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# How dependent is the Chinese economy on exports and in what sense has its growth been export-led?

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ABSTRACT

This paper studies the interaction between foreign trade and domestic demand and supply in China's economic transformation. It compares China's export dependency with other economies using input–output analysis. The paper also conducts econometric analysis of provincial level data to examine causality between the growth of foreign trade and components of domestic demand, and causality between the growth of foreign trade and total factor productivity. The main message is that China's export dependency is significantly lower than implied by the headline exports-to-GDP ratio. Moreover, the contribution of export to economic growth in China came mainly from its impact on total factor productivity growth from a supply perspective rather than its multiplier effect from a demand perspective. This relationship was found to be stronger in the more developed coastal areas than in the less developed inland areas.



## 1. Introduction

After 30 years of economic transformation, China has emerged as the fourth largest economy and the third largest trading nation in the world. What role has foreign trade played in China's stellar growth performance? While there is a large body of literature that studies the rise of China as a major trading nation and its impact on the rest of the world, there has been little analysis of the relationship between foreign trade and China's domestic economy. This paper attempts to fill the void and devote its attention to the linkages between foreign trade and the domestic economy in China's remarkable story of "reform and opening up".

In popular debates about the role of foreign trade in China's growth, it has often been argued that, while the rate of economic growth in China has been high, the growth pattern has been unbalanced; the Chinese economy has become too export-dependent and is thus vulnerable to cyclical fluctuations in external demand, and needs to switch to a domestic-demand-led growth model. Lardy (2007), for example, claims that excessive reliance on net exports has been an important factor prompting Chinese government to switch to a more consumption-driven growth pattern. Ha (2008, p. 7) is a typical example of analyses that use exports-to-GDP ratio as the evidence of excessive reliance on exports by the Chinese economy.

However, the switch-of-growth-model argument is problematic because it mixes up the effects of external trade on an economy's cyclical developments and its long-term growth potential. From a longer term perspective, it is technological progress rather than demand that creates growth. When a country is open to international trade and competes on world markets, it is forced to adopt the most advanced production and management techniques; export growth should lead to economy-wide productivity gains through technological spillovers and other positive externalities. This is true for small

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economies like Hong Kong, for large economies like Mainland China, and also for industrialised countries like the US. Note, however, that the export-oriented growth model does not necessarily imply the existence of either a trade surplus or a trade deficit. It certainly does not promote trade surpluses.[1]

We focus in this paper on the interaction between foreign trade and domestic demand, and the role foreign trade has played in promoting technological progress and institutional changes in China's economic transformation. We define export dependency as the share of domestic value-added induced by exports to total value-added, and compare China's export dependency with other economies using input–output analysis. We find that China's export dependency is significantly lower than implied by conventional indicators such as the headline exports-to-GDP ratio. We also conduct econometric analysis with data at provincial levels to examine the relationship between the growth of international trade and different components of domestic demand, and also the relationship between the growth of international trade and total factor productivity. We test for Granger causality of fixed coefficients with panel data and find that the contribution of export to economic growth in China stems mainly from its impact on total factor productivity growth from a supply perspective rather than its multiplier effect from a demand perspective. We also find that this relationship was stronger in the more developed coastal areas than in the less developed inland areas. These findings indicate that the vulnerability of the Chinese economy as a whole to cyclical fluctuations in its major export markets is limited, even though the vulnerability of the coastal area is higher than the inland area.

The remainder of the paper proceeds as follows. In the second section we briefly review the strategies and policies that increased the openness of the Chinese economy and brought the "rules of the game" in China more in line with international standards and norms. Section III discusses the concepts of export dependency and their measurements by making use of industrial linkage analysis based on input–output tables. Section IV studies the contribution of foreign trade to growth by employing a newly developed methodology of Granger-causality tests in a panel data setting to analyse the relationship between export growth and the growth of different components of domestic demand, and between export growth and TFP growth, which is estimated using a non-parametric approach. The last section concludes the paper.

## 2. Strategies and policies

The story of the increasing domestic importance of China's foreign trade can be clearly understood from two perspectives. The first part of this story is the close relationship between foreign direct investment (FDI) and export growth. The second part of the story is the efficiency gains associated with external competitive pressures. While the Chinese government created "special economic zones" (SEZ) to promote export processing in the early 1980s, leakage of goods and components into the domestic economy and outright smuggling increased the connection between the export processing enclaves and the local economy.[2] In the second half of the 1990s, the Chinese government came to the view that international competition was an essential source of pressure that would ultimately force state-owned enterprises (SOEs) and banks to improve corporate governance and operating efficiency, and made extensive commitments to the World Trade Organization (WTO) to advance their domestic agenda of structural reforms. From a demand side perspective, the WTO membership would also allow the Chinese government to avoid having to get yearly renewals of the Most Favoured Nation (MFN) treatment through the US Congress, thus securing China's market access to the member economies of the WTO.

When China emerged in the late 1970s from two decades of self-imposed isolation, it found its capital stock outdated and technology significantly lagging behind its neighbours in East Asia. In order to update its capital stock and technology, it urgently needed foreign exchange to pay for imports of capital goods. It quickly came to the attention of the top Chinese leaders that China could learn from the export-led growth strategy of the four "small dragons" of Hong Kong, Korea, Singapore and Taiwan. To achieve this goal, the authorities launched a series of foreign trade reforms and promulgated a package of preferential policies to foreign invested enterprises (FIEs).[3] They relaxed controls on imports and encouraged exports by reducing tariff as well as non-tariff barriers, reforming the exchange rate system and broadening the scope of exports licenses and quotas.

Four SEZs were created in the southeast coastal area, aiming mainly at developing processing exports. To exploit and capture overseas markets, China also endeavoured to attract FDI but required the FIEs to sell a significant portion of their products in overseas markets. In other words, in the first phase of foreign trade reforms, there was a conscious effort by the government to shield domestic firms and markets from SEZs and FIEs. Overtime, however, processing trade and FIEs penetrated areas other than the SEZs. Processing trade grew to account for a half of China's total trade in the 1990s, while 60% of total trade in 2006 was attributable to FIEs (China Statistical Yearbook 2007).

As domestic economic and institutional reforms approached a deadlock in the later part of the 1990s, senior officials in China realized that international competition was an essential source of pressure that would ultimately force SOEs and banks to improve corporate governance and operating efficiency. Therefore, the authorities took the preparation for the entrance into the WTO as an opportunity to speed up domestic reforms and made substantial commitments in agricultural, industrial

[1] These arguments draw on He, Cheung, and Chang (2007).
[2] Panagariya (1991), for example, states that illegal imports covered a variety of products (watches, radios, televisions, cars etc al.), with the value of items confiscated by customs officials amounting to USD25 million in 1984.
[3] A comprehensive review of China's opening up and trade reforms is beyond the scope of this paper. Interested readers can refer to Lardy (2002) for a review of these reforms.

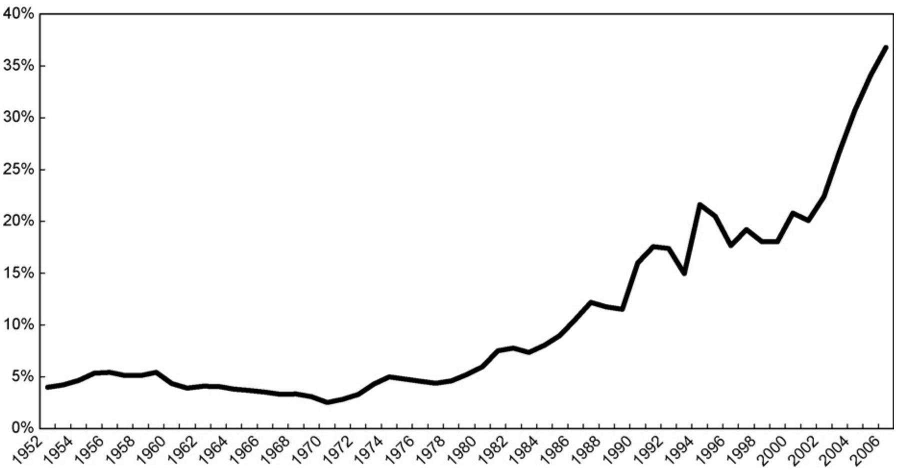


**Fig. 1.** China's exports-to-GDP ratio. Sources: China Statistical Yearbook 2007 and authors' estimates.

and service sectors despite the attendant risks and costs brought about to the economy. In addition to more tariff reductions, the WTO accession, as a milestone in China's foreign trade development, has pushed the march toward a market economy by playing important roles in, among others, SOE and banking system reforms.

Despite repeated efforts to reform the SOEs since the late 1970s, the SOE sector was still relatively inefficient and in great need of improvement in the 1990s. Mainly supported by government's direct subsidies as well as indirect subsidies in the form of state-owned banks' loans, SOEs accounted for over half of total investment but produced less than 30% of total output in 1999.[4] In the WTO commitment China fully signed the agreement on subsidies and countervailing measures, which stipulated that all central government subsidies should be removed. As China also committed to open up its financial sector, state-owned banks were obliged to operate in a manner consistent with market economy principles and not to offer subsidies to SOEs as before. In addition, China agreed to loosen terms of countervailing measures to cope with injuries to other economies caused by inappropriate subsidies. Positioned at the frontier of international competition, the SOE sector accelerated its pace of reforms while privatization flourished, leading to productivity growth across the board. Fu and Floor (2004), for example, by estimating the effects of exports on China's productivity at industry level during 1990–1997, find that export-oriented industries have been more efficient than non-export industries.

With regard to the banking system, the Asian financial crisis of 1997–1998 served as a wake-up call to the Chinese authorities and impressed upon them the urgency of shaking up the state-owned banks, which were technically insolvent with non-performing loans ratio once estimated to be over 50%,[5] reflecting the lack of effective corporate governance, competition and a modern legal framework. Against this backdrop, China made wide-ranging commitments to the WTO in banking, insurance, telecommunications and professional services such as accounting and legal services. Thus, foreign banks are allowed to conduct foreign currency businesses upon accession into the WTO and renminbi business within five years of accession. A new round of reforms, exemplified by the foundation of the China Banking Regulatory Commission (CBRC) and four asset management companies (AMC), were launched. As a result, banking efficiency was improved while non-performing loans ratio declined to below 9% in late 2005 (CEIC database).

In short, as foreign competition was deliberately used to counteract bureaucracy and inertia in China's institutional reforms in the 1990s, foreign trade reform and the opening-up strategy shifted from purely seeking economic benefits (foreign exchange and FDI) to a broader range of gains. The WTO membership, by locking in economic reforms and making them irrevocable, and by securing China's market access in major economies, has not only promoted China's foreign trade but at the same time facilitated the modernization of China's legal and political systems and cut transaction costs. Although it is difficult to quantify gains from the decline in transaction costs as a result of increased foreign competition, some economists have taken exports as an additional factor in production functions. Grossman and Helpman (1991) for instance, assuming endogenous technological progress, set up a two-country model in which exports can accelerate growth by propelling knowledge diffusion. In the following sections we will shed more light on this issue at empirical levels.

## 3. How dependent is the Chinese economy on exports?

As exports had grown faster than GDP for years, the exports-to-GDP ratio in China reached 37.5% in 2007, which is much higher than observed in other large economies (Fig. 1). This ratio in the US, for example, has been around 12%. Even in Japan,

[4] CEIC database and authors' estimates.

[5] See Matthews, Guo and Zhang (2007). There are various estimates of China's non-performing loans in the literature.

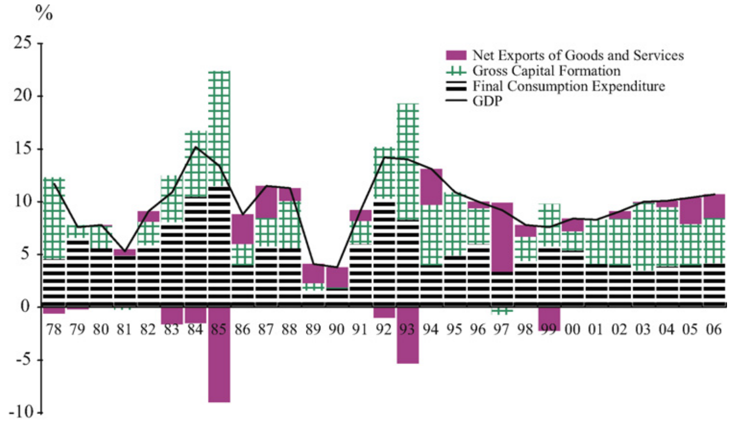


**Fig. 2.** Contribution to GDP growth by expenditure components (China). Sources: China Statistical Yearbook 2007 and authors' estimates.

which is well-known for its export competitiveness, it is less than 18%. This observation has led to charges that China has become too export-dependent, which makes the Chinese economy vulnerable to the vagaries of external demand. Nevertheless, as pointed out by Anderson (2007), the exports-to-GDP ratio is a poor indicator of export dependency. Comparing export and GDP is akin to comparing apples and oranges; while export is measured on a gross basis in a similar fashion as sales revenue of a company, GDP is measured on a value added basis in a similar fashion as profits of the company.

A second interpretation of export dependency relates to the contribution of net exports to overall GDP growth. However, the contribution of various expenditure components of GDP to its growth summarises at best short-run or cyclical economic conditions. It can vary greatly from quarter to quarter and from year to year, and such variation does not have any predictable relationship with the structure of an economy. The reason for this is that the conventional measure of the contribution to growth is purely an accounting relationship, suggesting no causal relationships or theoretical underpinning.[6] Hence, based on such decomposition, net exports may well be the main contributor to GDP growth for a large and relatively closed economy like the US in a particular quarter, while at the same time domestic demand is the main contributor in a small and open economy like Hong Kong.

As shown in Fig. 2, the relative contribution of domestic demand and net exports to GDP growth in China varied greatly from year to year, bearing no particular relationship to the openness of the economy. Even though the contribution from net exports to growth has been growing in recent years, it has not been larger than in the late 1980s. Note also that there is no necessary relationship between surpluses in the balance of trade and the contribution of exports to economic growth. It is the change in net exports that contributes to an economy's growth, not its size nor whether it is positive or negative.

A proper understanding of an economy's export dependency would call for the use of input–output tables. Input–output tables make it possible to analyse sectoral linkages within the economy and allow us to have a clear understanding of the role that foreign trade plays in the total demand for and supply of output of different sectors. In this paper, we calculate a measure of China's export dependency using China's 1997 and 2002 input–output tables with imported intermediary goods separated out from domestic intermediate inputs. Such tables are constructed by Koopman, Wang, and Wei (2008) using a mathematical programming procedure that combines information from detailed trade statistics with conventional input–output tables.[7] We then compare China's situation with a number of other neighbouring economies whose input–output tables with non-competitive imports are available from public sources.

As a first step, it is useful to note that the share of exports in the total demand for gross output in China (i.e., the proportion of gross output that is exported to foreign economies rather than sold domestically), while larger than in the US, was smaller than in Japan and significantly smaller than in the neighbouring economies such as Korea, Taiwan and Singapore (Tables 1 and 2). There is also substantial variation in the shares of exports across different sectors. Thus, while exports only accounted for a small share in the total demand for gross output produced in the US as a whole, 30% of the gross output produced in the computer and electronics sector were exported. In China, only the textile and the machinery industries rely to a significant extent on foreign markets to sell their products.

Nevertheless, Tables 1 and 2 do not tell us to what extent China's economy is dependent on exports. In other words, we do not know the amount of value-added induced by exports at either sectoral or aggregate level. The analysis below aims at answering this question. Because we are interested in the contribution of exports to *domestic* value-added, it is necessary to

[6] From the national income identity we can write $\frac{\Delta y}{y} = \frac{\Delta(c+i+g)}{y} + \frac{\Delta(ex-im)}{y}$ where y deotes real GDP, $\Delta$y the change in real GDP, $\Delta$(c + i + g) the change in domestic demand, and $\Delta$(ex-im) the change in net exports. The contribution of domestic demand is the first term on the right hand side of the above equality, while the contribution of net exports is given by the second term.

[7] The officially released input–output tables do not distinguish domestic intermediate inputs from imported intermediate inputs.

**Table 1**
Share of exports in total demand for gross output in China.

| | 1997 (%) | 2000 (%) | 2002 (%) |
|---|---|---|---|
| Agriculture | 1.7 | 2.2 | 1.7 |
| Mining and Quarrying | 5.7 | 5.0 | 4.3 |
| Foodstuff | 5.3 | 6.4 | 6.2 |
| Textile, Sewing, Leather and Furs Products | 25.2 | 26.1 | 35.1 |
| Other Manufacturing | 14.6 | 14.6 | 15.0 |
| Production and Supply of Electric Power, Heat Power and Water | 0.8 | 0.0 | 0.6 |
| Coking, Gas and Petroleum Refining | 5.7 | 2.7 | 4.1 |
| Chemical Industry | 10.0 | 8.9 | 10.1 |
| Building Materials and Non-metal Mineral Products | 3.4 | 6.3 | 7.2 |
| Metal Products | 8.9 | 9.2 | 7.1 |
| Machinery and Equipment | 15.4 | 19.6 | 23.5 |
| Construction | 0.1 | 0.1 | 0.4 |
| Transportation, Postal and Telecommunication Services | 8.3 | 7.2 | 9.9 |
| Wholesale and Retail Trades, Hotels and Catering Services | 9.7 | 8.9 | 11.9 |
| Real Estate, Leasing and Business Services | 10.1 | 9.1 | 5.8 |
| Banking and Insurance | 0.5 | 0.3 | 0.3 |
| Other Services | 0.5 | 0.5 | 3.9 |
| Total | 8.3 | 9.0 | 9.9 |

Sources: input–output tables, China Statistical Yearbook (various issues) and authors' estimates.

distinguish domestic intermediate inputs from imported intermediate inputs as the latter do not add domestic value-added. An input–output table with non-competitive imports is shown as Table A1 in Appendix A, which implies that the value-added induced by exports reads

$$V^E = A_v(I - A^D)^{-1}E \quad (1)$$

with $V^E$ denoting the column vector of value added induced by exports, $A_v$ a diagonal matrix whose $i$th element on the diagonal is ratio of sector $i$'s value added to its gross output (total inputs), $A^D$ is the direct input coefficient of domestic products (see Appendix A) and $E$ denotes the column vector of exports. The term $A_v(I - A^D)^{-1}$ is the value-added multiplier of final demand. Then sector $j$'s ($j$ = 1, 2, . . ., $n$) dependency ratio of value added on exports reads $D^j = V^{jE}/V^j$ with $V^{jE}$ denoting the $j$th element of $V^E$, and $V^j$ the value added of sector $j$. Dividing the economy into 17 sectors as in Table 1, we have estimated the dependency ratios across sectors for both 1997 and 2002 (Table 3).

The 2002 results show that textile, sewing, leather and furs products feature the highest dependency ratio, followed by machinery and equipment, chemical industry and other manufacturing. Comparing the results of 1997 and 2002, we find that dependency ratios increased in most sectors, particularly in sectors of machinery and equipment, textile, real estate and leasing (warehousing). Furthermore, comparing Table 3 with Table 1, one finds that sectors with a higher share of exports in total demand also feature higher dependency ratios. At the aggregate level, China's dependency on exports was comparable to that of Korea, but was substantially lower than those of Singapore and Taiwan. In particular, China has an overall dependency of 18.2% in 1997 and 20.7% in 2002, while Korea, Singapore and Taiwan have dependency ratios of 23.6%, 31.7% and 55.2%, respectively.[8] This looks consistent with the share of exports in total demand shown in Table 2. It would have been interesting to compare China's export dependency calculated with input–output tables with those of large economies such as the US and Japan. Unfortunately, we could not find input–output tables with non-competitive imports for the US and Japan. However, judging from the observation that export dependency appears highly correlated with the share of exports in total demand, China's export dependency is likely to be larger than that of the US, but somewhat lower than that of Japan.

The estimates shown in Table 3 may overstate China's dependency on exports because a large portion of China's exports are processing exports, which are likely to have made a much less significant contribution to GDP than ordinary exports. Taking this problem into account, Koopman et al. (2008) study the foreign content of China's exports by using a quadratic programming approach and construct input–output tables that separate processing and ordinary exports. Their main finding is that studies that do not distinguish processing and ordinary exports have notably underestimated the foreign content of China's exports.

Here we also use the methodology of Koopman et al. (2008) to estimate China's dependency on ordinary and processing exports separately. An input–output table distinguishing processing exports and ordinary exports is shown as Table A2 in Appendix A. Let $A^{DD}$ denote the direct input coefficient matrix of domestic products for domestic sales and ordinary exports, $A^{DP}$ the direct input coefficient matrix of domestic products for processing exports, $A_v^D$ a diagonal matrix whose $i$th ($i$ = 1, . . ., $n$) element on the diagonal is the ratio of sector $i$'s value-added by domestic sales and ordinary exports to sector $i$'s domestic demand plus ordinary exports, and $A_v^P$ a diagonal matrix whose $i$th element on the diagonal is the ratio of sector $i$'s value-

[8] Employing China's input–output table of 1995, Chen et al. (2007) study the value-added and employment induced by China's exports to the US by separating domestic intermediate inputs from imported intermediate inputs. Our results for 1997 are comparable with their results for 1995.

**Table 2**
Share of exports in total demand for gross output in selected economies.

| Country | Share (%) |
|---|---|
| United States (2002) | |
| All sectors | 4.8 |
| Agriculture | 8.3 |
| Machinery | 25.6 |
| Computer and electronic products | 30.1 |
| Securities and investments | 6.1 |
| Educational services | 0.3 |
| Japan (2000) | |
| All sectors | 12.6 |
| Agriculture | 1.8 |
| General machinery | 33.5 |
| Electrical machinery | 42.2 |
| Financial and insurance | 8.6 |
| Education and research | 10.1 |
| Korea (2003) | |
| All sectors | 15.6 |
| Agriculture | 1.4 |
| Machinery and equipment of special purpose | 31.2 |
| Electronic components and accessories | 72.3 |
| Ship building and repairing | 80.1 |
| Finance and insurance | 3.0 |
| Educational and research services | 0.1 |
| Taiwan (2004) | |
| All sectors | 26.6 |
| Agriculture | 10.5 |
| Machinery | 54.7 |
| Electronic Components and Parts | 81.4 |
| Finance and Insurance Services | 1.2 |
| Education Services | 0.0 |
| Singapore (2000) | |
| All sectors | 49.9 |
| Agriculture | 38.6 |
| Manufacturing | 82.7 |
| Construction | 1.1 |
| Financial services | 27.0 |
| China (2002) | |
| All sectors | 9.9 |
| Agriculture | 1.7 |
| Mining and Quarrying | 4.3 |
| Manufacturing | 15.4 |
| Construction | 0.4 |
| Services | 7.0 |

Sources: input–output tables and statistical authorities of various economies.

added by processing exports to sector *i*'s processing exports, then the value-added induced by ordinary exports and processing exports read:

$$V^{ED} = A_v^D (I - A^{DD})^{-1} \times EO \quad (2)$$

$$V^{EP} = [A_v^D (I - A^{DD})^{-1} A^{DP} + A_v^P] \times EP \quad (3)$$

where $EO$ and $EP$ denote $n \times 1$ vectors of ordinary and processing exports, respectively. Note that ordinary and processing exports have different value-added multipliers, $A_v^D (I - A^{DD})^{-1}$ and $A_v^D (I - A^{DD})^{-1} A^{DP} + A_v^P$ respectively. Moreover, these multipliers are different from that of final demand combining processing and ordinary exports in equation (1), $A_v (I - A^D)^{-1}$. The sectoral value-added dependency on ordinary exports and processing exports can then be calculated as $D^{Di} = V^{ED,i}/V^i$ and $D^{Pi} = V^{EP,i}/V^i$ respectively, with $V^{ED,i}$ denoting the *i*th row of $V^{ED}$, $V^{EP,i}$ the *i*th row of $V^{EP}$ and $V^i$ the total value added of sector *i*.

The estimation results presented in Table 4 point to the following findings: (a) overall export dependency calculated by separating processing exports from ordinary exports was lower than that calculated by combining the two types of exports (14.2% versus 18.2% on average in 1997, and 15.0% versus 20.7% in 2002, respectively); (b) the dependency on processing exports was much lower than on ordinary exports (4.1% versus 11.1% on average in 1997 and 4.0% versus 13.0% in 2002, respectively); and (c) dependency on ordinary exports on average increased by about two percentage points from 1997 to 2002, whereas that on processing exports declined slightly. In particular, while the dependency of the textile sector on ordinary exports rose from 24.0% to 37.0%, its dependency on processing exports dropped from 16.0% to 8.0%.

**Table 3**
Dependency of value-added on exports (%).

| Sector | Economy | | | | |
|---|---|---|---|---|---|
| | China | | Korea (2003) | Singapore (2000) | Taiwan (2004) |
| | 1997 | 2002 | | | |
| Agriculture | 10.0 | 11.0 | 8.4 | 52.8 | 16.2 |
| Mining and quarrying | 25.1 | 24.1 | 22.6 | – | 11.5 |
| Foodstuff | 10.4 | 13.7 | 10.2 | 52.4 | 8.9 |
| Textile, sewing, leather and furs products | 43.2 | 52.5 | 55.8 | 80.8 | 81.0 |
| Other manufacturing | 28.3 | 30.2 | 29.8 | 70.2 | 54.9 |
| Production and supply of electric power, heat power and water | 19.9 | 20.6 | 21.5 | 58.1 | 36.1 |
| Coking, gas and petroleum refining | 23.0 | 24.4 | 39.6 | 96.0 | – |
| Chemical industry | 28.8 | 31.5 | 54.6 | 85.2 | 67.4 |
| Building materials and non-metal mineral products | 9.6 | 16.5 | 20.2 | 73.8 | 42.8 |
| Metal products | 28.1 | 28.5 | 56.1 | 74.9 | 68.3 |
| Machinery and equipment | 27.0 | 36.9 | 60.9 | 92.1 | 81.6 |
| Construction | 0.9 | 1.4 | 1.5 | 2.9 | 4.9 |
| Transportation, postal and telecommunication services | 21.5 | 23.8 | 31.3 | 67.6 | 24.3 |
| Wholesale and retail trades, hotels and catering services | 24.0 | 27.9 | 16.3 | 62.3 | 16.9 |
| Real estate, leasing and business services | 5.8 | 17.2 | 13.8 | 56.8 | 30.6 |
| Banking and insurance | 15.4 | 18.5 | 17.3 | 40.4 | 25.1 |
| Other services | 7.0 | 6.2 | 7.8 | 8.8 | 7.6 |
| Weighted average | 18.2 | 20.7 | 23.6 | 55.2 | 31.7 |

Sources: Koopman et al. (2008), Bank of Korea, National Statistics of R.O.C. (Taiwan), Department of Statistics of Singapore, and authors' estimates.

**Table 4**
Dependency on ordinary vs. processing exports (%).

| Sector | 1997 | | | 2002 | | |
|---|---|---|---|---|---|---|
| | Ordinary | Processing | Sum | Ordinary | Processing | Sum |
| Agriculture | 7.2 | 0.6 | 7.8 | 8.3 | 1.0 | 9.3 |
| Mining and quarrying | 16.9 | 1.4 | 18.3 | 16.0 | 1.6 | 17.6 |
| Foodstuff | 7.5 | 1.2 | 8.7 | 10.0 | 0.7 | 10.7 |
| Textile, sewing, leather and furs products | 24.0 | 15.7 | 39.7 | 36.6 | 8.1 | 44.7 |
| Other manufacturing | 14.0 | 7.8 | 21.8 | 16.6 | 5.2 | 21.8 |
| Production and supply of electric power, heat power and water | 12.1 | – | 12.1 | 12.6 | – | 12.6 |
| Coking, gas and petroleum refining | 14.2 | 2.5 | 16.7 | 16.6 | 1.8 | 18.4 |
| Chemical industry | 16.9 | 3.3 | 20.2 | 19.3 | 4.3 | 23.6 |
| Building materials and non-metal mineral products | 6.4 | 2.6 | 9.0 | 11.1 | 1.6 | 12.7 |
| Metal products | 13.5 | 4.2 | 17.7 | 14.4 | 4.1 | 18.5 |
| Machinery and equipment | 9.5 | 10.2 | 19.7 | 13.2 | 9.4 | 22.6 |
| Construction | 0.7 | – | 0.7 | 1.1 | – | 1.1 |
| Transportation, postal and telecommunication services | 16.7 | 3.9 | 20.6 | 17.8 | – | 17.8 |
| Wholesale and retail trades, hotels and catering services | 19.1 | – | 19.1 | 19.7 | – | 19.7 |
| Real estate, leasing and business services | 4.0 | – | 4.0 | 13.1 | – | 13.1 |
| Banking and insurance | 9.7 | – | 9.7 | 12.2 | – | 12.2 |
| Other services | 5.4 | 0.1 | 5.5 | 5.2 | —— | 5.2 |
| Weighted average | 11.1 | 4.1 | 14.2 | 13.0 | 4.0 | 15.0 |

Sources: Koopman et al. (2008) and authors' estimates.

In short, if we take into account the fact that half of China's exports are processing exports, then its dependency on exports, i.e. its share of value-added induced by exports in total value-added, is significantly less than that of Korea, despite its headline exports-to-GDP ratio being comparable to that of Korea.

Given the stellar growth in China's exports in the past few years, particularly during 2003–2004 however, one may argue that China's dependency on exports has risen. Unfortunately, the 2002 input–output table is the latest data available. Assuming the value-added multiplier of final demand to remain unchanged, we have roughly estimated the dependency of value-added on domestic final demand and therefore the value-added dependency on exports from 2003 to 2006. The estimates show that China's dependency on exports might have increased by about 2 1/2 percentage points in the past years.

## 4. In what ways have exports led growth in China?

The above evidence from input–output tables shows that China's dependency on exports has been less significant than implied by conventional indicators such as the exports-to-GDP ratio. The next question is then, in what ways have exports prompted China's output growth? We will address this issue from both demand as well as supply side of the economy. From a demand perspective, if the export sector employs a large number of workers, or a high share of total employment, export

**Table 5**
GDP per capita and exports-to-GDP ratio in coastal and inland areas (2006).

| Coastal | GDP per capita (RMB) | Exports/GDP (%) | Inland | GDP per capita (RMB) | Exports/GDP (%) |
|---|---|---|---|---|---|
| Beijing (BJ) | 50,467 | 25.3 | Shanxi (ShanX) | 14,123 | 10.9 |
| Tianjin (TJ) | 41,163 | 59.8 | Inner Mongolia (InMo) | 20,053 | 4.5 |
| Hebei (HeB) | 16,962 | 10.4 | Jilin (JL) | 15,720 | 5.0 |
| Liaoning (LN) | 21,788 | 24.5 | Heilongjiang (HLJ) | 16,195 | 9.0 |
| Shanghai (SH) | 57,695 | 83.4 | Anhui (AH) | 10,055 | 8.6 |
| Jiangsu (JS) | 28,814 | 59.9 | Jiangxi (JX) | 10,798 | 6.7 |
| Zhejiang (ZJ) | 31,874 | 54.5 | Henan (HeN) | 13,313 | 4.6 |
| Fujian (FJ) | 21,471 | 43.0 | Hubei (HuB) | 13,296 | 6.2 |
| Shandong (SD) | 23,794 | 21.8 | Hunan (HuN) | 11,950 | 5.4 |
| Guangdong (GD) | 28,332 | 92.8 | Guangxi (GX) | 10,296 | 6.3 |
| Hainan (HaiN) | 12,654 | 8.3 | Sichuan (SC) | 11,502 | 5.7 |
| | | | Guizhou (GZ) | 5,787 | 4.7 |
| | | | Yunnan (YN) | 8,970 | 6.1 |
| | | | Tibet (Tib) | 10,430 | 5.6 |
| | | | Shaanxi (ShaanX) | 12,138 | 7.7 |
| | | | Gansu (GS) | 8,757 | 5.7 |
| | | | Qinghai (QH) | 11,762 | 6.3 |
| | | | Ningxia (NX) | 11,847 | 12.3 |
| | | | Xinjiang (XJ) | 15,000 | 18.3 |
| Aggregate | 30,456 | 48.4 | Aggregate | 12,210 | 6.2 |

Sources: Provincial Statistical Yearbooks (2007).

growth is likely to lead to higher wages and therefore higher consumption. Nevertheless, some observers of China's economy have argued that China's workers probably have not benefited much from exports as growth of wages has remained tamed due to excessive labour supply. Lu (2007), for example, finds that China's unit labour cost in tradable sector (proxied by that in manufacturing) has been declining since mid-1990s. Moreover, empirical data shows that the manufacturing sector has accounted for less than 30% of total employment in the past years. Thus, there may not be significant correlation between exports and consumption.[9] As export earnings can be an important source of funding for investment, however, exports can lead to higher investment. From a supply perspective, as stated earlier, the exports- and opening-related reforms reviewed in Section II have positioned China's domestic firms at the frontier of international competition, and as a result, may have led to efficiency gains and higher growth in TFP. We will study these issues in the following sections by exploring how foreign trade may have Granger-caused domestic demand and TFP growth.

There are various approaches to studying the interactions between foreign trade and domestic demand. For example, one may calculate the export multiplier using a Keynesian model to see the long-run effects of exports. Alternatively, one can employ structural general equilibrium models to explore impacts of shocks stemming from external demand as well as domestic policies. In this paper we adopt the Granger-causality tests with panel data to study this issue. The tests allow us to study the dynamic interactions between foreign trade and domestic demand and analyse whether trade growth in the past causes the growth of various components of domestic demand in the current period.

### *4.1. Granger-causality between exports and domestic demand*

Following He, Zhang, and Shek (2007) we conduct the tests for coastal and inland China separately to see whether there exists any difference in the roles played by exports in the two areas. The coastal area includes 11 provinces (including Beijing and Shanghai) and the inland area includes the rest of 19 provinces with Chongqing counted as a part of Sichuan Province. As indicated by GDP per capita (Table 5), the coastal area is much more developed than the inland area. The GDP per capita of the former was about 2.5 times that of the latter in 2006. Moreover, the exports-to-GDP ratio has been much higher in the coastal area than in the inland area, with the ratio being about 50% in coastal provinces and as low as 6% in the inland area in 2006. Our sample period of regression covers 1993–2005 (annual data).[10] One has to consider the problem of potential heterogeneity of cross sections in Granger-causality tests with panel data, which has been ignored by conventional methodologies. In this study, we follow the methodology developed by Hurlin and Venet (2001) to test for Granger causality by estimating a dynamic panel data model with fixed coefficients.

[9] One may argue that exports had made material contributions to employment in China even though growth in wages has been flat because China does not have full employment. In a recent study, however, Feenstra and Hong (2007) find that most of the employment could be ascribed to the non-tradable sector during 1997–2002 and that the employment induced by domestic demand was three times that by exports during 2000–2005.

[10] Before starting the Granger-causality tests, we undertake the Phillips-Perron Fisher panel unit-root tests for real GDP, consumption, investment (gross fixed capital formation), imports and exports. Note that provincial GDP, imports and exports (in RMB) are deflated with provincial GDP deflators, while provincial consumption and investment are deflated with provincial CPI indexes and fixed assets investment (FAI) price indexes, respectively. The base year is 2000. The panel unit root test results are shown in Table A3 in Appendix II, which demonstrates that all time series are I(1). Therefore, in the research below we will test the Granger-causality between the first differences (annual growth) of corresponding variables.

**Table 6**
Homogenous non-causality test.

| | Variables | | Lags | $F_{hnc}$ | Result |
|---|---|---|---|---|---|
| | Dependent | Explanatory | | | |
| Coast | Consumption | Export | 3 | 0.60 | Accept |
| | Export | Consumption | 3 | 1.58 | Accept |
| | Investment | Export | 1 | 2.14 | Reject** |
| | Export | Investment | 1 | 5.29 | Reject*** |
| | Import | Export | 1 | 1.12 | Accept |
| | Export | Import | 1 | 4.42 | Reject*** |
| | GDP | Export | 2 | 0.71 | Accept |
| | Export | GDP | 2 | 2.58 | Reject*** |
| Inland | Consumption | Export | 3 | 1.40 | Accept |
| | Export | Consumption | 3 | 1.35 | Accept |
| | Investment | Export | 4 | 1.09 | Accept |
| | Export | Investment | 4 | 1.47 | Accept |
| | Import | Export | 2 | 4.44 | Reject*** |
| | Export | Import | 2 | 1.79 | Reject*** |
| | GDP | Export | 4 | 0.87 | Accept |
| | Export | GDP | 4 | 1.08 | Accept |

** Significant at 5% and 10%.
*** Significant at 1%, 5% and 10%.

**Table 7**
Homogenous causality test.

| | Variables | | Lags | $F_{hc}$ | Result |
|---|---|---|---|---|---|
| | Dependent | Explanatory | | | |
| Coast | Investment | Export | 1 | 1.00 | Accept |
| | Export | Investment | 1 | 2.71 | Reject*** |
| | Export | Import | 1 | 0.18 | Accept |
| | Export | GDP | 2 | 1.69 | Accept |
| Inland | Import | Export | 2 | 2.25 | Reject*** |
| | Export | Import | 2 | 1.00 | Accept |

Note: **significant at 5% and 10%.
*** Significant at 1%, 5% and 10%.

Hurlin and Venet (2001) propose four kinds of causality relationships based on the heterogeneity of the underlying processes: (a) *Homogenous non-causality* (HNC), (b) *homogenous causality* (HC), (c) *heterogeneous non-causality* (HENC), and (d) *heterogeneous causality* (HEC). HNC refers to the case in which there is no linear causality between dependent variable $y_{i,t}$ and explanatory variable $x_{i,t}$ for any individual. HC means there exists causality between $y_{i,t}$ and $x_{i,t}$ for all individuals. HENC refers to the situation in which at least one individual (and at most $N-1$, with $N$ being the number of individuals) does not manifest a causality relationship, and HEC means there exists at least one and at most $N$ individual causality relationship. Appendix C describes in detail the methodology. The hypothesis tests proceed as follows: One first tests the HNC hypothesis, and then the HC hypothesis if the HNC hypothesis is rejected. If the HC hypothesis is also rejected, one then tests the HENC hypothesis. If the HENC is accepted, there exists a subgroup of individuals for which $x_{i,t}$ does not Granger-cause $y_{i,t}$. If it is rejected, however, the HEC hypothesis holds. In other words, $x_{i,t}$ Granger-causes $y_{i,t}$ for all individuals although heterogeneity exists across sections. First, we conduct homogenous non-causality test between export growth and other variables with the results shown in Table 6 in which $F_{hnc}$ denotes the $F$-statistic of the HNC hypothesis.[11] When $F_{hnc}$ is lower than the critical value of significance, one should accept the HNC hypothesis, otherwise the HNC hypothesis should be rejected.

The results in Table 6 indicate that (a) export and consumption do not Granger-cause each other in either coastal or inland area; (b) export does not Granger-cause import or GDP in the coastal area; (c) investment and export do not Granger-cause each other in the inland area; and (d) GDP and export do not Granger-cause each other in the inland area. As the second step, we conduct homogenous causality tests for variables for which the homogenous non-causality hypothesis has been rejected (Table 7). The results in Table 7 indicate that (a) export homogeneously Granger-causes investment in the coastal area; (b) GDP Granger-causes export in the coastal area, and (c) import homogeneously Granger-causes export in both areas.

In addition, we reject the hypotheses that investment homogeneously Granger-causes export in the coastal area, and that export homogeneously Granger-causes import in the inland area. Nevertheless, this does not necessarily imply that there is

[11] In the literature, several methods have been proposed to estimate the dynamic panel data model. Here we follow Hurlin and Venet (2001) and employ the GMM. Before running the GMM estimation, we will run bivariate VARs to determine the optimal number of lags in the estimation according to the Schwarz criterion and Akaike information criterion.

**Table 8**
Main findings.

| Causality relationship | Coast | Inland |
|---|---|---|
| Does export GC consumption? | No | No |
| Does consumption GC export? | No | No |
| Does export GC investment? | Yes (homogeneous) | No |
| Does investment GC export? | Yes (heterogeneous) | No |
| Does export GC import? | No | Yes (heterogeneous) |
| Does import GC export? | Yes (homogeneous) | Yes (homogeneous) |
| Does export GC GDP? | No | No |
| Does GDP GC export? | Yes (homogeneous) | No |

**Table 9**
Average annual TFP growth (1994–2005, %).

| Province | BJ | TJ | HeB | LN | JS | ZJ | SD | GD | HaiN | SH |
|---|---|---|---|---|---|---|---|---|---|---|
| TFP | 3.4 | 4.4 | −2.4 | 5.9 | 6.9 | 3.7 | 0.6 | 0.3 | 1.4 | 1.0 |
| Province | FJ | ShanX | InMo | JL | HLJ | AH | JX | HeN | HuB | HuN |
| TFP | −0.7 | 4.1 | 5.3 | 2.7 | 2.9 | 2.2 | 3.4 | 3.8 | 2.0 | −0.7 |
| Province | GZ | YN | ShaanX | GS | QH | NX | XJ | GX | SC | Tib |
| TFP | −4.3 | −2.4 | 2.8 | 2.1 | 0.4 | 1.4 | 4.2 | −1.4 | 0.8 | 0.0 |

no causal relationship between these variables, since there may exist heterogeneous causality even if homogeneous causality is absent. Therefore, as a third step, we undertake the heterogeneous non-causality tests, with results shown in Tables A4 and A5 in the appendix.

From the results in Table A4, we may conclude that in the coastal area investment Granger-causes export although the data generating process is heterogeneous. Moreover, results shown in Table A5 indicate that export Granger-causes import in the inland area despite the heterogeneous data generating process. The main findings of the tests with provincial data (1993–2005) are summarized in Table 8 with GC standing for Granger-cause.

In sum, consumption and export do not Granger-cause each other in either coastal or inland area, while import Granger-causes export in both areas. This may suggest that gains from exports have not been notably distributed to consumers possibly owing to labour surplus, as mentioned earlier. Export does not Granger-cause GDP, whereas GDP seems to have driven exports in east China. In addition, export and investment have Granger-caused each other in the coastal area, while no causality is found between the two variables in the inland area. There seem to be stronger interactions between exports and domestic demand in the coastal area than in the inland area, with the contribution of exports in the latter lying mainly in fuelling imports.

However, it is useful to note that exports-related investment is not a major part of total investment in China. As shown in Barnett and Brooks (2006), fixed asset investment (FAI) in manufacturing accounted for less than 30% of total investment in the past few years (25% and 27% in 2004 and 2005, respectively).[12] Thus, while exports and investment in the manufacturing industries have been closely linked, exports did not have a tangible impact on aggregate demand. Instead, as shown below, the impact on productivity growth of export-oriented industries may have been a more important channel of export's contribution to growth.

### *4.2. Granger-causality between exports and total factor productivity growth*

In order to study the contribution of exports from the supply side, we have to estimate China's TFP growth. In the literature there have been various approaches to estimating TFP growth, with the main methodology focusing on a production function (Cobb-Douglas function, for example). A main drawback of the production function approach is that it assumes production is conducted on the frontier of technology, and as a result, technical inefficiency is assumed away. In this paper we employ a non-parametric approach, the Malmquist index developed by Fare, Grosskopf, Norris, and Zhang (1994), to estimate provincial TFP growth for China.[13] We use the provincial data of GDP, employment and capital stock to calculate TFP growth for China from 1993 to 2005. Capital stock data are taken from He, Zhang, et al. (2007) constructed with the methodology of Li (2003). Following He, Zhang, et al. (2007) we estimate TFP growth for coastal and inland areas separately.[14] The average TFP growth rates from 1994-2005 of all provinces are presented in Table 9.

Hebei and Fujian are the two provinces featuring negative average TFP growth in the coastal area, while Jiangsu experienced the highest TFP growth in the same period. In the inland area, Hunan, Guizhou, Yunnan and Guangxi have had average TFP growth below zero, while Inner Mongolia has had the highest growth. The simple average of TFP growth in the

[12] Our estimate shows that the share of manufacturing FAI in total FAI increased modestly from 26% in 2003 to about 31% in 2006.
[13] Appendix IV describes the methodology to estimate the Malmquist productivity index.
[14] The estimation is conducted with the algorithm developed by Scheel (2000), assuming variable returns to scale.

**Table 10**
Homogenous non-causality test for foreign trade and TFP.

| | Variable | | Lags | $F_{hnc}$ | Result |
|---|---|---|---|---|---|
| | Dependent | Explanatory | | | |
| Coast | TFP | Export | 2 | 2.10 | Reject*** |
| | TFP | Import | 2 | 2.44 | Reject*** |
| Inland | TFP | Export | 2 | 4.33 | Reject*** |
| | TFP | Import | 2 | 2.56 | Reject*** |

*** Significant at 1%, 5% and 10%.

**Table 11**
Homogenous causality tests.

| | Variable | | Lags | $F_{hc}$ | Result |
|---|---|---|---|---|---|
| | Dependent | Explanatory | | | |
| Coast | TFP | Export | 2 | 1.04 | Accept*** |
| | TFP | Import | 2 | 1.11 | Accept*** |
| Inland | TFP | Export | 2 | 4.03 | Reject*** |
| | TFP | Import | 2 | 2.21 | Reject*** |

*** Significant at 1%, 5% and 10%.

coastal area is 2.25%, compared to 1.55% in the inland area in the same period. Employing the same methodology of Granger-causality tests as the previous section, we have presented the results in Table 10.[15]

The results in Table 10 show that the homogenous non-causality hypothesis can be rejected in both areas. The next step is to test homogenous causality from foreign trade to TFP, with results presented in Table 11. Obviously, export and import homogenously Granger-cause TFP in the coastal area, while neither Granger-causes TFP in the inland area, possibly suggesting that foreign trade has made a greater contribution to TFP growth in the coastal area than in the inland area.

The fact that foreign trade does not homogenously Granger-cause TFP does not necessarily imply no causality at all, since heterogeneous causality may exist. Therefore, as a further step, we test the heterogeneous (non-)causality for the inland area, with results shown in Table A6 in the appendix. We can reject heterogeneous non-causality hypothesis for 6 provinces and accept it for the rest of 13 provinces. Statistics of tests in this case suggest that the heterogeneous non-causality hypothesis can be accepted for the area overall, suggesting that although exports have propelled TFP in some provinces, they have not shown significant effects on productivity in the inland area as a whole. Similarly, we test heterogeneous non-causality from import to TFP in the inland area, with results shown in Table A7 in the appendix. Obviously, only four provinces reject the heterogeneous non-causality hypothesis and statistics of tests in this case indicate that the hypothesis of heterogeneous non-causality from import to TFP should be accepted for the inland area overall, implying insignificant effects of imports on productivity in this area on the whole.

In short, the above empirical evidence indicates that while both export and import (homogenously) Granger-cause TFP in the coastal area, neither Granger-causes TFP in the inland area in general. In addition, one can also study the impacts of foreign trade on productivity by replacing growth in imports and exports in the above regressions with openness. Openness is usually measured by the ratio of the sum of exports and imports to GDP. One channel through which openness shows positive impacts on TFP growth is specialization. In a recent paper, Alcala and Ciccone (2004) argue that the openness measured in this way may not show a positive correlation with TFP growth. To be precise, they argue that "... an increase in the degree of specialization affects openness in two opposite ways. Holding the price of non-tradable goods constant, a higher degree of specialization raises openness as more specialization necessarily implies a larger volume of imports. ... a higher degree of specialization also raises the price of non-tradable goods, which lowers openness." (Alcala & Ciccone, 2004, p. 617). In order to analyse the relation between productivity and foreign trade, they create the so-called Real Openness, measured as the ratio of the sum of exports and imports to the PPP GDP in the same currency (the US dollar for example). They name the openness constructed with the conventional approach Nominal Openness to distinguish it from the real openness.

We have constructed the PPP GDP at the provincial level for China with the formula: $GDP_{ppp,i} = (GDP_i/GDP)GDP_{ppp}$, where $GDP_{ppp,i}$ denotes the PPP GDP of province $i$ in the US dollar. $GDP_i$ denotes the nominal GDP of province $i$ in RMB, GDP denotes the national GDP in RMB, and $GDP_{ppp}$ denotes the national PPP GDP in the US dollar, taken from World Bank. The average real openness and nominal openness in the coastal and inland areas during 1993–2005 are shown in Figs. 3 and 4 respectively. Obviously, real openness is much lower than nominal openness.

Next, we use the same methodology as before to test whether real openness Granger-causes TFP and find that homogenous causality exists in the coastal area, while no homogenous causality is found in the inland area. The results of the

[15] Before conducting the Granger-causality tests, we run a VAR to determine the number of lags in the estimation according to the Schwarz criterion.

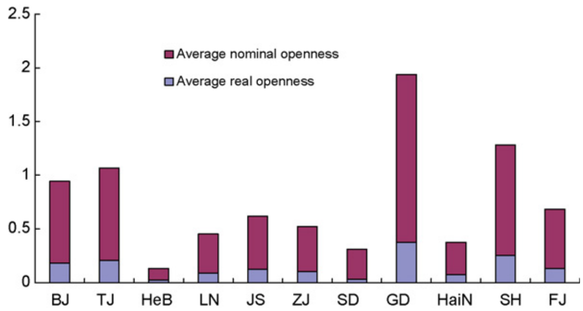


**Fig. 3.** Real and nominal openness in the coastal area (93-05). Sources: World Bank, CEIC and authors' estimates.

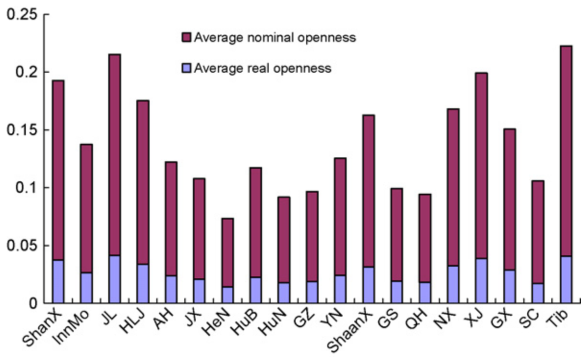


**Fig. 4.** Real and nominal openness in the inland area (93-05). Sources: World Bank, CEIC and authors' estimates.

heterogeneous non-causality tests from real openness to TFP in the inland area (Table A8 in the appendix) suggest that we should accept the heterogeneous non-causality hypothesis in the inland area.

In sum, the main finding from the supply-oriented analysis is that while export, import and real openness have Granger-caused TFP in the coastal area, no significant effects of foreign trade on productivity in inland China are found. This may be attributed to the fact that foreign trade has been much less developed in the inland area than in the coastal area. In fact, the coastal area accounted for about 90% of China's total trade in the past 10 years.

## 5. Concluding comments

Employing input–output tables, we have first shown that China's export dependency is much lower than implied by conventional indicators. Moreover, although exports have to some extent led to China's investment, there is little evidence that exports have fuelled China's consumption significantly. This may suggest that gains from trade have mainly been distributed to producers rather than consumers. Studies from the supply side of the economy further indicate that the contribution of exports to economic growth should best be understood from its role in promoting total factor productivity growth rather than its impact on domestic demand through the multiplier effect. These productivity gains have been obtained through exports-related reforms launched in the past decades, particularly in the preparation for the access into the WTO.

Based on the findings of this paper, we would argue that China's increasing trade surpluses in recent years should not be seen as symptoms of a structural malaise that the Chinese economy is too dependent on exports. These trade surpluses may be a problem from a demand management point of view, but they should not be used as an excuse to turn the Chinese economy away from its successful model of improving total factor productivity by taking advantage of international trade and investment.

While there may well be a need to strengthen domestic demand from a cyclical perspective, it can be achieved at the same time as the economy continues to develop and improve its export sector, and growth in both sectors could be complementary and mutually reinforcing in terms of technology deepening. As such, China's export-oriented growth model does not conflict with its effort to strengthen domestic demand. In other words, strengthening domestic demand does not require abandoning the export-oriented growth strategy.

## Acknowledgments

The views in this paper are solely those of the authors and should not be interpreted as those of the HKMA. We are grateful to Zhi Wang and Shang-jin Wei for kindly sharing data of China's input–output tables with non-competitive imports and separate tables for processing and ordinary exports.

## Appendix A. input–output tables

**Table A1**
input–output table with non-competitive imports (Chen et al., 2007).

| | | Intermediate demands | Final demands | Gross domestic output ($X_i$) or imports ($M_i$) |
|---|---|---|---|---|
| | 1<br>2 | 1,2,. . ., n | Domestic final demand + exports | |
| Domestic intermediate inputs | 2 | $X_{ij}^D$ | $F_i^D$ | $X_i$ |
| Imported intermediate inputs | . | $X_{ij}^M$ | $F_i^M$ | $M_i$ |
| Value added | n | $V_j$ | | |
| Total inputs | n | $X_j$ | | |

The above table implies the following equations: $\begin{array}{l} A^D X + F^D = X \\ A^M X + F^M = M \end{array}$ where $A^D$ denotes the matrix of direct input coefficients of domestic products, $X$ total output column vector, $M$ total imports vector, $A^M$ the matrix of direct input coefficients of imported products, $F^D$ column vector of final demand for domestic products and $F^M$ column vector of final demand for imports. In particular, $A^D = [X_{ij}^D / X_j]$, $A^M = [X_{ij}^M / X_j]$.

**Table A2**
Input–output table separating ordinary and processing exports (Koopman et al., 2008).

| | | Intermediate demands | | Final demand | Gross output or imports |
|---|---|---|---|---|---|
| | | Production for domestic demand and ordinary exports 1,2, . . ., $n$ | Production for processing exports 1,2, . . ., $n$ | | |
| Domestic intermediate inputs | Production for domestic demand and ordinary exports<br>1<br>.<br>.<br>$n$ | $Z^{DD}$ | $Z^{DP}$ | $Y^D$ | $X - E^P$ |
| | Processing exports<br>1<br>.<br>.<br>$n$ | 0 | 0 | $E^P$ | $E^P$ |
| Imported intermediate inputs<br>1<br>.<br>.<br>$n$ | $Z^{MD}$ | $Z^{MP}$ | $Y^M$ | $M$ | |
| Value added | $V^D$ | $V^P$ | | | |
| Total inputs (gross output) | $X - E^P$ | $E^P$ | | | |

where $Z^{DD}$: domestically produced intermediate inputs used for domestic sales and ordinary exports; $Z^{DP}$: domestically produced intermediate inputs used for processing exports; $Y^D$: domestic final demand plus ordinary exports; $X$: gross output of domestic sales and ordinary exports; $E^P$: processing exports; $Z^{MD}$: imported intermediate inputs for domestic sales and ordinary exports; $Z^{MP}$: imported intermediate inputs for processing exports; $Y^M$: final imports; $M$: total imports; $V^D$: value added of domestic sales and ordinary exports; $V^P$: value added of processing exports.

## Appendix B. Statistics of tests

**Table A3**
Panel unit root tests (null hypothesis is unit root).

| Time series | Statistics | | Probability | |
|---|---|---|---|---|
| | PPF-C-S. | PPF-C. Z. | PPF-C-S. | PPF-C. Z. |
| In level | | | | |
| Consumption | | | | |
| Coast | 63.911 | 0.784 | 0.000 | 0.784 |
| Inland | 37.156 | 5.001 | 0.508 | 1.000 |
| Investment | | | | |
| Coast | 18.070 | 2.095 | 0.702 | 0.982 |
| Inland | 34.717 | 2.548 | 0.622 | 0.995 |
| Export | | | | |
| Coast | 35.397 | −1.281 | 0.035 | 0.100 |
| Inland | 40.791 | 0.166 | 0.349 | 0.566 |
| Import | | | | |
| Coast | 6.416 | 2.618 | 1.000 | 0.996 |
| Inland | 31.789 | 1.571 | 0.751 | 0.942 |
| GDP | | | | |
| Coast | 29.547 | 2.484 | 0.130 | 0.994 |
| Inland | 35.461 | 2.988 | 0.588 | 0.999 |
| First difference | | | | |
| Consumption | | | | |
| Coast | 63.038 | −3.425 | 0.000 | 0.000 |
| Inland | 75.559 | −2.636 | 0.000 | 0.004 |
| Investment | | | | |
| Coast | 49.195 | −3.576 | 0.001 | 0.000 |
| Inland | 65.025 | −3.350 | 0.004 | 0.000 |
| Export | | | | |
| Coast | 109.609 | −7.808 | 0.000 | 0.000 |
| Inland | 157.967 | −9.190 | 0.000 | 0.000 |
| Import | | | | |
| Coast | 61.141 | −4.959 | 0.000 | 0.000 |
| Inland | 143.083 | −7.447 | 0.000 | 0.000 |
| GDP | | | | |
| Coast | 38.490 | −1.741 | 0.016 | 0.041 |
| Inland | 82.065 | −3.466 | 0.000 | 0.000 |

**Table A4**
$F^i_{henc}$ of the coastal area (export and investment).

| Prov. | BJ | TJ | HeB | LN | JS | ZJ | SD | GD | HaiN | SH | FJ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $F^i_{henc}$ | 3.33 | 17.18 | 7.44 | 15.90 | 28.70 | 19.00 | 16.40 | 15.90 | 1.28 | 4.87 | 6.67 |
| Result | A | R** | R*** | R*** | R*** | R*** | R*** | R*** | A | R** | R** |

Note: Dependent variable: export; explanatory variables: investment; A: accept; R: reject.
** Significant at 5% and 10%.
*** Significant at 1%, 5% and 10%.

**Table A5**
$F^i_{henc}$ of the inland area (import and export).

| Prov. | ShanX | InMon | JL | HLJ | AH | JX | HeN | HuB | HuN | Tib |
|---|---|---|---|---|---|---|---|---|---|---|
| $F^i_{henc}$ | 0.25 | 3.14 | 2.29 | 0.45 | 1.14 | 0.02 | 1.14 | 1.39 | 2.27 | 6.73 |
| Result | A | R** | R*** | R*** | R*** | R*** | R*** | R*** | A | R*** |
| Prov. | GZ | YN | ShaanX | GS | QH | NX | XJ | GX | SC | |
| $F^i_{henc}$ | 0.75 | 2.86 | 2.50 | 5.43 | 2.42 | 0.45 | 0.87 | 0.00 | 0.79 | |
| Result | A | R* | R* | R*** | A | A | A | A | A | |

Note: Dependent variable: import; Explanatory variables: export; A: accept; R: reject.
* Significant at 10%.
*** Significant at 1%, 5% and 10%.

**Table A6**
$F^i_{henc}$ of the inland area (TFP and export).

| Prov. | ShanX | InMo | JL | HLJ | AH | JX | HeN | HuB | HuN | Tib |
|---|---|---|---|---|---|---|---|---|---|---|
| $F^i_{henc}$ | 5.49 | 9.89 | 0.55 | 0.55 | 3.85 | 1.65 | 0.00 | 1.10 | 1.10 | −0.55 |
| Result | R*** | R*** | A | A | R** | A | A | A | A | A |
| Prov. | GZ | YN | ShaanX | GS | QH | NX | XJ | GX | SC | |
| $F^i_{henc}$ | 0.55 | 1.10 | 0.55 | 0.55 | 3.57 | 3.30 | 1.65 | 3.30 | 0.00 | |
| Result | A | A | A | A | R** | R** | A | R** | A | |

Note: Dependent variable: TFP; Explanatory variable: export; Lags: 2 A: accept; R: reject.
** Significant at 5% and 10%.
*** Significant at 1%, 5% and 10%.

**Table A7**
$F^i_{henc}$ of the inland area (TFP and import).

| Prov. | ShanX | InMo | JL | HLJ | AH | JX | HeN | HuB | HuN | Tib |
|---|---|---|---|---|---|---|---|---|---|---|
| $F^i_{henc}$ | 3.33 | 3.75 | 1.67 | 0.00 | 0.90 | 0.00 | −0.42 | 0.90 | 0.00 | 0.42 |
| Result | R** | R** | A | A | A | A | A | A | A | A |
| Prov. | GZ | YN | ShaanX | GS | QH | NX | XJ | GX | SC | |
| $F^i_{henc}$ | 0.00 | 0.00 | 0.00 | 6.25 | 0.83 | 0.83 | 0.42 | 4.58 | 0.00 | |
| Result | A | A | A | R*** | A | A | A | R** | A | |

Note: Dependent variable: TFP; explanatory variable: import; Lags: 2 A: accept; R: reject.
** Significant at 5% and 10%.
*** Significant at 1%, 5% and 10%.

**Table A8**
$F^i_{henc}$ of the inland area (TFP and real openness).

| Prov. | ShanX | InMo | JL | HLJ | AH | JX | HeN | HuB | HuN | Tib |
|---|---|---|---|---|---|---|---|---|---|---|
| $F^i_{henc}$ | 7.50 | 13.13 | 0.63 | 0.63 | 0.00 | 1.88 | 0.00 | 0.63 | 0.00 | 1.88 |
| Result | R*** | R*** | A | A | A | A | A | A | A | A |
| Prov. | GZ | YN | ShaanX | GS | QH | NX | XJ | GX | SC | |
| $F^i_{henc}$ | 2.50 | 0.63 | 0.00 | 0.00 | 4.38 | 5.00 | 1.88 | 5.00 | 0.00 | |
| Result | A | A | A | A | R** | R*** | A | R*** | A | |

Note: Dependent variable: TFP; Explanatory variable: real openness; Lags: 2 A: accept; R: reject.
** Significant at 5% and 10%.
*** Significant at 1%, 5% and 10%.

## Appendix C. Panel Granger-causality test developed by Hurlin and Venet (2001)

Consider the following model:[16]

$$y_{i,t} = \sum_{k=1}^{p} \gamma^k y_{i,t-k} + \sum_{k=1}^{p} \beta_i^k x_{i,t-k} + v_{i,t}, \quad v_{i,t} = \alpha_i + \varepsilon_{i,t} \tag{A1}$$

with $i \in [1,N]$ denoting individual cross sections and $\varepsilon_{i,t}$ individual white noises. $y_{i,t}$ and $x_{i,t}$ are covariance stationary variables. The autoregressive coefficients $\gamma^k$ and the regression coefficients slopes $\beta_i^k$ are assumed to be constant over time. Moreover, while $\gamma^k$ is assumed to be identical across individuals, $\beta_i^k$ may differ across individuals.[17] Detailed assumptions about the intercepts $\alpha_i$ and white noises $\varepsilon_{i,t}$ are stated in Hurlin and Venet (2001).

Define $\bar{y}_{i,t} = (y_{i,-p}, \ldots, y_{i,0}, \ldots, y_{i,t-1})'$, and $\bar{x}_{i,t} = (x_{i,-p}, \ldots, x_{i,0}, \ldots, x_{i,t-1})'$, and let $E(y_{i,t}|\bar{y}_{i,t}, \bar{x}_{i,t})$ denote the best linear predictor of $y_{i,t}$ given $\bar{y}_{i,t}$ and $\bar{x}_{i,t}$, one then has the following definitions. The HNC refers to the situation in which
$\forall\, i \in [1, N], E(y_{i,t}|\bar{y}_{i,t}, \alpha_i) = E(y_{i,t}|\bar{y}_{i,t}, \bar{x}_{i,t}, \alpha_i)$.

[16] Hurlin and Venet (2001) also consider the possibility of instantaneous effects of $x_{i,t}$ on $y_{i,t}$. Here we ignore this possibility because we would like to focus on exploring to what extent the past values of $x_{i,t}$ can be of help in predicting $y_{i,t}$.
[17] Hurlin and Venet (2007) also consider the possibility of different $\gamma^k$ across individuals. The test statistics in the text below are then slightly different. In this paper we follow Hurlin and Venet (2001) because $\beta_i^k$ rather than $\gamma^k$ is the main parameter of interest.

The null and alternative hypotheses for the HNC case are:

$H_0: \beta_i^k = 0, \forall\, i \in [1, N], \forall\, k \in [1, p]$
$H_a: \exists\, (i, k), \beta_i^k \neq 0$

with the $F$-statistic being[18]:

$$F_{\text{hnc}} = \frac{(RSS_2 - RSS_1)/(N\,p)}{RSS_1/[NT - N(1 + p) - p]}, \tag{A2}$$

where $RSS_2$ denotes the sum of squared residuals obtained under $H_0$, and $RSS_1$ the sum of squared residuals produced by the unrestricted model in Eq. (A1).

In the HC case the $N$ individual predictors based on $\bar{y}_{i,t}$, $\bar{x}_{i,t}$ and $\alpha_i$ are assumed to be identical:

$\forall\, i \in [1, N], E(y_{i,t}|\bar{y}_{i,t}, \alpha_i) \neq E(y_{i,t}|\bar{y}_{i,t}, \bar{x}_{i,t}, \alpha_i)$
$\forall\, (i, j) \in [1, N], E(y_{i,t}|\bar{y}_{i,t}, \bar{x}_{i,t}, \alpha_i) = E(y_{j,t}|\bar{y}_{j,t}, \bar{x}_{j,t}, \alpha_j)$

The null and alternative hypotheses of the HC are:

$H_0: \forall\, k \in [1, p], \beta_i^k = \beta^k\ \forall\, i \in [1, N]$
$H_a: \exists\, k \in [1, p], \exists\, (i, j) \in [1, N], \beta_i^k \neq \beta_j^k$

with the $F$-statistic being:

$$F_{\text{hc}} = \frac{(RSS_3 - RSS_1)/[(N - 1)\,p]}{RSS_1/[NT - N(1 + p) - p]} \tag{A3}$$

with $RSS_3$ being the sum of residual squares obtained when one imposes the homogeneity for each lag $k$ of the coefficients associated to $x_{i,t-k}$.

The HENC implies

$\exists\, i \in [1, N], E(y_{i,t}|\bar{y}_{i,t}, \alpha_i) = E(y_{i,t}|\bar{y}_{i,t}, \bar{x}_{i,t}, \alpha_i)$

with the null and alternative hypotheses being:

$H_0: \exists\, i \in [1, N], \forall\, k \in [1, p], \beta_i^k = 0$
$H_a: \forall\, i \in [1, N], \exists\, k \in [1, N], \beta_i^k \neq 0$

This hypothesis will be tested with two nested tests, with the first test on the hypothesis that for each $i$, $\beta_i^k = 0, \forall\, k \in [1, p]$, with the $F$ statistic being:

$$F_{\text{henc}}^i = \frac{(RSS_{2,i} - RSS_1)/p}{RSS_1/[NT - N(1 + 2p) + p]} \tag{A4}$$

where $RSS_{2,i}$ denotes the sum of residual squares obtained from model (A1) when one imposes $\beta_i^k = 0, \forall\, k \in [1, p]$ for each $i$. That is, the $x_{i,t-k}$ of the individual in question is excluded from the panel data of $\bar{x}_{i,t}$ in estimating model (A1). The second step tests the joint hypothesis that there is no causality relationship for a subgroup of individuals. Let $I_c$ and $I_{nc}$ denote sets with and without causal relationships respectively, then model (A1) can be written as

$$y_{i,t} = \sum_{k=1}^{p} \gamma^k y_{i,t-k} + \sum_{k=0}^{p} \beta_i^k x_{i,t-k} + \nu_{i,t}, \nu_{i,t} = \alpha_i + \varepsilon_{i,t} \quad \text{with} \quad \begin{cases} \beta_i^k \neq 0, i \in I_c \\ \beta_i^k = 0, i \in I_{nc} \end{cases}$$

and let $N_c$ and $N_{nc}$ denote the dimension of $I_c$ and $I_{nc}$ respectively, the $F$-statistic to calculate reads:

$$F_{\text{henc}} = \frac{(RSS_4 - RSS_1)/(N_{nc}\,p)}{RSS_1/[NT - N(1 + p) - N_c\,p]} \tag{A5}$$

where $RSS_4$ is the sum of residual squares obtained when one imposes $\beta_i^k = 0$, for $i \in I_{nc}$.

In the HEC case, the individual predictors based on $\bar{y}_{i,t}$, $\bar{x}_{i,t}$ and $\alpha_i$ are heterogeneous:

$\exists\, i \in [1, N], E(y_{i,t}|\bar{y}_{i,t}, \alpha_i) \neq E(y_{i,t}|\bar{y}_{i,t}, \bar{x}_{i,t}, \alpha_i)$
$\exists\, (i, j) \in [1, N], E(y_{i,t}|\bar{y}_{i,t}, \bar{x}_{i,t}, \alpha_i) \neq E(y_{j,t}|\bar{y}_{i,t}, \bar{x}_{i,t}, \alpha_j)$.

[18] Note that $N$, $P$ and $T$ denote the number of panel members, lags in regression and periods of observations, respectively.

## Appendix D. The Malmquist index

The general idea of the Malmquist index approach is to measure productivity with distance functions. For each period, $t = 1, \ldots, T$, the production technology $S_t$ models the transformation of inputs $X_t \in \Re^N_+$, into outputs, $Y_t \in \Re^M_+$,

$$S_t = \{(X_t, Y_t) : X_t \text{ can produce } Y_t\}, \tag{A6}$$

the output distance function at $t$ is then defined as

$$\begin{aligned} D_t(X_t, Y_t) &= \inf\{\theta : (X_t, Y_t/\theta) \in S_t\} \\ &= (\sup\{\theta : (X_t, Y_t/\theta) \in S_t\})^{-1} \end{aligned} \tag{A7}$$

Here $D_t(X_t,Y_t) \leq 1$ if and only if $(X_t,Y_t) \in S_t$ and $D_t(X_t,Y_t) = 1$ if and only if $(X_t,Y_t)$ is on the frontier of technology. In order to estimate TFP growth, one needs to define distance functions for two periods of $t$ and $t + 1$. The Malmquist productivity index is defined as:

$$M(X_{t+1}, Y_{t+1}, X_t, Y_t) = \left[\left(\frac{D_t(X_{t+1}, Y_{t+1})}{D_t(X_t, Y_t)}\right)\left(\frac{D_{t+1}(X_{t+1}, Y_{t+1})}{D_{t+1}(X_t, Y_t)}\right)\right]^{1/2} \tag{A8}$$

which can also be expressed as

$$\frac{D_{t+1}(X_{t+1}, Y_{t+1})}{D_t(X_t, Y_t)} \times \left[\left(\frac{D_t(X_{t+1}, Y_{t+1})}{D_{t+1}(X_{t+1}, Y_{t+1})}\right)\left(\frac{D_t(X_t, Y_t)}{D_{t+1}(X_t, Y_t)}\right)\right]^{1/2}$$

with the term outside the brackets measuring changes in relative efficiency (the change in how far observed production is from the maximum potential production) between period $t$ and $t + 1$, and the term inside the brackets measuring the shift in technology between the two periods. Therefore,[19]

$$\text{Efficiency change} = \frac{D_{t+1}(X_{t+1}, Y_{t+1})}{D_t(X_t, Y_t)},$$

$$\text{Technical change} = \left[\left(\frac{D_t(X_{t+1}, Y_{t+1})}{D_{t+1}(X_{t+1}, Y_{t+1})}\right)\left(\frac{D_t(X_t, Y_t)}{D_{t+1}(X_t, Y_t)}\right)\right]^{1/2}.$$

The crucial problem in constructing the Malmquist index is how to estimate the production frontier. Assuming there are $k = 1, \ldots, K$ decision making units (DMU, firms for example) using $n = 1, \ldots, N$ inputs $X^k_{n,t}$ in each period to produce $m = 1, \ldots, M$ outputs $Y^k_{m,t}$, the frontier technology can be constructed as follows:

$$S_t = \left\{(X_t, Y_t) : Y_{m,t} \leq \sum_{k=1}^{K} z_{k,t} Y^k_{m,t}, m = 1, \ldots, M; \sum_{k=1}^{K} z_{k,t} X^k_{n,t} \leq X_{n,t}, n = 1, \ldots, N;\right\}$$

with $z_{k,t} \geq 0$ for constant returns to scale (CRS), $\sum_{k=1}^{K} z_{k,t} \leq 1$ for non-increasing (NRS) returns to scale and $\sum_{k=1}^{K} z_{k,t} = 1$ for variable returns to scale (VRS). In order to calculate the Malmquist index for DMU $k'$, one needs to solve four linear programming problems:

$$\begin{aligned} &[D_t(X_{k',t}, Y_{k',t})]^{-1} = \max \theta_{k'} \quad \text{subject to} \\ &\theta_{k'} Y^{k'}_{m,t} \leq \sum_{k=1}^{K} z_{k,t} Y^k_{m,t}, m = 1, \ldots, M \\ &\sum_{k=1}^{K} z_{k,t} X^k_{n,t} \leq X^{k'}_{n,t}, n = 1, \ldots, N \end{aligned} \tag{A9}$$

[19] One can see the link between the Malmquist index and the conventional measure of productivity growth estimated from a Cobb-Douglas production function below. Let the production function be $Y_t = A_t \prod_{n=1}^{N} (X_{n,t})^{\alpha_n}$, $\alpha_n > 0$, with $A_t$ denoting TFP in level. Under the assumption that observed production is the same as the production frontier, one can easily show that $M(X_{t+1}, Y_{t+1}, X_t, Y_t) = \frac{A_{t+1}}{A_t} = 1 + \Delta TFP_{t+1}$.

In the presence of technical inefficiency, this approach would produce biased estimates of TFP growth.

and

$$\begin{aligned}&[D_t(X_{k',t+1},Y_{k',t+1})]^{-1}=\max\theta_{k'}\\&\theta_{k'}Y^{k'}_{m,t+1}\le\sum_{k=1}^{K}z_{k,t}Y^{k}_{m,t},m=1,\ldots,M\\&\quad\sum_{k=1}^{K}z_{k,t}X^{k}_{n,t}\le X^{k'}_{n,t+1},n=1,\ldots,N\end{aligned}\tag{A10}$$

with $z_{k,t}$ satisfying the corresponding conditions for CRS, NRS and VRS. $D_{t+1}(X_{k',t+1},Y_{k',t+1})$ is also computed using equation (A9) with $t+1$ replaced with $t$, while $D_{t+1}(X_{k',t},Y_{k',t})$ is calculated employing equation (A10) with subscripts $t$ and $t+1$ transposed. The above linear programming problem is solved $K$ times in each period and each linear programming produces a $\theta_{k'}$ and a vector of weights with elements of $z_{k,1}$, $z_{k,2}$, $z_{k,t}$.

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