Limited Catch-up and Economic Growth[1]

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Abstract: This paper provides both a theoretical and empirical analysis on the relationship between trade structure and economic growth. We propose the concept of limited catch-up to describe a country's strategy to exports products with technological contents higher than what the international division of labor based on comparative advantage allows it to. Based on a method developed by Hausmann et al. (2005) to measure the technological content of an exported product, we have defined the limited catch-up index (LCI) and calculated it for 112 countries in the period of 1965-2005. Our descriptive and econometric analysis shows that countries adopting the limited catch-up strategy have grown faster than those that have not. In addition, there is an optimal level of catch-up. We have also shown that China has adopted the limited catch-up strategy and has quickly upgraded the technological contents of its exports. It is invalid to claim that China's exports have been only in labor-intensive products.

Keywords: trade, economic growth, limited catch-up

[1] We thank Robert Feenstra for providing us with part of the data. Huiwen Li, Kai Guo, and participants of the East Asian Institute-School of Economics, Peking University conference on Chinese economy provided useful comments. Shi'e Zhu provided excellent supports in data analysis.

Limited Catch-up and Economic Growth

1. Introduction

With a bourgeoning foreign reserve that is soon to reach a trillion US dollars, it becomes a hotly debated issue that whether China is exporting too much. It is widely believed that China heavily relies on labor-intensive exports and this strategy is not sustainable. However, most studies fail to assess China's export strategy from an international perspective. The world trade pattern has generally followed the rule of comparative advantage with poorer countries exporting labor-intensive products and richer countries exporting capital-intensive products. Does China fit into this international division of labor, or has it overtaken it? The purpose of this paper is to provide an answer on this question and link a country's trade strategy with its record of economic growth.

We propose the concept of "limited catch-up" to describe the trade strategy by which a country exports products that have higher technological contents than what the comparative advantage-based international division of labor allows it to. The limited catch-up strategy, or the LC strategy subsequently, is different from the catch-up strategy defined by Lin, Cai, and Li (1994) in that it advocates a catch-up relative to a country's position in international division of labor, not an absolute catch-up that aims at catching up with the most advanced technology in the world. When it is compared with the world technological leaders, a country with the LC strategy is still located at a lower position in the world technological ladder. However, the LC strategy is also different with the comparative advantage strategy (subsequently, the CA strategy) defined by Lin et al. (1994) in that it indeed advocates a catch-up relative to a country's position in international division of labor.

We define an index to measure limited catch-up and call it the limited catch-up index (LCI). The definition is based on a method developed by Hausmann, Hwang, and Rodrik (2005) to measure the technological contents of a country's exports. The key element of Hausmann et al. (2005)'s method is what we call the technological sophistication index (TSI) for each exported product. It is the average per-capita GDP of countries that export the product, weighted by each country's relative weight of the

product in world trade. Then, the technological content index (TCI) of a country's exports is defined as the weighted average of the TSI's of the country's exported products. Using the COMTRADE data, we have calculated the TCI's for 112 countries in the period of 1965-2005. Then, for each year, we estimate a linear function between the logarithm of TCI and the logarithm of per-capita GDP. This linear function defines a match between each value of per-capita GDP and a value of TCI. Naturally, a country with a lower per-capita GDP tends to have a lower TCI, so the function defines what we call the comparative advantage-based international division of labor. Then, the LCI is defined the gap between a country's actual TCI and the value projected by the linear function based on its per-capita GDP. A positive LCI implies that a country's exports have higher technological contents than that is allowed by the international division of labor, so this country has limited catch-up. On the other hand, a negative LCI implies that a country falls behind the international division of labor.

Theoretically, the LC strategy can bring faster economic growth than the pure CA strategy. By the CA strategy, a country should improve the productivity of the products that it has comparative advantage on. However, this strategy will not expand the scope of a country's exports. In the case of a developing country, such a strategy will reinforce its position at the lower end of the technological ladder. On the contrary, the LC strategy requires that a country improve its productivity beyond the products that it currently has comparative advantage. As a result, its competitiveness edge moves outward toward the higher end of the technological ladder so it can export more products with higher technological contents.

Our descriptive and econometric studies have confirmed the theoretical prediction. We divide the period of 1965-2005 into eight five-year sub-periods and four ten-year sub-periods and use the LCI of the beginning year of each sub-period to predict the average growth rate of per-capita GDP in that sub-period. Our econometric analysis shows that following the LC strategy significantly increases a country's average growth of the next five and ten years by a significant margin. In addition, this positive effect exhibits an inverse U curve, which means that there exists an optimal level of catch-up. We have also found that China has not followed its comparative advantage defined by the international division of labor, but instead has followed the LC strategy. Our detailed

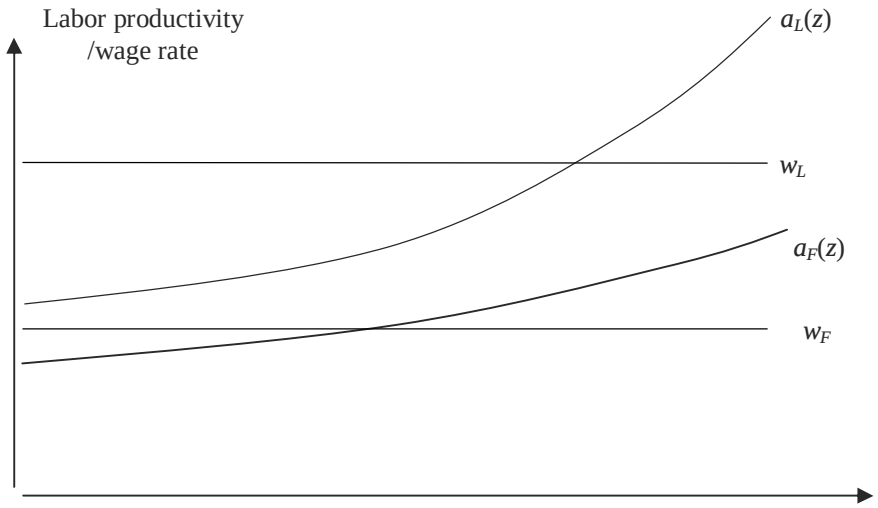
analysis further shows that China has fast upgraded its exports in the last 20 years.

The rest of paper is arranged as the follows. Section 2 uses a simple theoretical model to link the LC strategy with economic growth. Section 3 defines the LCI. Section 4 provides the econometric results. Section 5 presents data on China's technological upgrading in its exports in the last 20 years. Section 6 concludes the paper.

2. A simple model of limited catch-up

Our simple theoretical model is adapted from Krugman (1990). The key idea of the model is the follows. Countries compete with each other in exporting the same set of products. The competition is based on the real wage that a country has to pay in producing a specific product, which is defined as the wage rate weighted by the labor productivity. If a country has the lowest relative cost, then this country produces and exports the product, and all the other countries do not produce it. Low-income countries have the advantage to have lower labor cost, but high-income countries have the advantage to have higher labor productivity. It is usually the case that higher labor productivity is corresponding to higher technological contents. Therefore, there will emerge an international division of labor by which low-income countries produce and export products with low technological contents and high-income countries produce and export products with high technological contents. In the following analysis, we restrict our attention to the case of two countries.

Figure 1. Labor productivity and wage rates in the two countries

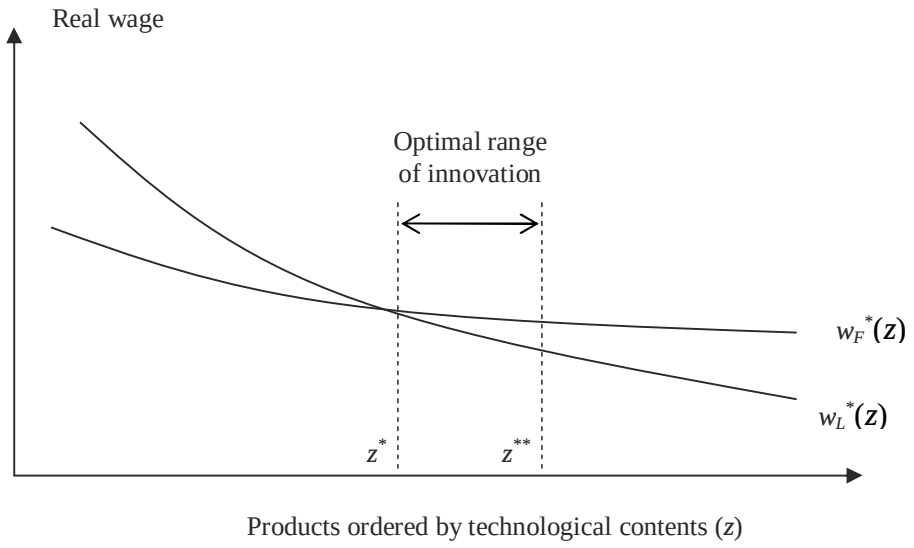


We start with assuming that the only factor needed to produce a product is labor and the technology exhibits constant return to scale. This second assumption ensures that there is only one producer for each product. There is a continuum of products ordered by their technological contents from the lowest to the highest. Let z be the index of the products as well as their technological contents. A larger z represents a product with a higher level of technological contents. There are two countries competing to produce the products. One of them is the technological leader, and the other is the technological follower. Let $a_L(z)$ represent the leader's labor productivity in producing the product z, and $a_F(z)$ represent the follower's. We follow Krugman (1990) to assume that both a_L and a_F increases in z, but a_L is higher than a_F for any z, that is, the follower has lower labor productivity than the leader in producing every product. Figure 1 shows this assumption. The figure also present the wage rates of the leader and the follower, w_L and w_F. It is natural to assume that w_L is higher than w_F.

The competition between the two countries is centered at the two countries' real wage rates, which are defined as $w_L^*(z) = w_L/a_L(z)$ and $w_F^*(z) = w_F/a_F(z)$, respectively. If a country can produce a product with lower real wage than the other country, then it can

drive out the other country out of the market by lowering the price of the product. Because of our assumption about the labor productivity and wage rates, the real wage rates in both countries decline as z increases, but the leader's decline faster than the follower's. This leads to a single cross, z^*, between the two wage rate schedules, as shown in Figure 2. Thus, for products with $z < z^*$, $w_F^*(z) < w_L^*(z)$, so the follower has an advantage to produce them; for products with $z > z^*$, $w_F^*(z) > w_L^*(z)$, so the leader has an advantage to produce them.

Figure 2. Real wage rates and the division of labor



Now suppose that the follower wants to improve its labor productivity. Should it make improvements on the products that it has comparative advantage over and is currently producing, i.e., the products with an index less than z^*, or do that on the products beyond z^*? If improvements are made to products below z^*, the competitiveness and profitability of these products are enhanced. However, since the competitiveness of the products beyond z^* has not been improved, the country cannot expand its range of exports. Moreover, if the leader keeps innovating new products, sticking to its comparative advantage will enlarge the follower's technological gap with the leader. In the long run, economic growth depends on the expansion of the range of products. Therefore, improving the productivity of products above z^* will help more with a country's growth than improving the productivity of products below z^*.

However, the above analysis did not consider the cost of innovation. It is conceivable that the cost of innovation increases with the sophistication of products. Therefore, a country faces the tradeoff between producing a wider range of products and higher marginal costs of innovation when it improves the labor productivity of products beyond z^*. This tradeoff leads to an optimal cutoff point for innovation, denoted by z^{**} in Figure 2, at which the marginal revenue of producing a new product is equal to the marginal cost of it. The interval $(z^*, z^{**}]$ thus is the optimal range of innovation. It is natural to predict that a country grows the fastest in the long-run when it produces and exports products up to z^{**}. When its range of production is below or above z^{**}, the country grows slower.

Therefore, limited catch-up means that a country expands its production, and thus exports, beyond z^* and up to z^{**}. It is a catch-up because it defies the international division of labor defined by comparative advantage (which allows a country to produce and export up to z^*); it is "limited" because the catch-up has a limit, i.e., it is not profitable for the country to produce and export beyond z^{**} given its comparative advantage defined by z^*. This implies that there is an inverse-U relationship between limited catch-up and economic growth: between z^* and z^{**}, expanding the scope of exports leads to higher growth rates; beyond z^{**}, expanding the scope of exports leads to lower growth rates.

3. The limited catch-up index

Starting in this section, we will implement an empirical test of the LC strategy. The key to the implementation is to empirically identify the international division of labor and to measure limited catch-up. This section will take up these two tasks. Our strategy to identify the international division of labor is similar to that of the revealed comparative advantage. Unlikely what we have assumed in the simple theoretical model, in reality each country exports a wide range of products instead of those below a certain level of technological contents (i.e., z^* in the model). Therefore it is a question that how we assess whether a country is following its comparative advantage. We deal with this issue by adopting the method developed by Hausmann et al. (2005) to obtain a compounded index, i.e., the TCI, of the technological contents of a country's exports. Then we regress TCI on

per-capita income to obtain the world average export pattern, which defines the international division of labor. Having a higher TCI than what is predicted on the regression line implies that a country adopts the LC strategy. Below, we first introduce the data that we are going to use.

Data

We obtain trade data for 112 countries/regions in the period of 1965-2005 from two sources. One is the World Trade Flow (WTF) compiled by Robert Feenstra that provides us data for the period of 1965-2000. The other is the COMTRADEE maintained by the United Nations that provides us data for the period of 2001-2005. Appendix 1 lists the names of these countries/regions. WTF uses SITC 4-digit product classification system and has about 1200 products. It gives primacy to the trade flows reported by the importing country, assuming that these are more accurate than reports by the exporters (Feenstra et al., 2005). If the importer report is not available for a country-pair, then the corresponding exporter report is used instead. From 1984 to 2000, WTF excludes trade flows at 4-digit SITC classification when they are less than 1000 US dollars. COMTRADE uses the HS 6-digit system and has more than 5000 products. It relies on the reports by the exporting countries. In our sample countries, there were countries that failed to report their trade data in certain years. Some countries had a lag of several years in reporting their data. Therefore, data missing is more severe in more recent years. But the total trade volume in the resulted sample accounts for about 80% of the actual world total in each year. We do not convert the two systems into one because our main purpose is to get the compounded technology content index at the country level, using the two systems for different years will not affect our results in significant ways.

GDP figures are in PPP US dollars complied by PWT 6.1. We have obtained data from three sources. For 1965-2000, we get data from PWT 6.1. Detailed description of the data can be found in Heston, Summers, and Aten (2002). For 2001-2005, we get data for most countries from the data source compiled by the Groningen Growth and Development Centre (GGDC). We use the GGDC figures primarily because GGDC uses PPP converters similar to those used by PWT 6.1. In cases that GGDC does not provide

data, we use the figures published in the UNDP *Human Development Report*.[2]

Construction of the LCI

We start with constructing the technological sophistication index (TSI) for each 4-digit product. Our method is directly adopted from Hausmann et al. (2005). To start, we use subscript *j* to index countries and *l* to index products, and superscript *t* to denote years. Then, let Y_j^t stand for the per-capita GDP of country *j* in year *t*, and x_{jl}^t stand for the export value of product *l* in country *j* in year *t*. The total export value of country *j* in year *t* is $X_j^t = \sum_l x_{jl}^t$. Then, the TSI of product l in year *t* is defined as

$$(1)\quad TSI_l^t = \sum_j \frac{x_{jl}^t / X_j^t}{\sum_j x_{jl}^t / X_j^t} Y_j^t .$$

The reason that the share, rather than the absolute value, of a particular product is used as the weight is to avoid the dominance of large countries. Higher income countries tend to have higher labor productivity, so by our theoretical model they tend to produce products with more technological contents. The construction of the TSI uses an approach similar to that used by the revealed comparative advantage: a product has a higher TSI if it is exported more by high income countries.

The technological content index of country *j*'s exports is then defined as the weighted average of the TCI's of its exported products:

$$(2)\quad TCI_j^t = \sum_l \frac{x_{jl}^t}{X_j^t} TSI_l^t .$$

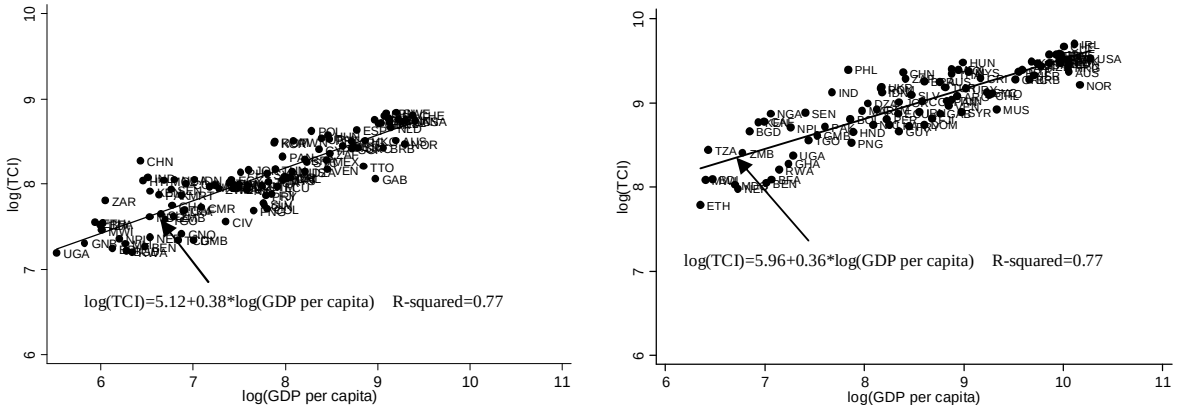
This definition facilitates our treatment of the relationship between TCI and per-capita GDP as a way to represent the international division of labor. TCI of a country is a weighted average of the per-capita GDP of all the countries in world. Indeed, for any year,

[2] GDP figures of the following countries/regions in 2001-2003 come from the HDR: Barbados, Benin, Bolivia, Burkina Faso, Burundi, Cameroon, Central African Republic, Costa Rica, Dominica, El Salvador, Fiji, Gabon, Gambia, Guinea, Guyana, Honduras, Jamaica, Madagascar, Malawi, Mali, Mauritius, Mozambique, Nepal, Nicaragua, Niger, Panama, Papua New Guinea, Paraguay, Rwanda, Senegal, Seychelles, Togo, Trinidad and Tobago, Tunisia, Uganda, Tanzania, Uruguay, Zambia, and Zimbabwe. The HDR has not published data after 2004. We extrapolate the GDP figures of the above countries for 2004 and 2005 by assuming that they grew by their respective average growth rates of 2001-2003.

we have $\sum_j TCI_j^t = \sum_j Y_j^t$; that is, the TCI and per-capita GDP have the same mean. It is well understood that only a weak form of comparative advantage exists when the number of products exceeds two (Dixit, 1980). It is thus a question as to how we represent comparative advantage in international trade. In the framework of our theoretical model, high-income countries tend to produce and export products with more technological contents. A corollary is that the international division of labor should require that a country's TCI depend positively on its per-capita GDP. One scenario is that the TCI is equal to per-capita GDP for each country in each year. In reality, though, a positive correlation between the two variables suffices to show comparative advantage at working.

We still adopt the "revealed" approach to use the existing trade pattern of a particular year to represent the working of comparative advantage. For that, we run a linear regression of the logarithm of TCI on the logarithm of per-capita GDP for each year and treat the fitted line as the representation of the international division of labor defined by comparative advantage in each year. Figure 3 shows the data and the regression lines for 1980 and 2003. The goodness of fit is almost perfect for both years (and actually for all the years).

Figure 3. International division of labor: 1980 and 2003



1980 2003

Let $(\ln TCI_{jt})^f$ be the fitted value of $\ln TCI_{jt}$ on the regression line. Then we define the

limited catch-up index of country *j* in year *t* as

(3) $LCI_{jt} = \ln TCI_{jt} - (\ln TCI_{jt})^{f}$.

When the index is positive, a country is exporting goods that have higher technological contents than what are implied by its per-capita GDP in line with comparative advantage; when the index is negative, the reverse is true. Since it is defined in logarithm terms, the TCI provides an intuitive interpretation to a deviation from the comparative advantage. If the TCI is 0.1 for a country in a specific year, then we can say that this country is catching up by a pace of 10% over its comparative advantage. Our theoretical prediction is that a country's growth rate depends on its LCI in an inverse U relationship. This makes our approach to catch-up different from Hausmann et al. (2005)'s approach. Hausmann et al. use the absolute value of TCI to predict a country's growth rate, so the catch-up in their paper is absolute catch-up in our framework. However, as our theoretical model has shown, catch-up beyond a certain level is detrimental rather than helpful to growth. So our approach is more sensible than theirs.[3]

Some descriptive evidence

Our aim is to study the relationship between the LC strategy and economic growth. To establish a positive relationship between the two, we ought to show that countries with higher TCI's grow faster than countries with lower TCI's. Here we compare several countries/regions in terms of TCI's. Figure 4 shows the trends of TCI's in several economies in the period of 1965-2005. The chat on the left is for South Korea and Taiwan, and the chat on the right is for the US, UK, and France. It is evident that the world technological leader should have a TCI of zero because by definition it does not need to catch up with anyone, nor does it fall behind anyone. Another interpretation is that the technological leader strictly follows its comparative advantage. Interpreting in this way, we find that there was a clear trend of convergence in the case of South Korea and Taiwan. Both economies started with very high LCI's but have followed a declining trend in the last 40 years. By 2005, South Korea approached zero, which means that it was

[3] In their regression analysis, Hausmman et al. (2005) add per-capita income as a control variable, so our approach is the same as theirs if we only run a linear regression. However, our theoretical model predicts that the relationship between GDP growth rate and our LCI follows an inverse-U curve. This means that we need to consider nonliearity in our regression. Then our approach differs from Hausmman et al. (2005)'s.

close to its position of comparative advantage. The US started in 1960 with a TCI equaling to zero, but has since followed a downward trend. This shows that the US is falling behind in technological innovations relative to its income. The UK and France started with small positive TCI's but gradually fell down, and began to have negative TCI's in recent years.

Figure 4. TCI's of several advanced economies

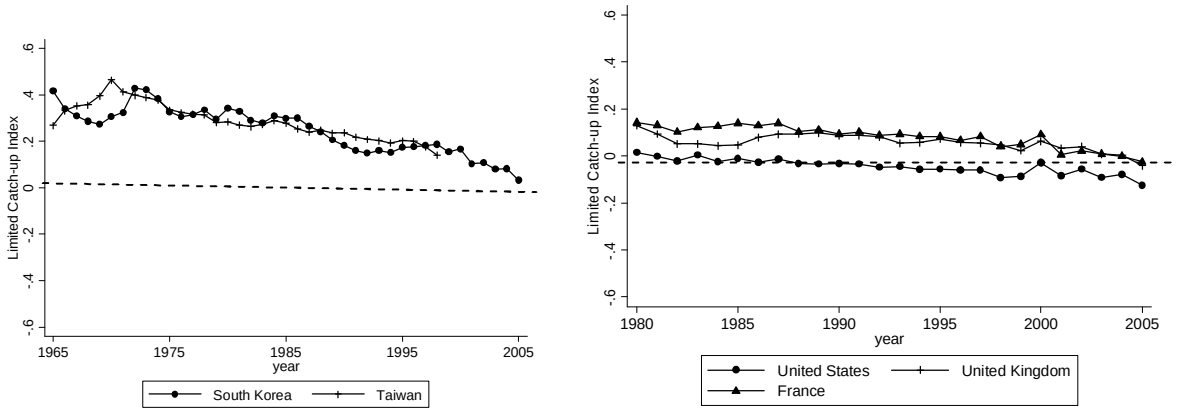


Figure 5. TCI's of China, India, and Argentina

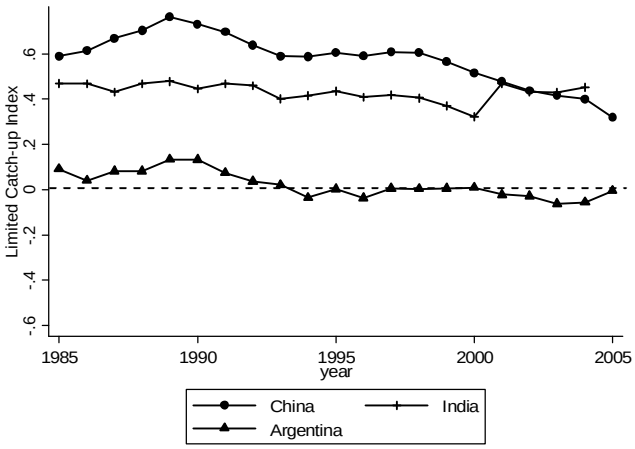


Figure 5 further compares the TCI's of three countries, China, India, and Argentina in the period of 1985-2005. Argentina maintained positive but small TCI's before 1992, but has since fallen below zero. China has maintained very high TCI's. It was 0.5 in 1985,

and increased in the late 1980s. However, China's TCI has been decreasing since 1990 although it was still higher than 0.3 in 2005. Before 2001, India had had smaller TCI's than China, but began to overtake China in 2004. While Argentina had converged to its comparative advantage in the early 1990s, China still has a long way to do that despite that its speed of convergence is high. Comparing Figure 4 and Figure 5, we find that China's TCI in 2005 was the same as that of South Korea and Taiwan around 1985. Therefore, China will have 20 some years before it converges to its comparative advantage. To the extent that catch-up leads to higher economic growth rates, we expect that China's high growth will last for another 20 years.

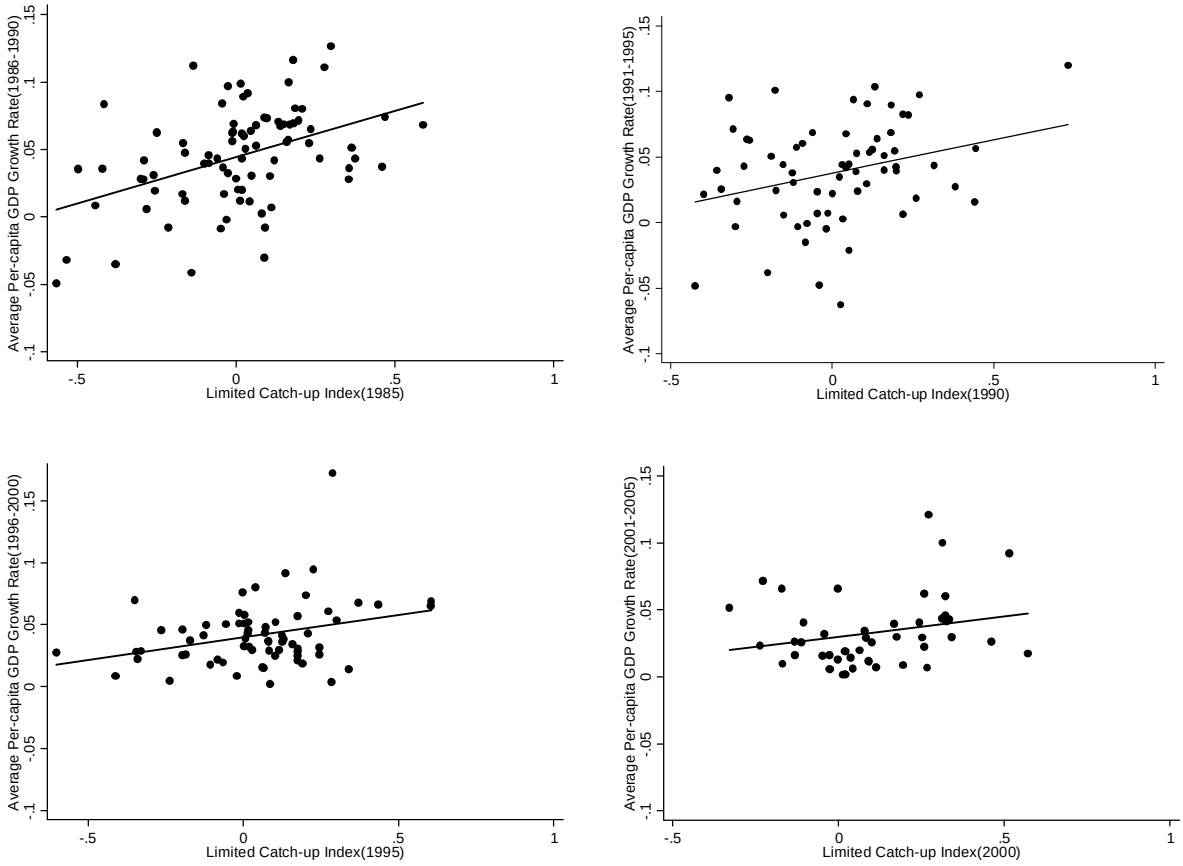
Porter (1990) distinguishes three stages for a country's development in terms of its competitiveness. The first stage is the investment stage. In this stage, a country does not need to engage in innovations, but can simply adopt technologies innovated by advanced countries. The second stage is the innovation stage. Countries in this stage need to innovate in order to maintain their competitiveness. The third stage is the consumption stage. When countries achieve this stage, innovations slow down and people can enjoy the benefits of innovations accumulated in the second stage. Putting Porter's theory into our framework, we find that the investment stage corresponds to the period when a country has both negative TCI's and low income; the innovation stage corresponds to the period when a country maintains positive TCI's; and the consumption stage corresponds to the period when a country has high income and zero or negative TCI's. In this regard, the US, UK, and France have entered the consumption stage, but Argentina is a pre-mature consumption society because it began to have negative TCI's with relatively low income. Taiwan and South Korea are finishing their innovation stage and are about to enter the consumption stage. China and India are still in the innovation stage. If the recent trend is to last, India will stay longer in the innovation stage than China in the future. This is because China started its takeoff earlier than India did.

4. Cross-country analysis

To provide a flavor of our analysis, we take 1985, 1990, 1995, and 2000 as the

starting year, respectively, and plot in Figure 6 the average per-capita GDP growth rates of the next five years against the TCI's in each starting year.[4] It is evident that higher TCI's lead to higher average economic growth in the next five years. The coefficient of LCI in the simple linear regression is 6.9, 4.8, 3.6, and 4.7 for the four periods, respectively. This means that when a country increases its degree of catch-up by 10 percentage points, its income growth rate will increase 0.69, 0.48, 0.36, and 0.47 percentage points. Because of the impacts of the Asian Financial Crisis, the coefficient for the period of 1996-2000 is relatively low.

Figure 6. LCI and Per-capita GDP growth: 1985-2005



Using the above calculated figures, we can gauge the contribution of limited catch-up to economic growth in China. In the period of 1990-2005, China's per-capita GDP grew by an average of 8.7% per annum and its average TCI was 0.58. Using the

[4] We only plot data of larger economies and exclude a few cases with military coups.

average of the three coefficients of TCI in the period, which is 4.37, as the marginal contribution of limited catch-up, we get the contribution of limited catch-up to be 2.53, which is 29% of China's average growth rate in this period. This is a very large effect.

Our econometric analysis adopts the two-way fixed-effect panel model to control for time and country-specific effects. According to our theoretical model, the impact of LCI on economic growth should exhibit an inverse U relationship. Therefore, the LCI and its square in the starting year are the major concerns for us.

We will also include in our regressions the following control variables, all measured in the starting year, the logarithm of per-capita GDP (PPP USD), share of investment in GDP (%), share of trade in GDP (%), share of government expenditure in GDP (%), a political liberty index, an exchange rate regime index, and the illiteracy rate (%). Data for the shares of investment, government expenditure, and trade are from PWT6.1. The political liberty index is provided by Polity IV (Marshall and Jaggers, 2004), which is a widely accepted dataset to measure world democratization. Polity IV includes annual composite indicators measuring both "institutionalized autocracy" and "institutionalized democracy". The polity score is defined as the difference between the democracy indicator and the authoritarian indicator. Since each indicator is an additive eleven-point scale (0-10), the index is scaled between -10 and 10 consequently. The higher is the number, the higher is the level of political liberty of a country. The exchange rate regime index is from Reinhart & Rogoff (2002) who study the exchange rate regimes across more than one hundred countries after World War II. They develop a novel system of re-classifying historical exchange rate regimes. One important difference between their study and previous classification efforts is that they employ an extensive data base on market-determined parallel exchange rates. They arrive at 14 classes of exchange rate regime and give each class a number between 1 and 14; the larger is the number, the more liberal is the exchange regime. Lastly, the illiteracy rates are from Barro and Lee (2000).

We run two sets of regressions. One set is based on data of five-year averages, and the other is based on data of ten-year averages. Their results are presented in Table 1 and Table 2, respectively. For each dataset, we first run four regressions that use different control variables. The first only includes the share of investment in GDP and the share of

trade in GDP; the second adds log-per capita GDP to control the Solow-type convergence; the third adds the share of government expenditure in GDP, the political liberty index, and the exchange regime index; and the last adds the illiteracy rate. Changes of the illiteracy rate in most countries are small, so its results in a panel estimation are not reliable. We also run one regression with all the control variables but with the square of LCI being dropped.

Table 1. Effects of the LC strategy on economic growth: 5-year averages (1965-2005)

	(1)	(2)	(3)	(4)	(5)
LCI	4.92*** (1.37)	3.96*** (1.30)	7.09*** (1.72)	4.95*** (1.17)	4.79*** (1.10)
LCI^2	-3.59 (4.05)	-4.31 (4.02)	-4.07 (4.23)	1.83 (3.04)	
Share of investment in GDP (%)	0.14* (0.08)	0.12* (0.07)	0.12* (0.69)	0.01 (0.03)	0.01 (0.03)
Share of trade in GDP (%)	0.00 (0.01)	0.01 (0.01)	0.01 (0.01)	-0.00 (0.01)	-0.01 (0.01)
Log(per-capita GDP)		-0.21E-3*** (0.04 E-3)	-0.08E-3** (0.04 E-3)	-0.16E-3*** (0.05 E-3)	-0.16E-3*** (0.05E-3)
Share of government expenditure in GDP (%)			0.04 (0.04)	0.02 (0.03)	0.02 (0.03)
Political liberty index (-10 – 10)			0.02 (0.03)	0.01 (0.03)	0.02 (0.03)
Exchange rate regime (1 – 14)			0.35*** (0.08)	0.28*** (0.05)	0.28*** (0.05)
Illiteracy rate (%)				0.07*** (0.02)	0.07*** (0.03)
Number of observations	849	849	773	662	662
Number of countries	112	112	95	84	84
Adjusted R^2	0.35	0.36	0.41	0.49	0.49

Notes: Standard errors are reported in the parentheses. *, **, and *** indicate, respectively, the 10% significance level, 5% significance level, and 1% significance level.

By the results of regression (5) in Table 1, increasing the LCI by 10 percentage points will result in an increase in the average GDP growth rate in the next five years by

0.48 percentage points. This result is significant at the 1% significance level. Regression (5) in Table 2 shows that the effect is smaller for the next ten years, which is only 0.34, but nevertheless still statistically significant. The inverse U curve is not found in none of the regressions using the dataset of five-year averages, but is found in three out of the four regressions using the dataset of ten-year averages. The insignificant result of regression (4) has something to do with the illiteracy rate whose lack of variations could have caused a multicollinearity problem. Using the results of regression (3), it is found that the peak of the inverse U curve is at LCI = 0.27. That is, a catch-up of 27% is the best for GDP growth.

Table 2. Effects of the LC strategy on economic growth: 10-year averages (1965-2005)

	(1)	(2)	(3)	(4)	(5)
LCI	4.91***	3.72**	6.00***	3.28***	3.35***
	(1.87)	(1.72)	(2.01)	(1.20)	(1.10)
LCI^2	-10.26*	-11.47*	-11.09*	-0.92	
	(5.93)	(5.98)	(5.96)	(2.90)	
Share of investment in GDP (%)	0.15	0.12	0.11	-0.03	-0.03
	(0.10)	(0.09)	(0.07)	(0.03)	(0.03)
Share of trade in GDP (%)	-0.00	0.01	0.00	-0.011*	-0.011*
	(0.01)	(0.01)	(0.01)	(0.006)	(0.006)
Log(per-capita GDP)		-0.27E-3***	-0.12E-3***	-0.22E-3***	-0.22E-3***
		(0.06 E-3)	(0.05 E-3)	(0.06E-3)	(0.05E-3)
Share of government expenditure in GDP (%)			0.11**	0.01	0.01
			(0.05)	(0.03)	(0.03)
Political liberty index (-10 – 10)			0.04	0.02	0.02
			(0.04)	(0.04)	(0.03)
Exchange rate regime (1 – 14)			0.36***	0.19***	0.19***
			(0.10)	(0.06)	(0.06)
Illiteracy rate (%)				0.07***	0.07***
				(0.02)	(0.02)
Number of observations	435	435	394	334	334
Number of countries	112	112	95	84	84
Adjusted R^2	0.31	0.33	0.41	0.56	0.56

Notes: Standard errors are reported in the parentheses. *, **, and *** indicate, respectively, the 10% significance level, 5% significance level, and 1% significance level.

Judging by this result, China is now catching up too much. One explanation is that more than 60% of Chinese exports are processing trade so the technological contents of its own manufacturing are not as high as its TCI shows. Ping et al. (2006) finds that about 20% of China's exports can be explained by vertical integration. Taking 20% as the share of contribution made by imported inputs to China's TCI, then China's pace of catch-up was about at the optimal level in 2005 (Figure 5).

Among the control variables, initial level of GDP and the exchange rate regime have the most robust results. Initial per-capita GDP unambiguously reduces the average growth rate in both the next five and ten years. The speed of convergence is about 0.2 percentage points of reduction in GDP growth rate for one percent increase of per-capita GDP. A more flexible exchange rate regime strongly supports GDP growth. Moving up by one category from a less flexible regime to a more flexible regime increases GDP growth rate by 0.28 percentage points in the next five years and by 0.19 in the next ten years. Investment share in GDP has a positive effect only in the next five years, but not in the next ten years.

5. Technological upgrading in Chinese exports

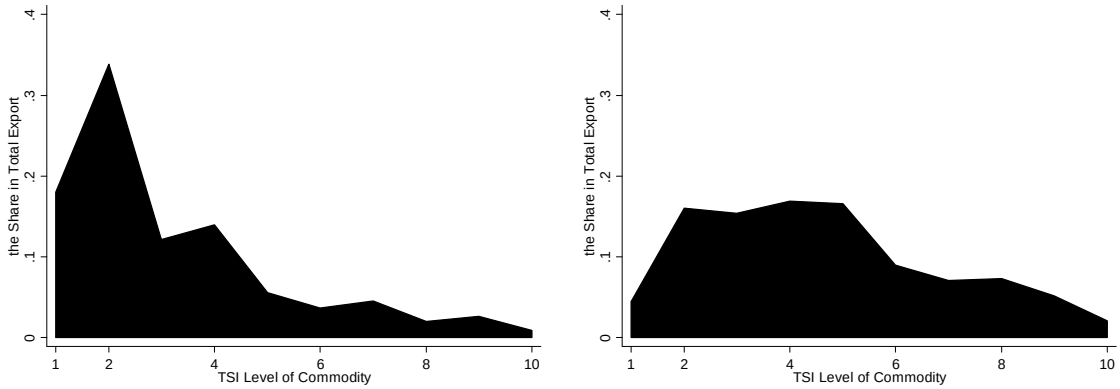
Up to this point, we have shown that China has adopted the LC strategy and shown that this strategy leads to higher economic growth in the world. In this section, we move a step further to provide more detail information on how China has upgraded the technological contents in its exports.

Technological upgrading and competitiveness of Chinese exports

In the last twenty years, the sophistication of Chinese exports has been improved fast. Figure 7 compares the situations in 1980 and 2000. The horizontal axis is the TSI of SITC 4-digit products. We divide the products into ten equal groups on the TSI scale. The vertical axis is the share of export of each group of products. It is clear that in the 20 years between 1980 and 2000, Chinese exports have uniformly moved from low TSI to high TSI products. In 1980, Chinese exports were highly concentrated in the first and second groups; in 2000, the concentration was fairly spread from the second to the fifth

groups.

Figure 7. Technological upgrading in Chinese exports: 1980-2000



1980 2000

Table 3 lists the top five exports in China in 1985, 1990, 1995, 2000, and 2005. The information provided by this table reinforces the information that we wanted to convey in Figure 7. Although exports of garments and shoes have always been strong, Chinese exports have decisively moved away from resource-based products, and the presence of electronic and other manufacturing goods has been greatly enhanced.

Table 3. Five most exported products in China

Year	Product code	Product name	Value (billion USD)	The share in total export(%)	Notes
1985	05	Vegetables and fruits	1.3	3.8	Primary products
	26	Cotton and other fibers	2.1	6.2	Primary products
	84	Garments and accessories	3.7	11.1	
	65	Textile fibers and related products	4.3	12.8	
	33	Crude oil and products	6.9	20.8	Primary products
1995	64	Footwear, gaiters and the like; parts of such articles	6.7	4.5	
	61	Articles of apparel and clothing accessories, knitted or crocheted	6.9	4.7	
	84	Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof	8.7	5.8	
	62	Articles of apparel and clothing accessories, not knitted or crocheted	14.3	9.6	
	85	Electrical machinery and equipment and parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles	19.0	12.8	
2000	64	Footwear, gaiters and the like; parts of such articles	9.9	4.0	
	61	Articles of apparel and clothing	13.4	5.4	

		accessories, knitted or crocheted			
	62	Articles of apparel and clothing accessories, not knitted or crocheted	18.9	7.6	
	84	Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof	26.8	10.8	
	85	Electrical machinery and equipment and parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles	46.1	18.5	
2005	90	Optical, photographic, cinematographic ,measuring, checking, precision, medical or surgical instruments and apparatus; parts and accessories thereof	25.5	3.3	
	61	Articles of apparel and clothing accessories, knitted or crocheted	30.9	4.1	
	62	Articles of apparel and clothing accessories, not knitted or crocheted	35.0	4.6	
	84	Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof	149.7	19.6	
	85	Electrical machinery and equipment and parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles	172.3	22.6	

Notes: The classification of commodities for 1985 is SITC-4 digits. Data are from Feenstra et al.

(2005). The classification of commodities for 1995, 2000, and 2005 is HS-6 digits. Data are from the Bureau of Customs of China.

We can also use Ballasa (1965)'s RCA index to show the upgrading of Chinese exports. Table 4 presents the RCA indices for several key products in selected years. It is clear that China's revealed comparative advantage has been decreasing in resource-intensive products including meats and meat products (01), vegetables and fruits (05), crude oil and related products (33), and textile fibers (65). On the other hand, China has become much more competitiveness in capital and technology-intensive products including metal products (75), office automation and data processing equipment (76), and electric equipment (77). Finally, China has maintained a strong position in garments (84) and shoes (85).

Table 4. The RCA Index of key Chinese exports in selected years[5]

Product code / Year	01	05	33	65	69	75	76	77	84	85
1985	186	206	175	453	84	5	30	17	398	176
1990	80	123	85	289	114	21	187	70	506	438
1995	51	108	33	225	127	78	211	80	483	804
2000	45	91	18	191	151	137	181	99	420	726

Source: Feenstra et al.(2005).

The problem of value-added

It is often argued that the contribution of domestic firms to China's technological upgrading has been weak because 60% of China's exports are processing trade. By this view, China is the world factory, but it is only an assembling factory. We do not deny that processing trade plays an important role in China's exports, but in the same time we believe that processing trade alone cannot fully account for China's technological upgrading. Table 5 presents Ping et al. (2006)'s calculation of the ratio of processing

[5] The product codes in the table are SITC two digit codes. Code 01is meat and meat products; 05 is vegetables and fruits, 33 is crude oil and products; 65 is textile fibers, 69 is metal products, 75 is office and automation and data processing equipment, 76 is telecom and recording equipment, 77 is electric equipment, 84 is garment and accessories, and 85 is shoes.

trade in the value-added of China's exports from 1992 to 2003. This ratio had indeed increased but the highest was only 22%. Therefore, processing trade cannot fully explain China's export upgrading.

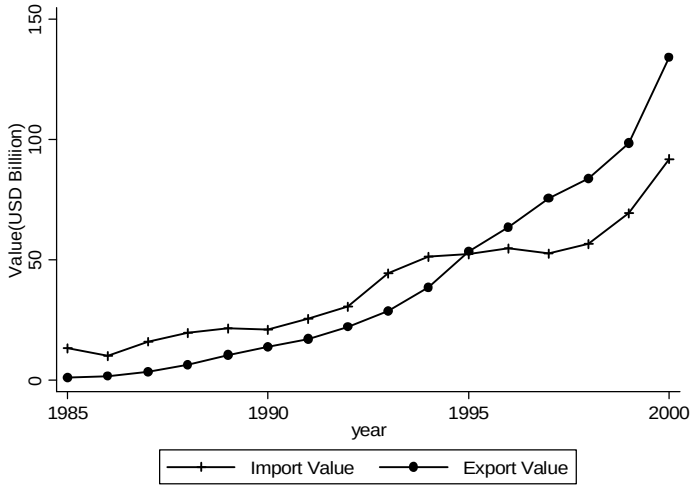
Table 5. Ratio of processing trade in value-added: 1992-2003

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Ratio of specialization	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.15	0.20	0.20	0.21	0.22

Source: Ping et al. (2006).

To further explore the issue, we compare the import and export values of products in SITC 7 in the period of 1985-2000. SITC 7 includes capital intensive products. Figure 8 presents the comparison. Before 1995, the export value of SITC 7 was smaller than its import value; after 1995, the trend has been reversed. This transition from a net importer to a net exporter shows that China has gained competitiveness in capital-intensive products. At the minimum, the fact that China can now compete in the world market itself is a sign for China's technological progress because it now can produce products that it could not in the past.

Figure 8. Export and import values of SITC 7: 1985-2000



6. Conclusions

In this paper we have studied China's trade strategy and linked it to its economic growth. Our central idea is the concept of limited catch-up. We have shown that China has adopted the limited catch-up strategy instead of the comparative advantage strategy in its exports. Our theory shows that the limited catch-up strategy could lead to higher economic growth, and our empirical analysis has proved this assessment. By our calculation, about 29% of China's annual per-capita GDP growth rate in the period of 1990-2005 was contributed by its adoption of the limited catch-up strategy. We have also provided detailed data on the technological upgrading of Chinese exports in the last 20 years.

One important implication of our analysis is that a developing country has to overtake its comparative advantage in order to catch up with advanced countries. In the long run, however, each country will converge to its comparative advantage. To reach a higher income level, however, the task for a country is to postpone this convergence. To use Porter (1990)'s jargon, a country should stay longer in the innovation stage. Our theory and empirical analysis provide a hint to reconcile comparative advantage and catch-up: in the short run, catch-up is necessary for a country to close its gap with advanced countries; in the long run, every country follows its comparative advantage.

Our empirical analysis shows that China is still in the catch-up stage. Using Korea and Taiwan as the reference, we have shown that China has about 20 years more for fast economic growth. This will ensure that China's per-capita GDP converges to nearly 8,000 USD before it falls to its comparative advantage. It is a decent income and would enable China to comfortably compete in the international market by then.

Appendix: Countries in the dataset

Algeria,Angola,Argentina,Australia,Austria,Bangladesh,Barbados,Belgium,Benin,Bolivia,Brazil,Burkina Faso,Burundi,Cameroon,Canada,Cent.Afr.Rep,Chad,Chile,China,China HK SAR,Colombia,Congo,Costa Rica,Cote Divoire,Cyprus,Dem.Rp.Congo,Denmark, Dominican Rp,Ecuador,Egypt,El Salvador, Eq.Guinea, Ethiopia, Fiji, Finland, France, Monac, Gabon, Gambia, Germany,Ghana,Greece,Guatemala,Guinea,GuineaBissau, Guyana,Haiti,Honduras,Hungary,Iceland,India,Indonesia,Iran,Ireland,Israel,Italy,Jamaica ,Japan,Jordan,Kenya,Korea Rep.,Madagascar,Malawi,Malaysia,Mali,Mauritania, Mauritius, Mexico,Morocco,Mozambique,Nepal,Netherlands,New Zealand, Nicaragua, Niger, Nigeria, Norway, Pakistan, Panama, Papua N.Guin,Paraguay,Peru,Philippines, Poland,Portugal,Romania,Russian Fed,Rwanda,Senegal,Seychelles,Sierra Leone, Singapore, South Africa, Spain, Sri Lanka,Sweden,Switz.Liecht,Syria,Taiwan, Tanzania, Thailand,Togo,Trinidad Tbg,Tunisia,Turkey,UK,USA,Uganda,Ukraine,Uruguay, Venezuela, Zambia,Zimbabwe

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