest in HK (2006) are not in the least dense part of the forest in the present study (referred to as Dynamics of Structural Transformation, or DST). Table A.4 shows their orders and paths in HK (2006) and in DST.

Table A.1. Descriptive statistics of proximity, 1985

	DST	**HK (2006)**	**Difference**
Number of products	1007	1006	1
Number of observations	1014049	1012036	2013
Minimum	0	0	0
Maximum	1	1	0
Mean	0.1341659	0.129338	0.0048279
Standard deviation	0.1426936	0.1410314	0.0016622

Table A.2. Descriptive statistics of average proximity, 1998–2000

	DST	**HK (2006)**	**Difference**
Number of products	1007	1006	1
Number of observations	1014049	1012036	2013
Minimum	0	0	0
Maximum	1	1	0
Mean	0.1007412	0.1007126	0.0000286
Standard deviation	0.1230228	0.1240665	–0.0010437

Table A.5 reports the 15 goods in the densest part of the forest. As that table shows, six goods in the densest part of the forest in HK (2006) are not in the 15 goods in the densest part of the forest in DST. Their orders and paths in HK (2006) and in DST are reported in Table A.6.

It is obvious from tables A.3 through A.6 that discrepancies exist between our paths and those reported in HK (2006). These discrepancies are probably due to the difference in the data cleaning procedure. In this study, we first identify year per year any country with a share of total exports in

[19] HK (2006, 29) report the descriptive statistics of the proximity for 1985 and average proximity for 1998–2000. The column referring to our study is headed "Dynamics of Structural Transformation," or DST.

products A and X in total exports of more than 5%. Once a country satisfies the above criterion, it is dropped in the data set not only in that particular year but in all other years. In HK (2006), it is not obvious how the selection of countries on the basis of the 5% threshold is done.

Table A.3. The 15 goods in the least dense part of the forest, 1998–2000

SITC4	Order: DST	Order: HK	Path: DST	Path: HK	Path Diff.
9110	1	2	6.435	7.3	–0.865
6553	2	3	8.248	9.6	–1.352
0019	3	1	9.547	3.2	6.347
2655	4	4	11.645	12.6	–0.955
5620	5		16.662		
0901	6		24.909		
6344	7	8	24.909	28.9	–3.991
5723	8	11	25.099	31.5	–6.401
2235	9	9	26.415	29.2	–2.785
4245	19	5	26.554	25.9	0.654
2231	11	7	32.52	26.7	5.82
2440	12	12	35.566	31.1	4.446
0742	13	15	36.624	40.7	–4.076
2654	14	13	36.759	34.5	2.259
0721	15	14	37.54	40.3	–2.76

Table A.4. Goods in the least dense part of the forest in HK but not in DST

SITC4	Order: DST	Order: HK	Path: DST	Path: HK	Path Diff.
2640	18	6	46.71	26.0	20.71
6545	22	10	53.28	31.2	22.08

Table A.5. The 15 goods in the densest part of the forest, 1998–2000

SITC4	Order: DST	Order: HK	Path: DST	Path: HK	Path Diff.
7439	1		195.684		
5114	2		196.636		
7492	3		197.424		
6418	4		197.888		
7449	5	12	197.891	200.5	–2.609
8932	6	7	199.037	196.2	2.837
6633	7		199.858		
8121	8		199.873		
8935	9	10	200.361	199.2	1.77
8939	19	9	200.97	198.1	2.87
6921	11	13	204.664	204.6	0.064
5335	12	8	205.506	197.5	8.006
6210	13	11	206.641	199.8	6.841
6785	14	14	210.472	208.2	2.772
6996	15	15	211.659	208.7	2.959

Table A.6. Goods in the densest part of the forest in HK but not in DST

SITC4	Order: DST	Order: HK	Path: DST	Path: HK	Path Diff.
6632	62	6	182.733	195.5	−12.767
7139	56	5	183.956	195.1	−11.144
7849	24	4	192.184	194.8	−2.616
6911	25	3	191.896	194.4	−2.504
7919	18	2	194.137	192.9	1.237
7868	29	1	190.677	192.1	−1.423

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