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TRADE, TECHNOLOGY, AND CAPITAL FLOWS

by

GISELA MARIA SOBRAL PINHEIRO TÁVORA RUA

A dissertation submitted in partial satisfaction of the
requirements for the degree of
Doctor of Philosophy

in

Economics

in the

GRADUATE DIVISION
of the
UNIVERSITY OF CALIFORNIA, BERKELEY

Committee in charge:
Professor Barry Eichengreen, Co-Chair
Professor Maurice Obstfeld, Co-Chair
Professor Andrew Rose
Professor Bronwyn Hall

Fall 2012

TRADE, TECHNOLOGY, AND CAPITAL FLOWS

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GISELA MARIA SOBRAL PINHEIRO TÁVORA RUA

Abstract

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GISELA MARIA SOBRAL PINHEIRO TÁVORA RUA
Doctor of Philosophy in Economics

University of California, Berkeley

Professor Barry Eichengreen, Co-Chair
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This dissertation consists of three essays about two interconnected aspects of globalization: global trade integration and global imbalances. The first two essays focus on containerization, a technology that played a pivotal role in twentieth century global trade integration. Containerization, an intermodal system of door-to-door shipping, replaced traditional breakbulk methods of shipping and enabled the swift movement of cargo across the world. In the first essay, I present evidence on the historical evolution of containerization. For that purpose, I constructed a comprehensive dataset with information on the timing and intensity of adoption of containerization for 147 countries. I find that adoption moves in an S-shaped pattern, while usage moves more slowly and linearly. Additionally, I identify four stages in the historical diffusion of containerization, based on my data analysis and on historical and anecdotal sources: innovation and early adoption (1956–1965), internationalization (1965–1974), worldwide adoption and intensification of use (1975–1983), and late adoption and growth of usage (1984–2008). These findings guide the construction of a theoretical framework for understanding the determinants of adoption and usage of containerization. The theoretical model focuses on firms' choices between two transportation technologies (containerization and breakbulk) and on the decision by the country's transportation sector to construct, maintain and operate a container port (adoption). Changes in fixed costs and network effects generate the patterns observed in the data.

In the second essay, I investigate the determinants of adoption and usage, using a two-step procedure which is derived from the theoretical model presented in the previous essay. The empirical results, which are consistent with the theoretical predictions, show that fixed costs and network effects are the main determinants of usage of containerization. Fixed costs affect containerized trade as a result of the spread of leasing companies and changes in the domestic transportation network. Network effects operate through network size, network

usage, and network income. With regards to adoption, my results show that expected future usage of containerization, institutions, a country's size in terms of trade and geographical area, and trade with Australia and the United Kingdom are the main determinants. Trade with the United States, surprisingly, has no effect.

In the third essay, co-authored with Barry Eichengreen, I turn to the other aspect of globalization, global imbalances. First, we extend the two-country model presented in Obstfeld and Rogoff (2007) and investigate the exchange-rate implications of several rebalancing scenarios. We find that it matters tremendously how many countries are on the other side of the US current account adjustment; whether surplus countries like China, as they continue to grow, concentrate their investment in productive capacity in traded or nontraded goods; and the nature of structural reforms that change spending patterns in the US and abroad. Second, we investigate the likelihood of a sustained reduction in global imbalances. While previous literature has provided evidence on the circumstances under which large deficits come to an end, we add evidence on how chronic current account surpluses are also eliminated. We find that large current account surpluses tend to be eliminated when they have been allowed to rise previously to exceptionally high levels, when the economy doing the reducing is less open (smaller political resistance to resource allocation), when an earlier period of rapid growth comes to an end (presumably both moderating the rate of growth of the capacity to produce tradable goods and rebalancing demand toward domestic goods), after reductions in budget surpluses, and in the case of oil-exporting economies, when oil prices are unusually low.

Para a minha mãe, Alda.

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Chapter 1

Introduction

International economic integration increased dramatically in the five decades that preceded the current global financial crisis. In 2008, global trade was near 60 percent of world gross domestic product (GDP), compared with about 24 percent in 1960.[1] The growth in international capital flows was even steeper. For example, international banking claims, which were about 6.6 percent of GDP in 1983, rose to near 50 percent in 2008.[2] While the global financial crisis and the related "Great Trade Collapse" have temporarily halted this integration process, it is still a remarkable phenomenon, paralleled only by what is commonly known as the "first wave" of globalization, namely the period between 1870 and 1913. This dissertation examines two interconnected aspects of the recent phase of globalization: global trade integration and global imbalances.

Various technological advances in the areas of transportation, communications, and logistics management throughout the twentieth century have facilitated trade tremendously and therefore have served as major drivers of globalization. For instance, in the past few decades, especially, international shipping has become extremely fast and efficient, allowing countries at different stages of development to emerge into the global market. Firms that had been too distant from the rest of the world to trade internationally can now access foreign markets more easily, and many have become global players in the world economy. In the first two chapters of this dissertation, I focus on one technology that played a pivotal role in this global trade integration, containerization. Containerization revolutionized shipping and has, consequently, proven itself to be one of the most important innovations of recent globalization. As an intermodal system of door-to-door shipping, containerization enabled the swift movement of cargo across the globe, making it economically possible for the components of

[1] *World Development Indicators* (2011).
[2] *BIS Quarterly Review* (2012).

most products that we use daily to come from different parts of the world. For example, an Apple iPod, originally designed in California, may have a display made in Korea, a memory chip made in Japan, and was probably assembled in China.

One consequence of global competition for the location of different stages of production has been the emergence of large trade surpluses in countries like Japan, Germany, and China. Starting in the late 1990s, especially, trade surpluses in China and other East Asian economies (as well as in commodity-exporting countries, which have enjoyed a large windfall from high commodity prices) generated great wealth that could not be channeled into their own underdeveloped financial markets.[3] The United States has served as a safe haven for these countries' wealth, with large capital inflows from emerging economies toward the United States fueling excessive spending and a sustained rise in the US current account deficit. These large current account surpluses and large current account deficits in different parts of the world, known as global imbalances, have persisted in recent decades. Nonetheless, despite the persistence of these imbalances and the general agreement among academics and policymakers that global rebalancing is needed, a resolution to the problem of global imbalances is still a source of much debate. In the final chapter of this dissertation, I focus on the global imbalances that resulted from such rapid globalization, in particular the implications of different rebalancing scenarios and the circumstances under which persistent current account surpluses are eliminated.

Containerization brought dramatic efficiency to the global economy and has been widely accepted as a main facilitator of globalization. In the words of Peter Drucker, "without [containerization], the tremendous expansion of world trade in the last forty years – the fastest growth in any major economic activity ever recorded – could not possibly have taken place" (Drucker, 2007, p. 28). Shipping containers filled with goods move continuously between warehouses, ships, trains, and trucks. In spite of its ubiquitous presence in today's global economy, however, containerization was unimaginable as recently as the 1950s. Before the shipping container, goods were transported using traditional breakbulk methods, which were highly labor-intensive and slow. Ships could spend weeks at the port, while gangs of longshoremen loaded and unloaded cargo. Loss, pilferage, and damage of cargo were common, and shipping was much less reliable than it is today.

I study the international diffusion of containerization by asking the following important questions: (1) How did containerization become the central piece of world trade? (2) What determined its international diffusion? My answer comes in three parts. First, I present

[3] Caballero, Farhi, and Gourinchas (2008) show how the buildup in global imbalances can be understood as a consequence of underdeveloped financial markets in emerging economies, which were unable to create reliable financial instruments to keep up with their countries' rapid growth.

in Chapter 2 statistical and narrative evidence on the historical evolution of containerization. For this purpose, I have collected historical data on worldwide adoption and usage of containerization for the entire period from the inaugural container journey in 1956 up to 2008. This is a comprehensive dataset that includes all ports in 147 countries. My main findings show that adoption of containerization moves in an S-shaped pattern, which is consistent with previous findings in the innovation literature, while usage of containerization moves more slowly and linearly relative to adoption. Additionally, I identify four stages in the historical diffusion of containerization, based on my data analysis and on historical and anecdotal sources: innovation and early adoption (1956–1965), internationalization (1965–1974), worldwide adoption and intensification of use (1975–1983), and late adoption and growth of usage (1984–2008).

Second, still in Chapter 2, I present a theoretical framework for understanding the determinants of adoption and usage of containerization. The theoretical model focuses on firms' choices between two transportation technologies (containerization and breakbulk) and on the decision by the country's transportation sector to construct, maintain and operate a container port (adoption). Since each country's transportation sector's profits increase according to the number of countries in the container network (network effects), without further assumptions this problem would have two extreme Nash equilibria (either all transportation sectors adopt containerization immediately, or no one ever does), which is not what we observe in the data. For that reason, I introduce two additional assumptions into the model, based on the historical analysis presented previously. First, there is at least one country in the world whose transportation sector makes positive profits from using containerization for domestic trade only. This country will adopt containerization immediately, even if no other countries have adopted it yet. Historically, this was true for the first two countries using the technology. From 1956 to 1965, the U.S. used containerization for domestic trade only, and so did Australia from 1964 to 1966. Second, I introduce a limit to network effects: initially, transportation sectors make negative profits from containerization. This happens as a result of high initial fixed costs for firms wanting to export using containerization. Over time, as it becomes profitable for more firms to use containerization, transportation sectors' potential profits also increase, making them more likely to break even and build the container port. The two forces behind these dynamics are learning and competition between suppliers and the spread of leasing companies, which cause firms' fixed costs of exporting using containerization to decrease. The model generates the diffusion patterns present in the data: an S-shaped pattern of adoption and a slower and more linear pattern of usage.

Finally, in Chapter 3, I investigate the determinants of adoption and usage, using a two-step procedure which is derived from the theoretical model. More specifically, I use a hazard model of adoption where the odds of adopting containerization (i.e., building a

container port) depend, *inter alia*, on several measures of adoption costs and on anticipated containerized trade. The latter consists of the amount of containerized units that domestic and foreign firms are expected to export and import through the port. Since containerized trade cannot be observed before there is a container port, I estimate it in an auxiliary first step. The main findings are that fixed costs and network effects are the main determinants of usage of containerization. Fixed costs affect containerized trade as a result of the spread of leasing companies and changes in the domestic transportation network. Network effects operate through network size, network usage, and network income. Moreover, while network size matters equally for high- and low-income countries, the effect of network usage is stronger in low-income countries than in high-income countries. On the other hand, the domestic transportation network matters more for high-income countries, while growth in container leasing has a stronger effect on containerized trade in low-income countries. With regards to adoption, I find that expected future usage of containerization, institutions, a country's size in terms of trade and geographical area, and trade with Australia and the United Kingdom are the main determinants. Trade with the United States, surprisingly, has no effect. Also, the impact of expected future containerized trade is very strong, regardless of the time-horizon used: five, twenty, or even fifty years.

These results contribute to three literatures, those concerned with economic history, international trade, and innovation. First, the diffusion of containerization is one of the most important yet understudied aspects of 20th century globalization. Other technological improvements which were essential features of the 19th and early 20th centuries, such as the railroad (Fogel, 1964, Atack, Bateman, Haines, & Margo, 2010), the steamship (North, 1958), and the refrigerated car (Kujovich, 1970), have received fair attention in the economic history literature, from the perspectives of both their economic impact and their historical development. The first two chapters of this dissertation provide an in-depth analysis of another and more recent technology, which transformed the entire economics of shipping in the second half of the 20th century and became an essential piece of our globalized world.

Second, the international trade literature has shown that transport costs are a major determinant of trade. They play a central role in explaining trade patterns and are still a significant barrier to trade in many countries.[4] For example, Estevadeordal, Frantz, and Taylor (2003) provide evidence linking declines in shipping costs to the growth in trade in the period 1870–1913. Hummels (2001) shows direct and indirect evidence on trade barriers and finds that measured trade costs, such as tariffs and freight, are the main channel through which trade barriers affect trade volumes. Since changes in transportation technology impact transportation costs and ultimately trade patterns, understanding the diffusion of new

[4]See Anderson and Wincoop (2004) for a detailed survey on the effects of different trade costs on trade flows.

transportation technologies such as containerization is crucial for making sense of the rapid decline in transportation costs and the rise in trade volumes since 1950.[5] By investigating the determinants of the international diffusion of containerization, my work not only allows a better understanding of the role of trade in the diffusion of containerization, but it also helps guide future research on the reverse effect, the impact of containerization on trade. There are a few studies in the literature that quantify the effect of containerization on shipping costs, but they rely on U.S. data only (given the paucity of internationally comparable data). For example, using disaggregated commodity data from the U.S. Imports of Merchandise database for the period 1974–2004, Hummels (2007) finds that increasing the share of containerized trade lowers shipping costs between 2.9 and 13.4 percent. Blonigen and Wilson (2008) find a smaller effect using data provided by the National Data Center of the Army Corps of Engineers for the period 1991–2003: increasing the share of containerized trade by 1 percent lowers shipping costs by only 0.055 percent. The only study that quantifies the effect of containerization on trade is Bernhofen, El-Sahli, and Kneller (2011). They use the same data on the international adoption of container ports as I do and find a positive impact of containerization on trade. However, their econometric strategy suffers from endogeneity problems that could be solved by using evidence such as that presented in this dissertation.[6]

Finally, my research contributes to the literature on the diffusion of innovations, in particular at the international level. In a recent survey of the literature, Stoneman and Battisti (2010) observe that there are very few international studies of technology diffusion, primarily because of the limited availability of rich datasets with comparable international data.[7] My work fills this gap by constructing a dataset with extensive cross-country data for an important innovation.

Chapter 4, co-authored with Barry Eichengreen, turns to the other aspect of globalization, global imbalances. This chapter considers the general equilibrium between exchange rates and global imbalances. In the first part of the chapter, we investigate the exchange-rate implications of several rebalancing scenarios using extensions of the two-country model presented in Obstfeld and Rogoff (2007). Starting from a situation in which the US is in current account deficit and the rest of the world in surplus, we analyze the response of the

[5] In addition, Obstfeld and Rogoff (2000) argue that trade costs (including transport costs but also other trade barriers) are key to understanding the "six major puzzles" in international macroeconomics.

[6] In future research, I plan to use my results as a source of exogenous instruments to estimate the impact of containerization on trade.

[7] A recent exception is the work by Comin and Hobijn, which uses an extensive dataset covering the diffusion of many technologies in a large set of countries over 200 years (however, coverage is incomplete, especially during the introductory phases). In Comin and Hobijn (2004), they use this dataset to study cross-country diffusion of about twenty technologies in twenty-three countries, and in Comin and Hobijn (2010), they develop a model to explain the effect that cross-country differences in the timing of adoption have on total factor productivity (TFP). They estimate the model using 15 technologies in 166 countries.

real exchange rate and terms of trade to a decline in US spending and an increase abroad sufficient to eliminate the US deficit. We suppose, for example, that a financial crisis slashes the value of US households' retirement accounts, or that financial reforms in China eliminate credit constraints and create a social safety net which reduces the need for precautionary savings. In the second part, we investigate the likelihood of a sustained reduction in global imbalances. We argue that, since the deficit country, the United States, is a large economy, there needs to be a significant adjustment on both the deficit and the surplus sides. While previous literature has provided evidence on the circumstances under which large deficits come to an end, we add evidence on how chronic current account surpluses are also eliminated.

Our findings in the first part show that different rebalancing scenarios have a tremendous impact on the relative price adjustments that result from global rebalancing. First, we find that it matters immensely what countries participate with the US in the process of global rebalancing. If it is only China, the real exchange rate effects are extremely large; all of Asia and they are smaller; the rest of the world minus China and they are even smaller; the entire rest of the world including China and they are smaller still. Second, we find that it also matters greatly whether surplus countries like China, as they continue to grow, concentrate their investment in productive capacity in traded or nontraded goods. The real exchange rate changes needed to accommodate these different patterns of increased output are very different. While an increase in foreign capacity to produce traded goods would cause the dollar to depreciate in real terms, an increase in foreign production of nontraded goods, in contrast, would cause the dollar to appreciate. Finally, we find that shocks affecting spending patterns in the US and abroad can have a large effect on the real-exchange-rate adjustment as well. Stronger foreign preference for tradable goods would cause the dollar to appreciate, while declines in foreign taste for tradable goods or increases in US preference for tradable goods would cause the dollar to depreciate. Similarly, stronger foreign preference for US tradable goods would cause the dollar to appreciate, while declines in US home bias in tradable goods would cause the dollar to depreciate.

In the second part, we find that large current account surpluses do not last forever, and the larger the surplus, the more likely it is to eventually be wound down. We also find that this adjustment is more likely when an earlier period of rapid growth comes to an end, which supposedly moderates the rate of growth of the capacity to produce tradable goods and rebalances demand toward domestic goods. It is more likely in less open economies, where there is presumably less political resistance to resource allocation, and after reductions in budget surpluses. In the case of oil-exporting emerging economies, it is more likely when the price of oil is unusually low.

We conclude that the requisite adjustments are neither guaranteed nor likely to occur

automatically. Appropriate policy action would greatly increase the likelihood that countries on the surplus side of global imbalances contribute constructively to global rebalancing.

Chapter 2

Diffusion of Containerization: History and Theory

1 Introduction

> "The container made shipping cheap, and by doing so changed the shape of the world economy. (. . .) This new economic geography allowed firms whose ambitions had been purely domestic to become international companies, exporting their products almost as effortlessly as selling them nearby."
>
> Marc Levinson, *The Box: How the Shipping Container Made the World Smaller and the World Economy Bigger*, 2008, pp. 2–3.

Stacked container boxes are ubiquitous: we see them in ports, in truck chassis on highways, and in train stations. Yet the role of these simple structures of steel or aluminum in the mechanics of the global economy often goes unnoticed. Before cargo was handled in containers, international trade was expensive and slow. As recently as the 1950s, shipping was highly labor-intensive, and automation was limited. Vessels could spend weeks at the dock while cargo was handled, piece by piece, by gangs of longshoremen. Since different kinds of goods, with different destinations, were shipped together in the hold, loading and unloading cargo was a complex procedure. Many items were lost or damaged.[1]

This all changed in the late 1950s with the advent of containerization. Instead of gangs of longshoremen loading thousands of loose items at the dock, a container could be filled with cargo far away from the dock, moved to the port, and then hoisted onto the ship using specialized cranes. Unloading was similarly simplified. Ships' time in port was greatly

[1] See Ignarski (2006) and Woodman (1988) for vivid descriptions of the shipping business prior to containerization.

reduced. Loss, pilferage, and damage almost disappeared. Shipping became dramatically easier and faster.[2]

Today, containers filled with goods quickly move between warehouse, ship, train, and truck. They are the central piece of a complex global supply chain, with different stages of production located in various parts of the world. The IMF's *World Economic Outlook* called containers one of the "most important technological breakthroughs of the past fifty years" (International Monetary Fund, 2002, p. 116).

Despite the importance of containerization in 20th century globalization, an economic analysis of its diffusion is lacking. In this chapter, I construct a new and comprehensive dataset on containerization's international diffusion. The dataset consists of information on worldwide adoption and usage of containerization for the entire period from the inaugural container journey in 1956 up to the present. I use this dataset, together with statistical and narrative evidence, to document and characterize the diffusion of containerization. I identify four phases: innovation and early adoption (1956–1965), internationalization (1965–1974), worldwide adoption and intensification of use (1975–1983), and late adoption and growth of usage (1984–2008).

Two stylized facts emerge from this historical pattern of diffusion:

1. the adoption of port infrastructure follows an S-shaped curve (consistent with the innovation literature[3]), and

2. the use of containerization in international trade moves much more slowly and has a more linear trend than the adoption of port infrastructure.[4]

I then provide a theoretical analysis of the determinants of adoption and usage of containerization. The theoretical model focuses on firms' choices between two transportation technologies (containerization and breakbulk)[5] and on the decision by the country's transportation sector to construct, maintain and operate a container port. The model predicts that adoption, which follows an S-shaped path, is determined in particular by the cost of

[2] Levinson (2008), chapter 1, provides a window onto the intense and fast-paced activity of a container port.

[3] For example, Griliches (1957), Saloner and Shepard (1995), and Battisti and Stoneman (2003).

[4] Only after 50% of the countries in my sample had already built at least one container port did usage of containerization take off, around 1975.

[5] I consider only trade in containerizable goods, i.e., general cargo trade. General cargo comprises a large variety of goods, including both manufactured and semi-manufactured goods, but it does not include bulk goods such as oil, fertilizers, ore, and grain. It can be shipped either in containers or breakbulk (breakbulk refers to transporting general cargo goods in the ship's hold, packed in cartons, bags, bales, or pallets, instead of in containers). (Sources: Institute of Shipping Economics and Logistics, 2008 and U.S. Department of Transportation, 2008)

adoption and predicted containerized trade. Fixed costs and network effects determine firms' usage of containerization and therefore the share of trade that is containerized. These predictions are consistent with the broad patterns we see in the data and motivate the empirical analysis in Chapter 3.

2 The Dataset

I assemble historical data on the adoption and usage of containerization for the entire period from the inaugural container journey in 1956 up to the present. In particular, my dataset contains information for all general cargo ports on the initial adoption decision[6] and the share of trade that is containerized.

Since ports are the primary nodes of the world shipping network and because of the importance of maritime transportation in global freight trade,[7] I concentrate on traffic passing through ports, omitting that which passes through inland depots.[8] In order to extend my dataset further, however, I include river as well as sea ports. Therefore, my sample excludes only landlocked countries that have no access to navigable inland waterways.

The three main sources of data are *Containerisation International Yearbook*, *Shipping Statistics Yearbook*, and *Lloyd's Ports of the World*. In addition, I collected data from port websites and requested data directly from port authorities.[9] For most ports in my dataset, container tonnage data starts after 1969, since before then containerized trade was reported together with all general cargo trade (*Annual Report*, 1996). There are also ports in my dataset which have no available data on total and containerized trade.[10] My final dataset contains the year of adoption for 147 countries and the share of containerized trade for 98 of these.

After collecting all available data for the ports in my dataset, there were still some gaps: 5% of containerized trade and 8.7% of general cargo trade were missing. I explain my strategy for dealing with these missing values and describe the resulting augmented dataset

[6] Defined as the year when the first container port is constructed.

[7] Despite the recent growth in air transport, especially as regards value to weight, maritime shipping is still the dominant mode of transportation, accounting for 75% of world trade by volume in 2006 (Mandryk, 2009).

[8] To the best of my knowledge, these data are not available, but their omission is unlikely to have a significant impact on the coverage of my dataset.

[9] See appendices A and B, and C for detailed information about these sources, coding rules, and country coverage.

[10] These are mainly the smaller ports which most probably have also smaller shares of containerized trade. Their omission is likely to cause a small upward bias in my measure of a country's share of containerized trade, but given the small size of the ports that are omitted, I believe that it does not affect my results.

in Appendix D. This section also includes an explanation of how I aggregate port-level data to obtain each country's share of containerized general cargo trade.

3 Four Stages of Diffusion

Figure 2.1 depicts the two components of containerization diffusion: adoption and usage. The solid line is the share of countries (out of a total of 147) that have adopted containerization (i.e., they have built container-port infrastructure), while the dashed line is the average share of containerized trade (out of a total of 98 countries). The values shown are unweighted averages of the countries in the sample. We see that adoption of containerization follows an S-shaped curve while usage of containerization moves more slowly and linearly.

[Include Figure 2.1 here]

Figure 2.2 presents the same two components of diffusion as Figure 2.1, but the averages are weighted by each country's trade share. While accounting for countries' trade shares generates faster diffusion (since the first adopters are countries with large trade shares), the shape of both curves remains largely unchanged. Figure 2.3 compares adoption at the port level with adoption at the country level. Once more, the logistic pattern of adoption is still present.

[Include Figure 2.2 here]

[Include Figure 2.3 here]

Building on the shape of the diffusion curves generated by the data, as well as on historical and anecdotal sources, we can divide the whole period into four stages in which adoption and usage exhibit different behaviors:[11]

(i) 1956–1965: innovation and early adoption

(ii) 1966–1974: internationalization

(iii) 1975–1983: worldwide adoption and intensification of use

(iv) 1984–2008: late adoption and growth of usage

[11] See also Table 2.1 for descriptive statistics of each period.

The first period starts in 1956, when Malcom McLean sent a converted World War II tanker filled with fifty-eight truck trailers from Newark, NJ to Houston, TX.[12] In Newark, the trailers were filled with cargo not at the dock but at the shippers' inland warehouses, loaded onto trucks that moved them to the dock, and lifted by crane onto the ship. At the other end, in Houston, fifty-eight trucks "haul[ed the boxes] to their destinations" (Levinson, 2008, p. 1). This idea was not original; there are many historical accounts of earlier attempts to put freight into container boxes. But, as Marc Levinson points out, "those earlier containers did not fundamentally alter the economics of shipping and had no wider consequences" (Levinson, 2008, p. 53). McLean's did.[13] They were part of a new method of transporting goods that affected the whole shipping industry: road, rail, water, and air. They challenged the traditional breakbulk methods and transformed the centuries-old, slow, and labor-intensive process of port-to-port shipping into a radically new system of intermodal door-to-door shipping: containerization.

There were many advantages afforded by containerization. Ships' time in port was dramatically reduced.[14] Containerization involved fewer contracts and was more reliable; furthermore, by reducing the risk of losses, pilferage, and damage, it cut down insurance costs. Since container ships were larger and faster than conventional ships, they not only lowered sailing times, but also generated economies of scale. Containerization largely reduced the need for longshoremen, bringing substantial savings on wages (although not without strong opposition of labor unions worldwide). While extensive quantitative data on these various costs are not available, there are abundant anecdotal reports and localized studies corroborating these facts. For example, a study by the Port of New York Authority in the 1960s estimated that shipping Ballentine beer from Newark to Miami would cost 4 dollars per ton with breakbulk, while it would only cost 25 cents per ton with containerization (Levinson, 2008, p. 48). Ross (1970) cites industry estimates indicating that "it would take 126 men 84 hours each, or a total of 10,584 man-hours, to discharge and load about 11,000 tons of cargo aboard a conventional ship. The same amount of cargo on a container vessel can be handled by 42 men working 13 hours each or a total of 546 man hours" (Ross, 1970, p. 400). A similar estimate was presented in 1974 by Clifford O'Hara, Director of Port Commerce of the Port Authority of New York and New Jersey:[15] while six gangs of longshoremen would have taken 5 days to load and unload a conventional ship with approximately 10,000 tons of cargo in the 1950s, by 1974, five huge container cranes took less than 24 hours to load and

[12] The ship was equipped with on-board cranes to make it self-sufficient.

[13] The engineer behind McLean's vision about container shipping was Keith Tantlinger. He developed most of the technology that allows a shipping container to move between land and ship, for example, the corner fitting and twist-lock systems.

[14] Time in port was the largest and most important cost of running a vessel at the time.

[15] Previously the Port of New York Authority.

unload a container ship with 15,000 tons of cargo (O'Hara, 1974).

Given these advantages and simplicity of the technology, why did it take so long to develop containerization? Three convergent developments that occurred in the US in the first half of the 20th century provide an answer. While companies were sending small shipments of cargo across the country or overseas, carrying them in a big metal box was not economically optimal. These small shipments would have to be consolidated with others in order to fill the container, and therefore moving goods as loose cargo in trucks, boxcars, and the holds of breakbulk ships was a more viable business. It was only when the nature of retailing and wholesaling changed, starting in the 1920s, that organizing production to fill an entire trailer or container made economic sense. The transition from small neighborhood retailers to large companies that dominated retailing and wholesaling made shipping of large quantities of goods more practical. The second development was in land transportation. In the early 1950s, US railroads began to carry truck trailers in flatcars, a service they called "piggyback." Over longer distances, running a train was cheaper than running a truck (because of labor and fuel costs), and since rail rates were lower for full trailer loads, freight forwarding companies started to consolidate smaller shipments (Levinson, 2008, pp. 150–159). Furthermore, the smaller truck trip between the train and the final destination was also facilitated by the concurrent construction of the Interstate Highway System. Finally, US domestic maritime shipping was protected from foreign competition by legislation dating back to the 1920s. The Jones Act required that all goods transported by water between US ports be carried in US-flag ships with American crews.[16] Consistent with Schumpeterian models of innovation, this context of imperfect competition in the first half of the 20th century was the optimal market environment to generate innovation.[17] Moreover, because US labor costs were very high, these new technologies were likely to be labor-saving, as was the case with containerization.

[16]The Jones Act is another name for section 27 of the Merchant Marine Act of 1920.

[17]See Aghion and Howitt (1992), which formalizes Schumpeter's prediction of a negative relationship between competition and innovation (Schumpeter, 1943). If innovation is driven by the expectation of higher future profits, then lower competition (which raises profits) will increase the incentive to innovate. Aghion, Bloom, Blundell, Griffith, and Howitt (2005) reconcile the Schumpeterian theory with apparently contradictory empirical evidence by developing a new model that generates an inverted-U relationship between competition and innovation. They consider two opposing effects of competition on firms' innovation: the *Schumpeterian effect* (competition reduces post-innovation rents, therefore reducing innovation) and the *escape-competition effect* (competition reduces pre-innovation rents more than it reduces post-innovation rents, increasing the incremental profits from innovating). When competition is high, the *Schumpeterian effect* is more likely to dominate, while at low levels of competition the *escape-competition effect* will dominate. A lack of foreign competition, combined with competition between US companies operating US domestic maritime routes in the first half of the 20th century, generated an intermediate level of competition in the US domestic maritime industry during this period. At this intermediate level of competition, the *Schumpeterian effect* is still small while a strong *escape-competition effect* generates high incentives for innovation.

Despite the simplicity and obvious attractions of this new technology, between the late 1950s and early 1960s containerization remained exclusively American. Moreover, there were only two shipping companies using containers (McLean's Pan-Atlantic on the east coast and Matson on the west coast), and less than 10 ports – along both US coasts and in Puerto Rico – had been adapted to the new technology. The large initial capital outlay (in containers, chassis, forklifts, ships, and cranes) and uncertainty about the future (for instance, containers' ability to radically reduce transportation costs and their suitability for international trade) delayed others' adoption of containerization.

The first country to follow America was Australia, in 1964. Australia had two important characteristics in common with the US: high labor costs and an internationally non-competitive shipping industry. Like the US, they adopted containerization for domestic trade only, with newly-built cellular container ships sailing between Melbourne, Fremantle, and Brisbane. And yet, "viewed at the start of 1965, the balance on containerization's first nine years was positive but unspectacular" (Levinson, 2008, p. 164).

Everything changed in 1966, with the start of transatlantic container services between the east coast of the US and Europe. Two other events significantly accelerated the pace of containerization in this second period. First, the international standard for containers was approved in 1967, after six years of discussions and negotiations.[18] Setting the standard meant that containers could become entirely intermodal. Unlike the first companies in the US and Australia, which had built incompatible container boxes (each adjusted to the characteristics of their specific domestic trading markets), the new companies of the late 1960s were following standard dimensions and specifications for the container box.[19]

Standardization was also an important driver of container leasing. The first container lines had their own container boxes which they made available to firms as needed. These boxes differed in size and structure,[20] and therefore when firms began to containerize they had to load their goods into ship-line-specific container boxes. This caused great inefficiency and high logistics costs. For example, if a firm had contracted its containerized shipping with Sealand (which used 35-foot containers) but imported intermediate inputs from firms that worked with Matson (which used 24-foot containers), it could not interchange the containers and therefore incurred high fixed costs for managing these differently sized boxes.

[18] Negotiations at the International Standards Organization (ISO) had started in 1961, by American initiative and after an American standard had been approved in the same year. Not without much criticism from European and developing countries (UNCTAD's Group of 77), the ISO delegates approved the American design as the international standard.

[19] This was, however, not the case for existing companies. Both Sealand (previously Pan-Atlantic) and Matson clung to their traditional container dimensions for decades.

[20] They especially differed in the mechanism of their corner fittings, particularly relevant for handling by cranes and for stacking/storage.

Moreover, firms could rack up still more costs from delays in ship lines providing them with empty containers. During the first decade of containerization, a major user of containers complained that he had to return "empties" to the ship line within a short period of time but would then be waiting a day or longer for the same ship line to bring him an empty container in which he could pack his next outbound shipment. He added, "Sometimes my returning 'empty' passes the incoming container, which also is empty. It's a very wasteful and extravagant way of doing business" (Kendall, 1986, p. 233). Leasing companies, by providing an external source for container boxes, eased firms' initial adoption investment. As a result, they were key in reducing the fixed cost of containerization. They also played an important role in underwriting part of the risk of adoption, in meeting equipment shortfalls, and mitigating trade imbalances (Ignarski, 2006, pp. 126-141). As we see in Figure 2.4, container leasing started in the 1960s, but it only became commonplace in the 1970s.

[Include Figure 2.4 here]

The second event that greatly hastened the march of containerization's diffusion was the growth in US military operations. Both the buildup of military forces in Vietnam after 1965 and the military escalation of the Cold War created large demand for container services. There was a third event in this period, the closure of the Suez Canal between 1967 and 1975, which had a mixed effect on the diffusion of containerization. On the one hand, longer and more expensive journeys between Asia and Europe erased part of the gains from using containerization. The containerships of the 1960s, which had been designed to pass through the Canal, were too slow for longer distances, but its closure required many containerships to make the long voyage around the Cape of Good Hope. This might explain, in part, the very slow growth of containerized trade in many countries during this period. We can see this in Figure 2.5, which shows the dispersion of container usage across countries and over time. By 1974, only the US had a share of containerized trade of near 70%; most countries were containerizing less than 20% of their trade. On the other hand, despite the slow growth in container usage, the closure of the Suez Canal created an incentive for adoption by countries which were now part of the main trade routes between Asia and Europe. Some southern African countries possibly joined the network earlier than they would have otherwise.[21]

[Include Figure 2.5 here]

While by 1974 containerization was mostly used in North America, Europe, and East Asia (see Figure 2.6 and Appendix E), by the end of third period containerization had

[21]For example, South Africa adopted containerization as early as 1971, one of the first 40 countries to join the network.

reached almost all corners of the world. In 1983, 80% of countries had built at least one container port. However, despite worldwide adoption, use of the new technology was still slow, and only about 30% of world trade was containerized. Usage would only reach the 50% mark in the mid-1990s. During the last period, from 1984 to 2008, the network grew in density. Many countries greatly increased their number of container ports, and only thirteen small economies built their first container port. By 2008, only Gabon, Solomon Islands, and Somalia had yet to adopt containerization.

[Include Figure 2.6 here]

4 Theoretical Framework

In this section, I develop a theoretical framework that provides a rationale for the diffusion patterns that emerge from the data and motivates the econometric analysis presented in the next chapter. The theoretical framework is compatible with the two stylized facts discussed in the previous section: (1) the adoption of port infrastructure follows an S-shaped curve, and (2) the use of containerization in international trade moves much more slowly and linearly than the adoption of port infrastructure. The theoretical framework is also compatible with observed characteristics of the history of containerization (see below). It consists of three main features:

1. Monopolistic competition and heterogeneous firms (as in Melitz, 2003)
2. Two transportation technologies, containerization and traditional breakbulk shipping, which have different relative costs.
3. A transportation sector that constructs, maintains and operates the transport system

Containerization involves lower transport costs than traditional breakbulk shipping but also requires more complex distribution logistics and inventory management systems that raise the fixed cost of servicing a foreign market. In each country, the transportation sector decides whether or not to build a container port, based on its expectations about domestic and foreign firms' usage of containerization. Depending on the existence of a container port, productivity differences between firms determine firms' decisions about which transportation technology to use. Of firms that export to countries with a container port, only the most productive find it profitable to use containerization.

Since it is costly to build and maintain a container port, the transportation sector charges a fee per unit of containerized trade that passes through the port[22] and will only build a container port when it expects to break even. Transportation sectors in different countries will break even at different points in time because of differences in country characteristics, differences in the characteristics of a country's trade partners, and differences in the decisions of a country's trade partners' transportation sectors. In addition, expansion of the network of trade partners with container ports and reductions in the fixed cost of containerization will raise the total amount of containerized trade and therefore the profits of the transportation sector.

4.1 Setup of the Model

I use the model of international trade in differentiated goods in which heterogeneous firms face fixed and variable costs of exporting as presented in Melitz (2003). I consider a world economy with M countries, indexed by $j = 1, 2, \ldots, M$. Each period, the preferences of a representative consumer in country j are given by a constant elasticity of substitution (C.E.S.) utility function over a continuum of varieties indexed by k,

$$U_{j,t} = \left[\int_{k \in \Omega_{j,t}} (\bar{x}_{j,t}(k))^{\frac{\epsilon-1}{\epsilon}} dk \right]^{\frac{\epsilon}{\epsilon-1}} \tag{2.1}$$

where $\bar{x}_{j,t}(k)$ is consumption in country j of variety k at period t, and $\Omega_{j,t}$ is the mass of varieties available in country j at period t.

There are M varieties in the world, where each country has a measure one of firms, each producing a different variety. The varieties produced by country j's firms are different than those produced by country i's firms, for $i \neq j$. The elasticity of substitution between varieties, $\epsilon > 1$, is the same in every country.

Country j's consumers' utility maximization delivers the following demand for variety k at any given period t:

$$x_{j,t}(k) = \tilde{p}_{j,t}(k)^{-\epsilon} P_{j,t}^{\epsilon-1} Y_{j,t} \tag{2.2}$$

[22] Port fees include, among other things, charges for "pilotage, tuggage, wharfage, dockage, line-handling, stevedoring, vessel overtime, rental of terminal cranes, and (moving) containers (...) to and off the vessel" (Talley, 2009, p. 112). I follow the port economics literature in representing port charges as a cost per unit of cargo passing through the port. For example, Talley (2009) considers a generalized port price per unit of throughput. While a unit of throughput can be measured either in tonnage or in twenty-foot equivalent units (TEUs), it is common among maritime data analyses and consulting publications to use average conversion factors between these two. (See, for example, Drewry Shipping Consultants Ltd, 2005 and The Tioga Group, Inc., 2009).

where $x_{j,t}(k)$ is country j's optimal consumption of variety k at period t, $Y_{j,t}$ is country j's income at period t (which equals expenditures), $\tilde{p}_{j,t}(k)$ is the delivered price of variety k in country j, and $P_{j,t}$ is the aggregate C.E.S. consumer price index at period t, given by

$$P_{j,t} = \left[\int_{k \in \Omega_{j,t}} \tilde{p}_{j,t}(k)^{1-\epsilon} dk \right]^{\frac{1}{1-\epsilon}}. \tag{2.3}$$

Firms in each country produce 1 unit of output with an optimal combination of inputs costing $c_{j,t}a$. The $c_{j,t}$'s are country-specific measures of the cost of a bundle of inputs, and they reflect differences in factor prices across countries. Parameter a is a firm-specific measure of the number of bundles of the country's inputs that need to be used to produce 1 unit of output. Its inverse is the firm's productivity. It is distributed according to the cumulative distribution function $G(a)$ with support $[0, a_H]$. This distribution function is the same in all countries and over time.

There are two additional costs if a firm from country j exports to country i: a fixed cost of exporting, $c_{j,t}f_{j,t}$, and an "iceberg transport cost," τ_{ij}. These are the same for all firms in the country. "Iceberg transport costs" mean that τ_{ij} units must be shipped from country j to country i for 1 unit to arrive. This is because $\tau_{ij} - 1$ units "melt away" during shipment. We can think of these lost units as ship lines' compensation for transporting the goods. These fixed and variable trade costs are zero if the firm sells in the domestic market.[23]

Since firms are monopolistic, they set prices as a markup over marginal costs and take the aggregate price index as given. The price of a firm from country j is

$$p_{j,t}(a) = \frac{c_{j,t}a}{\alpha} \tag{2.4}$$

and the delivered price in country i is

$$\tilde{p}_{j,t}(a) = \frac{c_{j,t}a}{\alpha}\tau_{ij} \tag{2.5}$$

where $\alpha = (\epsilon - 1)/\epsilon$.

Given equilibrium prices, operating profits from selling in country i at period t are

$$\pi_{ij,t}(a) = (1-\alpha)\left(\frac{c_{j,t}a}{\alpha P_{i,t}}\tau_{ij}\right)^{1-\epsilon} Y_{i,t} - c_{j,t}f_{j,t} \tag{2.6}$$

[23] If there are no changes in transportation technology, the τ_{ij}'s remain constant over time. They are related to constant geographical trade frictions, such as bilateral distance. On the other hand, even if there are no changes in transportation technology, the f_j's may change over time (see Section 4.2). They are associated with distribution logistics and inventory management costs that are necessary to serve a foreign country.

Operating profits from selling in the domestic market are always positive since $f_{j,t} = 0$.[24] However, not all firms sell in the foreign market. This choice is determined by a cutoff productivity level, and only country j's firms with productivity above this cutoff find it profitable to sell in country i. This cutoff is implicitly determined by the zero profit condition:

$$\pi_{ij,t}(a_{ij,t}) = 0 \quad \Leftrightarrow \quad (1-\alpha)\left(\frac{c_{j,t}a_{ij,t}}{\alpha P_{i,t}}\tau_{ij}\right)^{1-\epsilon} Y_{i,t} = c_{j,t}f_{j,t} \qquad \forall j \neq i \tag{2.7}$$

and can be expressed as

$$a_{ij,t}^{1-\epsilon} = c_{j,t}^{\epsilon}\ \frac{f_j}{\tau_{ij}^{1-\epsilon}}\frac{\alpha^{1-\epsilon}}{(1-\alpha)}\frac{P_{i,t}^{1-\epsilon}}{Y_{i,t}} \tag{2.8}$$

Note that, since $a^{1-\epsilon}$ is monotonically increasing with firms' productivity $(1/a)$, we can think of it as a productivity index. Figure 2.7 is a graphical representation of firms' export decisions.

[Include Figure 2.7 here]

The fraction of country j's firms that exports to country i is

$$G(a_{ij,t}) = \int_0^{a_{ij,t}} a\ dG(a) \tag{2.9}$$

This implies that, in each period, the set of varieties available in country i, $\Omega_{i,t}$, is smaller than the total set of products produced in the world economy.

In each period, the value of country i's imports from country j is

$$m_{ij,t} = \left(\frac{c_{j,t}\tau_{ij}}{\alpha}\right)^{1-\epsilon}\frac{Y_{i,t}}{P_{i,t}^{1-\epsilon}}\int_0^{a_{ij,t}} a^{1-\epsilon}\ dG(a) \tag{2.10}$$

where the term with the aggregate price index can now be expressed as

$$P_{i,t}^{1-\epsilon} = \sum_{j=1}^{M}\left(\frac{c_{j,t}\tau_{ij}}{\alpha}\right)^{1-\epsilon}\int_0^{a_{ij,t}} a^{1-\epsilon}\ dG(a) \tag{2.11}$$

[24] This is a convenient assumption as it ensures that firms will always sell in the domestic market, and it allows me to ignore domestic profits hereafter and focus only on profits obtained from sales in the foreign market.

4.2 Transportation Technology

In each period, exporting firms can choose between two transportation technologies: containerization and traditional breakbulk shipping. This choice is available to all firms since they all produce varieties that are containerizable. However, it is only available in country-pairs where both countries have container-port infrastructure. When this infrastructure does not exist, firms can only use breakbulk shipping.

The transportation sector is responsible for constructing port infrastructure, maintaining it, and operating the system of maritime transport. This sector may be public or private.[25] There is no trade by land in the model, and all trade needs to pass through the port. There is also only direct shipping between countries.

Relative to breakbulk, a smaller amount of goods melts away during shipment with containerization. This amount is $\psi_{ij} - 1$ instead of $\tau_{ij} - 1$, with $1 < \psi_{ij} < \tau_{ij}$.[26] However, the transportation sectors in both country i and country j each take a fraction ϕ of the amount of containerized trade that passes through the container port as a fee for using it. Therefore, in order for 1 containerized unit to arrive at country i, firms in country j have to ship $\psi_{ij}/(1-\phi)^2$ units.[27] As a result, transport costs with containerization are[28]

$$t_{ij} = \frac{\psi_{ij}}{(1-\phi)^2} < \tau_{ij}, \qquad 0 < \phi < 1 \tag{2.12}$$

[25]Since containerization relies on special infrastructure and equipment at the port, it is only when these are present that we can say a country has a container port rather than a traditional port. Broeze describes container ports as "highly specialized and purposeful creations" (Broeze, 2002, p. 172).

[26]Modeling the costs of containerized shipping as "iceberg transport costs" is akin to assuming that ship lines determine freight rates based on the volume of goods transported. Although this is not very far from reality, there are several nuances in setting containerized freight rates that are not represented in the model. Container freight rates are generally calculated using three pieces of information: (1) the container load ("full container load" vs. "less than full container load"), (2) the weight (adjusted by a commodity's stowage factor and special needs, for example, whether or not it needs to be refrigerated), and (3) the shipping route (major trading routes are allocated large container ships and therefore benefit from greater economies of scale; regional trade imbalances and the need to therefore ship empty containers in one direction also affect freight rates). While the first two components are hard to measure without additional data, especially without data on the composition of containerized trade, I control for the third component in the empirical analysis (Chapter 3) by adding shipping region dummies.

[27]The fee is exogenously determined (it may, for example, be determined by regulation) and is the same for all countries. Assuming that this exogenous fee is different between countries does not quantitatively change the results. However, it would be interesting to investigate what happens if this fee is endogenously determined. If transportation sectors charge an optimal fee, there may additionally be interesting results stemming from competition between transportation sectors.

[28]Why containerization allows for lower transport costs than traditional breakbulk shipping has been explained in Section 1. In brief, it is because containerization is an intermodal system that reduces ships'

Despite reducing transport costs, containerization raises the fixed cost of exporting. This is because firms need more sophisticated distribution logistics and inventory management systems and must buy or lease container boxes.[29] The literature on technology diffusion has shown that learning and competition between suppliers are likely to lead to a drop in the price of a technology over time (Geroski, 2000, David & Olsen, 1992). Learning and competition effects push the price down at an initially high and subsequently declining rate. These changes in the price of containerization affect the fixed cost of exporting, such that $f_{j,t}$ decreases over time. Since breakbulk has been around for millennia, I assume that the fixed cost of exporting using traditional shipping has already reached its lowest bound and is therefore constant.[30] Hence, the relationship between the fixed costs of exporting using the two alternative transportation technologies is

$$f^c_{j,t} > f^b_j \qquad \text{where} \qquad f^c_{j,t+1} < f^c_{j,t} \qquad \forall t \tag{2.13}$$

These variable and fixed costs generate the following operating profits from exporting using breakbulk shipping and containerization respectively:

$$\pi^b_{ij,t}(a) = (1-\alpha)\left(\frac{c_{j,t}a}{\alpha P_{i,t}}\tau_{ij}\right)^{1-\epsilon} Y_{i,t} - c_{j,t}f^b_j \qquad \forall j \neq i \tag{2.14}$$

$$\pi^c_{ij,t}(a) = (1-\alpha)\left(\frac{c_{j,t}a}{\alpha P_{i,t}}t_{ij}\right)^{1-\epsilon} Y_{i,t} - c_{j,t}f^c_{j,t} \qquad \forall j \neq i \tag{2.15}$$

Define $(a^c_{ij,t})^{1-\epsilon}$ as the productivity cutoff at which these profits are the same, which equals

$$(a^c_{ij,t})^{1-\epsilon} = c^{\epsilon}_{j,t}\,\frac{f^c_{j,t} - f^b_j}{t^{1-\epsilon}_{ij} - \tau^{1-\epsilon}_{ij}}\,\frac{\alpha^{1-\epsilon}}{(1-\alpha)}\,\frac{P^{1-\epsilon}_{i,t}}{Y_{i,t}} \tag{2.16}$$

time in port, is more reliable, permits a considerable reduction in loss, pilferage, and damage, involves lower insurance fees, has large economies of scale, provides increased savings in labor costs, and involves fewer contracts.

[29] "The full benefits of containerization can only be derived from logistic systems designed with full use of containers in mind" (part of Frank Besson's testimony to Congress in 1970, quoted in Levinson, 2008, p. 184). Frank Besson was the head of the US Army supply operations at the time of the Vietnam War and one of the most passionate supporters of the use of containerization in military logistics.

[30] While improvements in forklift truck technology arguably reduced the fixed cost of traditional shipping, it is extremely unlikely that this reduction in the fixed cost was larger than containerization's. As Levinson points out, given the different sizes and nature of goods shipped in breakbulk, human muscle was often the ultimate solution, even with sophisticated forklift trucks readily accessible (Levinson, 2008, p. 18).

Define also $(a^b_{ij,t})^{1-\epsilon}$ as the productivity cutoff at which profits from exporting using breakbulk shipping are zero (see equation 2.8)

$$(a^b_{ij,t})^{1-\epsilon} = c^{\epsilon}_{j,t} \frac{f^b_j}{\tau^{1-\epsilon}_{ij}} \frac{\alpha^{1-\epsilon}}{(1-\alpha)} \frac{P^{1-\epsilon}_{i,t}}{Y_{i,t}} \quad . \tag{2.17}$$

This component of the model is a variant of the framework in Helpman, Melitz, and Yeaple (2004), which extends Melitz (2003) by allowing firms to choose between exporting and establishing an affiliate in the foreign market. In line with Helpman et al. (2004)'s strategy, I assume that there are productivity levels at which exporters have positive profits from breakbulk that are higher than profits from containerization. This implies that

$$(a^c_{ij})^{1-\epsilon} > (a^b_{ij})^{1-\epsilon} \tag{2.18}$$

which is equivalent to assuming the following condition for variable and fixed costs of both transportation technologies:

$$t^{\epsilon-1}_{ij} f^c_{j,t} > \tau^{\epsilon-1}_{ij} f^b_j \quad \Leftrightarrow \quad \frac{f^c_{j,t}}{t^{1-\epsilon}_{ij}} > \frac{f^b_j}{\tau^{1-\epsilon}_{ij}} \tag{2.19}$$

The increase in fixed costs from using containerization is high relative to the reduction in variable trade costs. In equilibrium, firms use one of the transportation technologies, but not both.

Conditional on the existence of a container port in both countries i and j at period t, which our atomistic firms take as given, the choice of transportation technology is determined by the cutoff level $a^c_{ij,t}$. Firms with productivity levels between $(a^b_{ij,t})^{1-\epsilon}$ and $(a^c_{ij,t})^{1-\epsilon}$ use breakbulk transportation, while only the most productive exporters, with productivity above $(a^c_{ij,t})^{1-\epsilon}$, find it profitable to use containerization. Figure 2.8 replaces Figure 2.7.

[Include Figure 2.8 here]

To understand this result, consider the cost of exporting 1 unit using each technology. Unit transport costs (UTC) are a function of firms' productivity and can be expressed as

$$UTC^b(a) = c_{j,t} a \tau_{ij} + \frac{c_{j,t} f^b_j}{x_{ij}(a)} \tag{2.20}$$

$$= c_{j,t} a \left(\tau_{ij} + \frac{c^{\epsilon}_{j,t} \tau^{\epsilon}_{ij} f^b_j P^{1-\epsilon}_{i,t}}{\alpha^{\epsilon} Y_{i,t} a^{1-\epsilon}} \right) \tag{2.21}$$

and

$$UTC^c(a) = c_{j,t}at_{ij} + \frac{c_{j,t}f^c_{j,t}}{x_{ij}(a)} \tag{2.22}$$

$$= c_{j,t}a\left(t_{ij} + \frac{c^\epsilon_{j,t}t^\epsilon_{ij}f^c_{j,t}P^{1-\epsilon}_{i,t}}{\alpha^\epsilon Y_{i,t}a^{1-\epsilon}}\right) \tag{2.23}$$

Condition (2.19) ensures that, compared to breakbulk, containerization requires high fixed costs relative to its savings in transport costs. This implies that only those firms which can spread the fixed transport cost over a larger amount of exports will be able to profit from exporting with containerization. For the same transportation technology, more productive firms export more (they charge lower prices), and the elasticity of substitution, which is higher than one ($\epsilon > 1$), magnifies this difference. Figure 2.9 shows how the unit transport costs of the two technologies vary with productivity. Containerization's unit transport costs are higher than breakbulk's for the least productive exporters, but they are lower for the most productive exporters. The point at which exporters switch from breakbulk to containerization is the productivity cutoff. At period t, exporters with productivity below $(a^c_{ij,t})^{1-\epsilon}$ choose breakbulk, while exporters with productivity above this cutoff choose containerization. Since firms set prices as a markup over marginal costs, the switch to containerization causes a reduction in the delivered price in the foreign market, and it is at the cutoff point that this reduction in average revenue is entirely compensated by the drop in unit costs.

Another way to understand firms' selection between the two technologies is by looking at their profits. Each period, the choice between transportation technologies does not affect firms' decisions to export but affects their export operating profits. For the reasons presented above, by choosing containerization, the most productive firms can enjoy higher profits than they would have using traditional breakbulk shipping, and the higher their productivity, the more their profits increase.

[Include Figure 2.9 here]

Because the fixed cost of using containerization is decreasing over time, due to learning and competition between suppliers, the productivity cutoff is also decreasing over time.[31] Figure 2.9 illustrates this point for a one-period transition.[32] This implies that some of the less productive exporters, whose unit transport costs were previously too high, can now

[31] While ship lines have undeniably invested in bigger and more efficient container ships, which arguably lowered transport costs, modeling an additional decline in τ would only reinforce the effects of declining fixed costs.

[32] For simplicity, I assume that c_j does not change between t and $t+1$.

switch to containerization. The more time that passes since the introduction of containerization, the higher the number of exporters that optimally choose the new technology instead of traditional breakbulk shipping.

4.3 The Transportation Sector

In each country, the transportation sector faces a choice between keeping the traditional port infrastructure and building new port facilities adapted to containerization. The transportation sector needs to spend Γ_j units of the numeraire at period t for the container port to be ready, and it costs γ_j per unit of containerized trade to maintain and operate it.[33] Adoption of containerization is an absorbing state; that is, after the container port is constructed, it operates forever. Investment in containerization is irreversible.[34]

When firms use container services and equipment at country j's container port (namely, those firms of country j which containerize exports and those foreign firms which containerize imports to country j), the transportation sector charges them a fee, ϕ, per unit of containerized trade.[35] The fee for breakbulk services is normalized to zero.

Under perfect foresight, the present value of the profits of country j's transportation sector from building the container port at period t are

$$\Pi_{j,t} = \sum_{s=t}^{\infty} \rho^{(s-t+1)} \left(\phi - \gamma_j\right) T^c_{j,s} - \Gamma_j \tag{2.24}$$

where $T^c_{j,s}$ is country j's aggregate containerized trade at period s, $s \geq t$, and ρ is the discount factor. For simplicity, I assume zero profits from operating a traditional port.

Define A_k as an indicator variable which equals 1 when there is a container port in country k and zero when country k has only a traditional port. In each period, country j's total containerized trade with k depends on the existence of a container port in k (A_k) and, conditional on k having a container port, on domestic and foreign firms' decisions about which transportation technology to use. Therefore, j's aggregate containerized trade at period s can be expressed as

$$T^c_{j,s} = \sum_{k \neq j} T^c_{kj,s} = \sum_{k \neq j} A_{k,s} \left(m^c_{kj,s} + m^c_{jk,s}\right) \tag{2.25}$$

[33] For simplicity, I assume that these costs are constant over time, but I will relax this assumption in the empirical analysis.

[34] Empirically, this is true at the country level – no country in the sample went from adoption to non-adoption of containerization. Some ports in a given country have stopped providing container services, but they have always been replaced by other container ports in the same country.

[35] As explained in the previous section, this fee raises containerization's transport costs.

where

$$m^c_{kj,s} = \left(\frac{c_{j,s}t_{kj}}{\alpha}\right)^{1-\epsilon} P^{\epsilon-1}_{k,s} Y_{k,s} \int_0^{a^c_{kj,s}} a^{1-\epsilon}\, dG(a) \tag{2.26}$$

$$m^c_{jk,s} = \left(\frac{c_{k,s}t_{jk}}{\alpha}\right)^{1-\epsilon} P^{\epsilon-1}_{j,s} Y_{j,s} \int_0^{a^c_{jk,s}} a^{1-\epsilon}\, dG(a) \tag{2.27}$$

Country j's transportation sector builds a container port at period t if domestic and foreign firms containerize enough trade over time that it will make positive profits, that is, $\Pi_{j,t} > 0$.

4.4 Equilibrium

The structure of the transportation sector's problem implies the existence of network effects: an increase in the number of countries in the container network will (non-strictly) increase the profits of all transportation sectors.[36] An additional implication is that each transportation sector makes zero profits when all other transportation sectors remain with traditional ports (if no one adopts, there is no one to trade with using containerization).

Given perfect and complete information, there is no value to waiting. Therefore, if it were the case that when adoption is profitable for one transportation sector, it is also profitable for all others, this problem would have two Nash equilibria: either all transportation sectors adopt containerization immediately, or no one ever does.

However, I introduce two additional assumptions, in line with the history of containerization, to match what we observe in the data. First, I assume that there is at least one country in the world whose transportation sector makes positive profits with a container port even if there are no other countries with container ports. This country is the US.[37] It was the first country to adopt containerization and used it for domestic trade only from 1956 to 1965.[38] This assumption guarantees that there is at least one country which adopts containerization immediately.

Second, I consider a limit to network effects such that other transportation sectors adopt containerization sequentially. I assume that transportation sectors initially make negative profits from containerization, even if all other countries have already built a container port. This assumption can be justified by going back to equation (2.24). Transportation sector

[36] The reason why profits are not strictly increasing in the number of countries in the container network is that, since productivity is bounded, there might be a subset of countries with zero bilateral trade. For those pairs, the adoption decision of one transportation sector does not directly affect the other's.

[37] The reasons for US' initial adoption have been discussed in detail in Section 1.

[38] I could, additionally, consider a second country, Australia, which adopted containerization in 1964 and also used it only for domestic trade until 1966.

j will make negative profits from constructing a container port if Γ_j is very high, or if no firm in country j finds it profitable to use containerization even if it is available. The latter occurs when containerization's productivity cutoff is too high: $(a_{ij}^c)^{1-\epsilon} \geq a_L^{1-\epsilon}$ for all countries i that are j's trade partners. This is conceivable if firms' fixed cost of exporting using containerization, f_j^c, is still very high or if the gain from decreased transportation costs, $\tau_{ij} - t_{ij}$, is too small.

Transportation sectors' profits need not remain negative forever since firms' fixed cost of exporting using containerization declines over time, due to learning and competition between suppliers and the spread of leasing companies (see Section 3). Furthermore, this drop in $f_{j,t}^c$ will affect firms' productivity cutoffs differently according to country.[39] Consequently, there is a threshold period t'_j when each transportation sector breaks even and adopts containerization. This threshold depends, for example, on how much the country trades with previous adopters, the magnitude of the gain from decreased transportation costs, differences in factor prices, and differences in the cost of building the container port. However, this threshold is not unique; it depends on other countries' decisions. This interconnection between countries' adoption decisions generates multiple equilibria but all of the same nature. They correspond to sequences of adoptions where at least one country adopts immediately and all other countries adopt when firms' fixed costs of using containerization are low enough that the transportation sector breaks even. Because of the limit to network effects imposed by fixed costs, at each period t there is a range of potential adoptions, each producing a different S-shaped path. Diffusion is faster or slower depending on which equilibrium prevails. Moreover, network effects explain why the resulting curve is S-shaped. The more countries that have adopted containerization, the stronger the effect of decreasing fixed costs on transportation sectors' profits. Analytically, this corresponds to having more countries included in the summation presented in equation (2.25).

To understand these multiple equilibria, we can look at a 2-country case. Assume that, at a given period t, both Portugal and England's transportation sectors do not break even from adopting containerization separately, but given the large amount of bilateral trade between the two countries, they would break even if they both adopted at t. There are therefore two Nash equilibria, one where neither country adopts and another where both adopt at t. Diffusion is slower in the former and faster in the latter, and decreasing fixed costs ensure that, if Portugal and England did not adopt at t, they will do so in the future. With M countries, multiple equilibria will originate from several combinations of the situation described above.

One way we can rule out these multiple equilibria is by assuming communication between

[39] The reduction in containerization's productivity cutoff caused by the drop in $f_{j,t}^c$ depends on $c_{j,t}$, $Y_{j,t}$, $P_{j,t}$, $\tau_{ij,t}$, and $t_{ij,t}$ (see equation 2.16).

countries. If, at each period t, countries can credibly negotiate with each other and governments can guarantee their adoption, the maximum number of countries that can adopt will do so. In this case, there will be only one S-shaped path of adoptions.

The model also explains why containerized trade moves more slowly and linearly than adoption of port infrastructure. First, since the decision to build a container port is based on the present value of future containerized trade, container-port infrastructure will be constructed ahead of firms' usage of the technology. Second, weaker network effects at the firm level (given heterogeneity) generate a more linear expansion of containerized trade. These predictions are in line with what we observe in Figure 2.1.

While the model provides simple predictions for the adoption and usage of containerization, it has a few limitations that are worth discussing. First, firms are differently affected by containerization only to the extent that there are productivity differences between them – containerization affects transport costs of all firms in a given country equally, but only the most productive choose to use it. In reality, of course, costs and benefits of containerization may vary across products. Some products are harder to accommodate inside "the box" because of their bulkiness or odd shape (e.g., Caterpillar equipment and machinery), fragile products need to be cushioned (e.g., electric light bulbs), some perishable goods need to be refrigerated (e.g., meats), and dangerous products take longer to pass security checks and clear through customs. The handling and stowage characteristics of exported products matter for their unit transport cost, whether one thinks of this only in terms of the shipping cost or also in terms of time. To the extent that these differences are not captured by differences in productivity, they are not included in the model.

Second, there are no intermediate goods. The model therefore does not capture the role of containerization in generating today's global supply chains, which are an important feature of the global economy.

Finally, in considering only direct shipping routes between countries, the model abstracts from the rise of some container ports as international hubs (e.g., Singapore).

Despite these shortcomings, the theoretical framework presented above still captures most of the main features of the diffusion of containerization, both in terms of adoption of container-port infrastructure and firms' usage of this technology.

5 Empirical Implications

In this section, I study how different variables affect transportation sectors' profits and, consequently, the timing of adoption, and derive the empirical specification implemented in Chapter 3. While equations (2.24) to (2.27) give exact measures of transportation sector's profits, in reality, decision-makers do not perfectly observe future values of all the variables

included in these equations. Some of these variables are often stochastic and uncertain, such as income and input costs. However, the rational decision-maker decides when to build a container port on the basis of all information available to her at each time t. This includes her knowledge of the structure of the market, firms' decision rules, and the probability distribution of stochastic processes. Therefore, at period t, j's transportation sector's expectation for aggregate containerized trade at period s, $\tilde{T}^c_{j,s}$, corresponds to the conditional expectation of $T^c_{j,s}$, given the information set Ω_{t-1}.

$$\tilde{T}^c_{j,s} = E[T^c_{j,s}|\Omega_{t-1}] \equiv E_{t-1}T^c_{j,s} \tag{2.28}$$

Without specifying the processes driving stochastic variables such as income and input costs over time, I assume that these are known to the transportation sector and that the conditional expectation of $T^c_{j,t}$ can be summarized in a coefficient θ such that $E_{t-1}T^c_{j,t} = \theta T^c_{j,t-1}$ and $E_{t-1}T^c_{j,s} = \theta^{s-t+1}\, T^c_{j,t-1}$. Given these assumptions, j's transportation sector's expected profits can be expressed as

$$\tilde{\Pi}_{j,t} = (\phi - \gamma_j) \sum_{s=t}^{\infty} \sum_{k \neq j} (\rho\theta)^{s-t+1}\, T^c_{kj,t-1} - \Gamma_j \tag{2.29}$$

Assuming $\rho\theta < 1$, we can rewrite equation (2.29) as $\tilde{\Pi}_{j,t} = (\phi - \gamma_j)/(1-\rho\theta)\; T^c_{j,t-1} - \Gamma_j$ and the adoption condition becomes $(\phi - \gamma_j)/(1-\rho\theta)\; T^c_{j,t-1} > \Gamma_j$. Taking logs on both sides, we get that adoption implies

$$a_1 + \ln(\phi - \gamma_j) + \ln(\hat{T}^c_{j,t-1}) - \ln(\Gamma_j) > 0 \tag{2.30}$$

where $a_1 = -\ln(1-\rho\theta)$ is a constant term.

Containerized trade, $T^c_{j,t-1}$, cannot be observed before adoption occurred. In other words, before there is a container port, there can be no containerized trade. However, despite not being able to observe it, j's transportation sector can still estimate the amount of containerized trade that would eventuate if there were already a container port in j, which will be consistent with the structure of the model, namely equations (2.25) to (2.27). I denote this potential containerized trade by $\hat{T}^c_{j,t-1}$ and explain its estimation below.

Equation (2.30) explains why countries decide to build container ports at different points in time. All else equal, transportation sectors in countries where it is more costly to construct a container port (Γ is high), or where it is more costly to maintain and operate it (γ is high), have lower profits and are therefore less likely to adopt containerization early. Trade also matters: countries where more firms would decide to containerize exports have higher profits and are therefore more likely to adopt containerization early.

To estimate equation (2.30), I define the latent variable $z_{j,t}$ as

$$z_{j,t} = a_1 + \ln(\phi - \gamma_j) + \ln(\hat{T}^c_{j,t-1}) - \ln(\Gamma_j) \tag{2.31}$$

I represent the uncertainty associated with unmeasured fixed and variable trade frictions and country characteristics by an *i.i.d.* stochastic term, μ^z, and as a result, the adoption condition can be expressed as $z_{j,t} + \mu^z_{j,t} > 0$. Assuming that μ^z is distributed independently of $z_{j,t}$ with a symmetric cumulative distribution $H(\mu^z)$, we can express the hazard rate of adoption at period t as

$$\begin{aligned}
\mathcal{H}_j(t) &= \Pr(A_{j,t} = 1 | A_{j,t-1} = 0, \text{observed variables}) && (2.32)\\
&= \Pr(z_{j,t} + \mu^z_{j,t} > 0 | .) && (2.33)\\
&= \frac{H(-z_{j,t}) - H(-z_{j,t-1})}{1 - H(-z_{j,t-1})} && (2.34)\\
&\equiv \mathcal{H}\left(\eta_j, \zeta_j, \hat{\nu}^c_{j,t-1}\right) && (2.35)
\end{aligned}$$

where $\eta_j = \ln(\Gamma_j)$ are costs associated with adoption (i.e, with constructing the container port), $\zeta_j = \ln(\phi - \gamma_j)$ are variable port costs, and $\hat{\nu}^c_{j,t-1} = \ln(\hat{T}^c_{j,t-1})$ is log containerized trade.

As explained above, because $\hat{\nu}^c_{j,t-1}$ cannot be observed before adoption, it needs to be estimated. This can be obtained by using equations (2.25) to (2.27). To produce a clear link between the model and the empirical analysis, I focus on the case of symmetry across countries and assume that each country is a fraction b of world income ($Y_{i,t} = bY^w_t,\ \forall j$). These assumption will be relaxed in the empirical analysis. In addition, I assume that input costs are the same in every country and normalized to one, and as is standard in the literature, that firms' productivity follows a Pareto distribution with shape parameter $\kappa > \epsilon - 1$,[40] such that $G(a) = (a/a_H)^\kappa$ and

$$\int_0^a a^{1-\epsilon} dG(a) = \frac{\kappa}{\kappa - \epsilon + 1} \frac{a^{\kappa-\epsilon+1}}{a^\kappa_H} \tag{2.36}$$

Under these assumptions, containerized trade can be expressed as

$$T^c_{j,t} = a_2 \left(\frac{Y^w_t}{P^{\epsilon-1}_t}\right)^{\frac{\kappa}{\epsilon-1}} \left(f^c_{j,t} - f^b_j\right)^{\frac{\kappa-\epsilon+1}{1-\epsilon}} \sum_{k \neq j} A_{k,t}\ t^{1-\epsilon}_{kj} \left(\frac{t^{1-\epsilon}_{kj} - \tau^{1-\epsilon}_{kj}}{1 + \frac{f^c_{k,t} - f^b_k}{f^c_{j,t} - f^b_j}}\right)^{\frac{\kappa-\epsilon+1}{\epsilon-1}} \tag{2.37}$$

and $\nu^c_{j,t-1}$ can therefore be estimated using equation (2.37).

In the next chapter, I operationalize this two-step approach suggested by the model in order to understand the determinants of adoption and usage of containerization.

[40] See, for example, Helpman et al. (2004) and Helpman, Melitz, and Rubinstein (2008).

Figure 2.1: Diffusion of containerization, unweighted averages

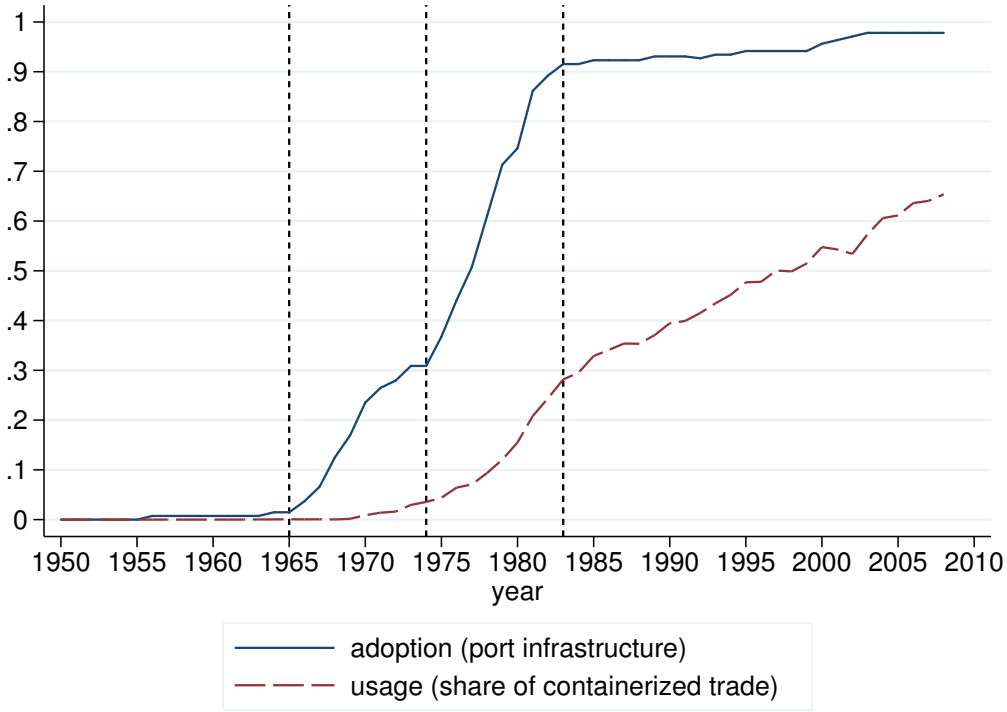


Figure 2.2: Diffusion of containerization, weighted averages

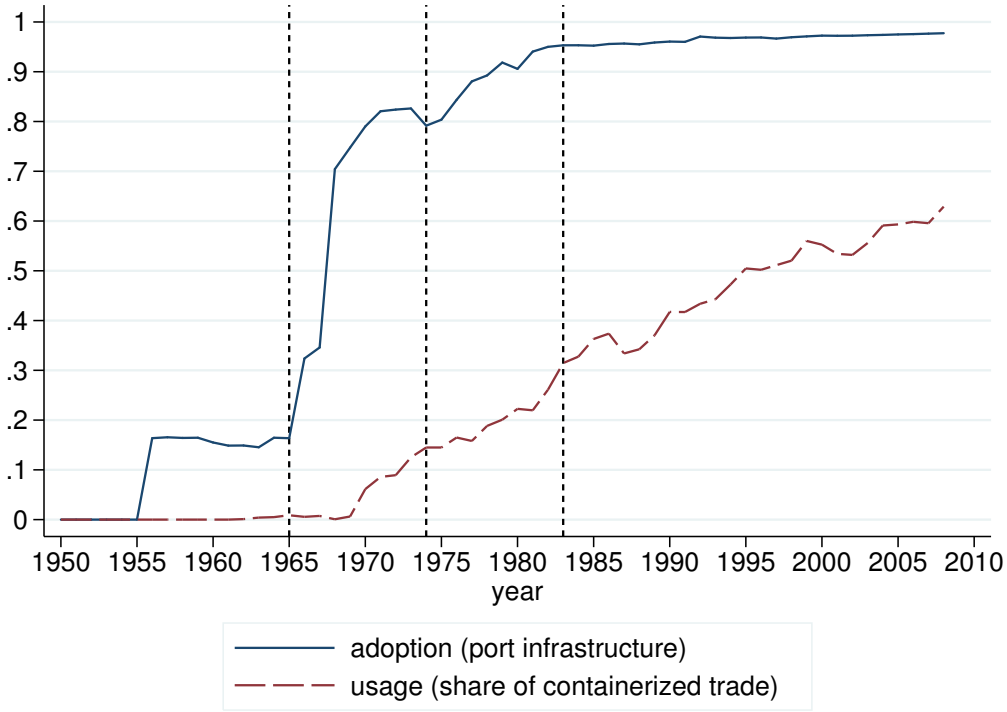


Figure 2.3: Diffusion of containerization, port level vs. country level

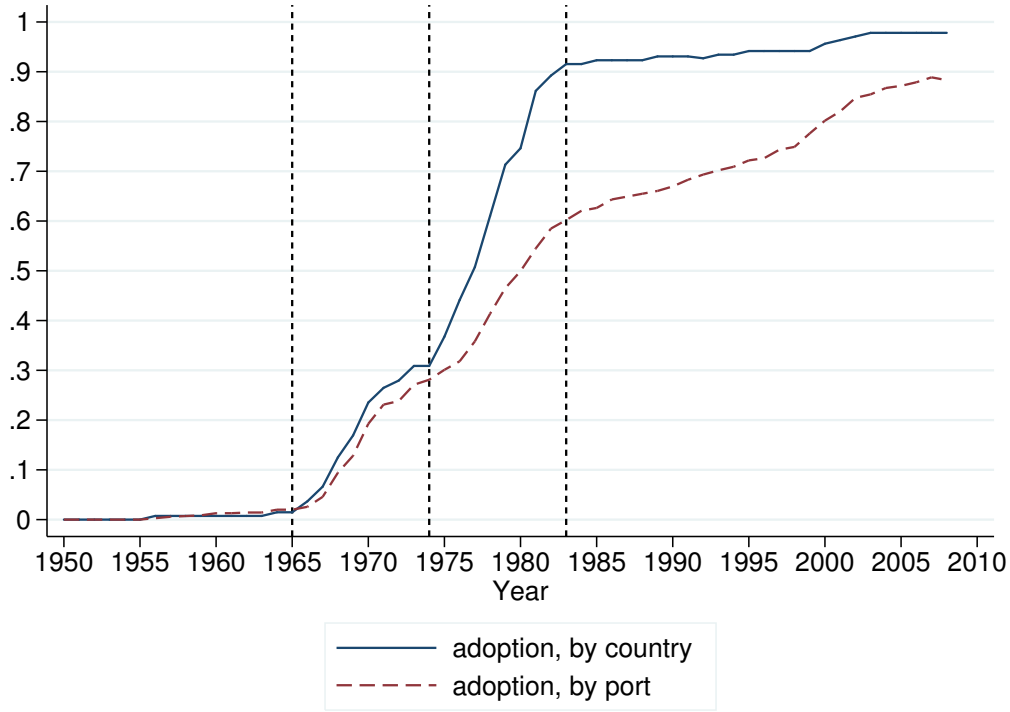
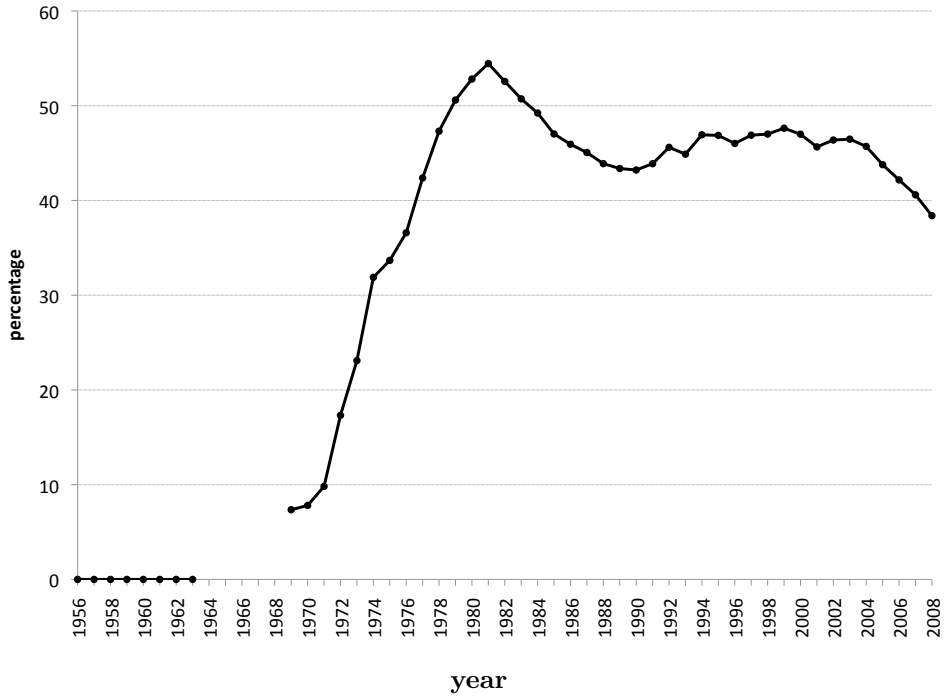


Figure 2.4: Share of world's "box fleet" on operating lease



Notes: Fleet figures are rounded TEUs and include all types of container boxes. Sources: *Containerisation International*, Sep. 1983, and *Containerisation International Market Analysis, 2009*, "Container Leasing Market 2009."

Figure 2.5: Dispersion of usage shares across countries and over time

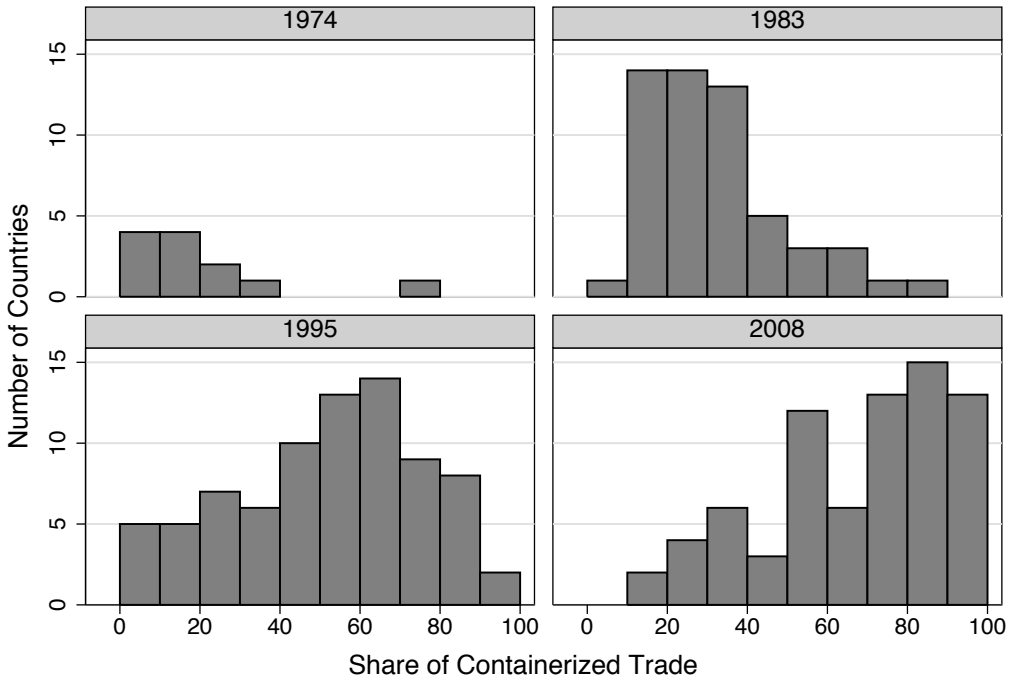


Figure 2.6: Diffusion of containerization across world ports



(a) Container ports in 1965



(b) Container ports in 1974

Figure 2.6: Diffusion of containerization across world ports (cont.)



(c) Container ports in 1983



(d) Container ports in 2008

Notes: Maps created at GPSVizualizer.com using Google GPS coordinates. Sources: *International Shipping Statistics*, *Containerisation International Yearbook*, and *Lloyd's Ports of the World*, various issues.

Figure 2.7: Firms' export decisions

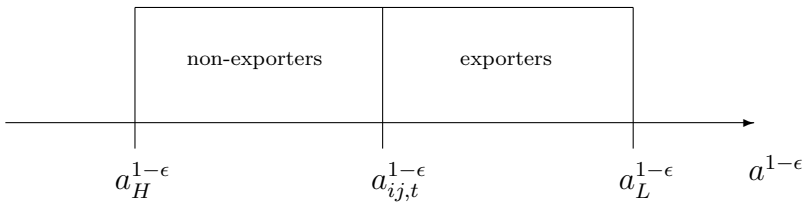


Figure 2.8: Exporters' choice of transportation technology

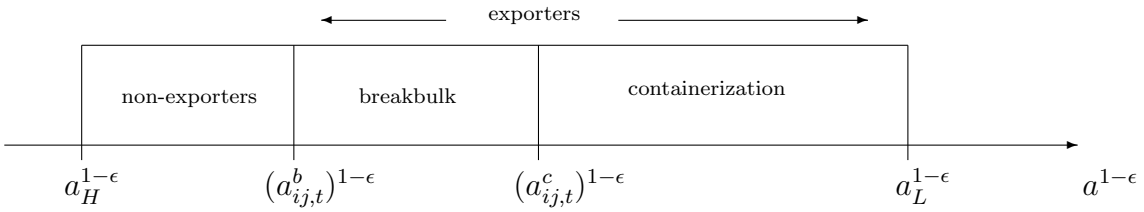


Figure 2.9: Selection of firms between transportation technologies

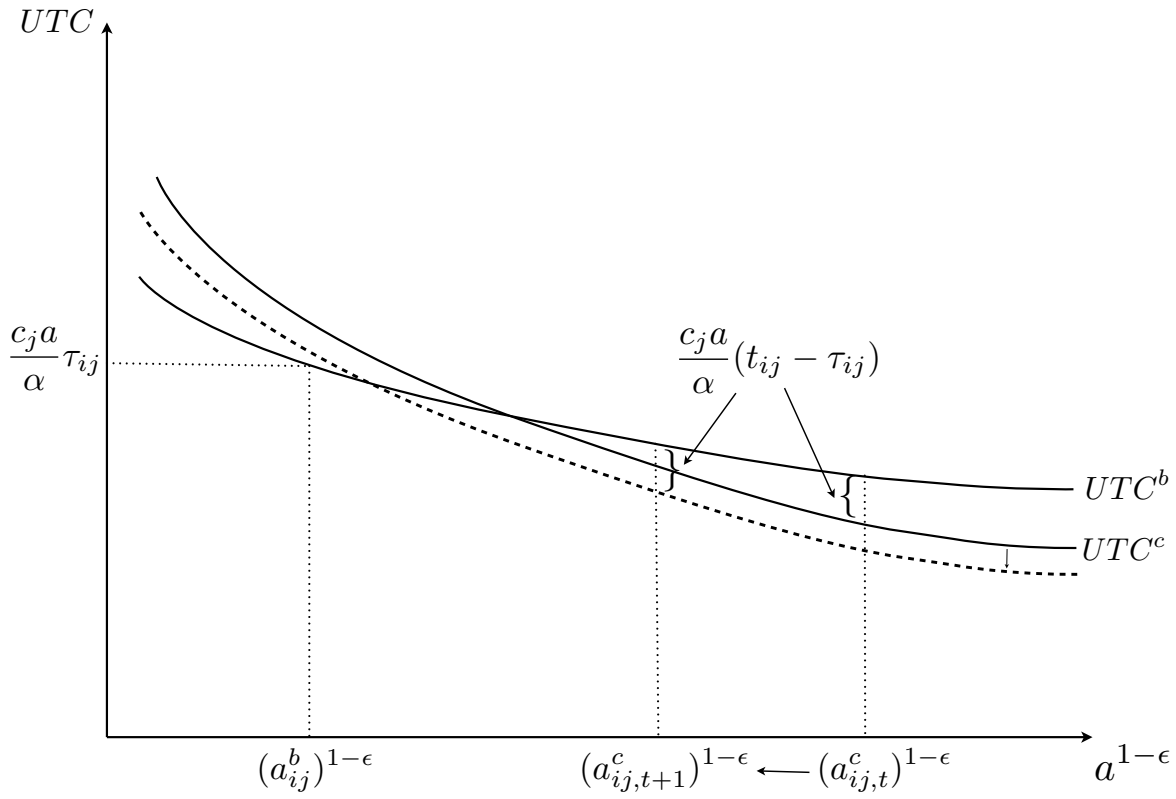


Table 2.1: The diffusion of containerization over time

	Adoption			**Usage**	
	New adoptions	New adoptions per year	Cumulative share of adoptions	Unweighted average share (end of period)	Annual average change in share
1956-1965	2	0.2	1.3	0.1	
1966-1974	43	5.4	30.2	3.5	0.3
1975-1983	86	10.8	87.9	28.7	1.6
1984-2008	17	0.7	99.3	65.5	1.5

Chapter 3

Diffusion of Containerization: Quantitative Analysis

1 Introduction

In this chapter, I present a quantitative analysis of the diffusion of containerization, building on the results presented in the previous chapter. Using the two-step approach suggested by the model in Chapter 2, I investigate the determinants of adoption and usage of containerization. I first estimate equation (2.37) and then use that estimate of containerized trade in equation (2.35). The main findings are that fixed costs and network effects are the main determinants of usage of containerization. Adoption is determined by expected future usage of containerization, institutions, a country's size in terms of trade and geographical area, and trade with Australia and the United Kingdom. Trade with the United States, surprisingly, has no effect.

While the theoretical framework presented in the previous chapter is built on the assumption that all firms produce general cargo goods,[1] the empirical analysis in this chapter requires that I relax that assumption to allow for differences in the composition of trade. A simple way to control for these differences is to normalize $T^c_{j,t}$ by general cargo trade, $T^G_{j,t}$, and to add the shares of general cargo trade, $S^G_{j,t} = T^G_{j,t}/T^T_{j,t}$, and total trade, $T^T_{j,t}$, as controls in the adoption estimation (see equation 3.4 below). The empirical analysis also requires that I relax the symmetry assumption used in the model. Without symmetry, j's income and j's trade partners' income will enter the equations for containerized and total trade both directly and as part of the network term. As a result, conditional on adoption, the share of containerized trade (out of total general cargo trade), $S^c_{j,t}$, can be expressed as a function of

[1] See Section 4.2 in Chapter 2.

four terms:

$$S^c_{j,t} = f\left(\frac{f^c_{j,t} - f^b_j}{f^b_j}, \sum_{k\neq j} A_{k,t}, \sum_{k\neq j} A_{k,t}\ g_1(Y_{k,t}), \sum_{k\neq j} A_{k,t}\ g_2(\tau_{kj}, t_{kj})\right) \tag{3.1}$$

The first term is the fixed cost of containerization relative to the cost of breakbulk, the second is the number of j's trade partners with container ports, the third is a measure of income in j's container network, and the fourth and last term is a function of j's average transport costs to trade partner countries with container ports, using both technologies.

Assuming that $f(.)$ can be log-linearized, the resulting two-step econometric model is:

$$\text{Step 1:} \quad s^c_{j,t} = \beta_0 + \beta_1 \ln\left(\frac{f^c_{j,t} - f^b_j}{f^b_j}\right) + \beta_2 \ln \sum_{k\neq j} A_{k,t}\ g_1(\tau_{kj}, t_{kj}) \tag{3.2}$$
$$+\beta_3 \ln \sum_{k\neq j} A_{k,t} + \beta_4 \ln \sum_{k\neq j} A_{k,t}\ g_2(Y_{k,t}) + \mu^s_{j,t}$$

$$\text{Step 2:} \quad log\left(\frac{\lambda(t|\mathbf{X}_{t-1})}{1-\lambda(t|\mathbf{X}_{t-1})}\right) = \delta\mathbf{X}_{t-1} + \mu^h_{j,t} \tag{3.3}$$

Step 1 estimates a linear model in which the dependent variable is log share of containerized trade (out of general cargo trade), $s^c_{j,t} = \ln(S^c_{j,t}) = \ln(T^c_{j,t}/T^G_{j,t})$. Step 2 estimates a discrete-time hazard model. I specify the hazard function $\mathcal{H}(.)$ as logistic, based on Figure 2.1 and the results of the model, and also because the logistic is the most commonly used discrete-time hazard function in the literature. The dependent variable in equation (3.3) is the conditional log odds that adoption occurs at year t (given that it did not occur before), and it is a linear function of $\mathbf{X}_{t-1}$. The product $\delta\mathbf{X}_{t-1}$ is expressed as

$$\delta\mathbf{X}_{t-1} = \delta_1\eta_j + \delta_2\zeta_j + \delta_3\hat{s}^c_{j,t-1} + \delta_4 s^G_{j,t-1} + \delta_5 T_{j,t-1} \tag{3.4}$$

where η_j are adoption costs, ζ_j are variable port costs, $\hat{s}^c_{j,t}$ is the predicted log share of containerized trade (estimated in step 1), $s^G_{j,t}$ is the log share of general cargo trade, and $T_{j,t}$ is log total trade.

2 Data

In this section, I explain and describe the data which I use to estimate the previous two-step model.[2] I start with the explanatory variables in step 1, followed by those in step 2. The

[2]See Appendix F for variable definitions and data sources.

first variable, $(f^c_{j,t-1} - f^b_j)/f^b_j$, is the fixed cost of exporting using containerization relative to the cost of breakbulk. This cost is tied to various country-specific factors such as the quality of physical infrastructure and administrative hurdles associated with exporting (for example, customs, tax, and security procedures). These factors are common to either mode of exportation and, to the extent that they tend to remain relatively constant over time, will be absorbed by country fixed effects. Country fixed effects will also absorb other unobserved factors that have affected the cost of breakbulk shipping for millennia and remain relatively constant today. However, the fixed cost of using containerization involves additional costs, which accrue from more complex logistics and distribution management services and the acquisition or leasing of container boxes. We can observe the evolution of these additional costs in two ways: first, through the spread of container-leasing companies, and second, through the stock of land transportation infrastructure.

Standardization in 1967 and the resultant advent of container-leasing changed early logistics systems. Firms became able to contract with different freight forwarders without having to be wedded to a single ship line, and this reduced their costs in terms of logistics and time. I use data on the share of the world's "box fleet" on operating lease as a way to capture the effect of container leasing on firms' fixed costs. However, since these data only vary by year and not by country, I cannot measure cross-country differences in containerization's fixed costs. To do that, I also consider another aspect of containerization, intermodality.

The potential of containerization can only be fully exploited if there is adequate intermodality. Standardization played an important role here, as well, since it made it possible for land and sea carriers to handle one another's containers. By doing so, it allowed firms (or freight forwarders that they had contracted) to select the most appropriate route for their shipments, whether it was the fastest route or the least costly. The more routes a firm can choose from, the larger an advantage standardization affords. I measure the intermodal potential of a country by the density of its network of railways and paved roads (the length of railway lines and paved roads relative to the area).

The second variable, $\sum_{k \neq j} A_{k,t}\ g_1(\tau_{kj}, t_{kj})$, is a function of transportation costs between a country and its container network. In the absence of internationally comparable freight cost data that go as far back as the 1950s, I look at the most cited determinant of transportation costs, geographical distance. In particular, I use maritime distance between countries.[3] I assume that containerization had a different impact on countries' transportation costs depending on their geographical remoteness. The reasons for this are twofold. First, there is narrative evidence showing that containerization reduced transit times relatively more for longer journeys. This is because, previously, ships making longer trips often called at various

[3] I use the "Reeds Maritime Distance Tables" (Reynolds & Caney, 2010), which are the standard reference in the shipping business.

ports during the journey, and with breakbulk, they could stay docked at each of these ports for weeks.[4] Containerization not only reduced transit time and the number of stops, but more importantly, it reduced the time spent at each intermediate port. The second reason for the different impact of containerization according to distance is related to economies of scale. Longer routes are served by huge container ships, some of which can now hold up to 18,000 TEUs.[5] Moreover, as Levinson points out, "a doubling of the distance cargo is shipped – from Hong Kong to Los Angeles, for example, rather than Tokyo to Los Angeles – raises (containerization's) shipping cost only 18 percent."[6]

If containerization did, in fact, provide a substantial reduction in transportation costs of firms located in countries that are geographically further away from the container network, I should find a positive effect of "distance to network" on the share of containerized trade. A country's distance to the network is the weighted average maritime distance to all its trade partners that have adopted containerization, weighted by the trade share of each trade partner.[7]

The other two elements of equation (3.2) depend on the number of countries in the container network and the network's income. Table 3.1 presents these and other measures of network effects, which I include in the estimation. I also include two additional explanatory variables, trade openness and population, to control for countries' exposure to foreign trade and their population size.

[Include table 3.1 here]

In addition to the estimated share of containerized trade, the hazard model in step 2 includes cost measures associated with building, maintaining, and operating the container port, the share of general cargo trade, and the size of the country in trade terms (see equation 3.4). I use real GDP per capita as a proxy for the costs associated with building, maintaining, and operating the container port, in particular labor costs. According to the Balassa-Samuelson effect (Balassa, 1964, Samuelson, 1964), real income differentials explain wage and price level differentials between economies. This is because productivity in the tradable sector tends to be higher in richer than in poorer countries, whereas productivity in the nontradable sector tends to be the same across all countries. If purchasing power parity (PPP) holds

[4] For example, a 1972 study by McKinsey & Company observed the following: "Previously, Australia-bound ships had spent weeks calling at any of eleven European ports before starting the southbound voyage. Containerships collected cargo only at huge container ports at Tilbury, Hamburg, and Rotterdam, whose enormous size kept the cost of handling each container low. Previously, shipments took a minimum of 70 days to get from Hamburg to Sydney, with each additional port of call adding to the time; containerships offered transit time of 34 days, eliminating at least 36 days' worth of carrying costs" (Levinson, 2008, p. 220).

[5] White (2011).

[6] Levinson, 2008, pp. 268–269.

[7] In order to exclude cyclical variations, I calculate trade shares using averages over the previous 5 years.

for tradable goods and there is free factor mobility, high wage levels in the tradable sector push up wages in the nontradable sector, leading to higher wages overall in richer countries. In addition, high wages and strong unions tend to be associated. Powerful longshoremen unions have been connected with numerous delays in ports' adoption of containerization, and there are various historical accounts of protracted negotiations between unions, port authorities, and governments.[8] Prolonged strikes have also caused exceptionally lengthy delays at ports, with container ships remaining docked for the duration.[9]

In addition, I use institutional barriers as a proxy for the adoption cost. They affect the political cost of building any new infrastructure, in particular a container port. The political economy literature has identified several institutional barriers that impair decision processes, especially when there are large amounts of money involved. These include the effectiveness of the judicial system, rule of law, and the general openness of political institutions. I use the measures of "efficiency of the judiciary" and "rule of law" from La Porta, Lopez-de-Silanes, Shleifer, and Vishny (1998). They are time-invariant and are scaled from 1 to 10, with lower scores corresponding to lower levels of judicial efficiency and rule of law. Constraints on the chief executive, from Polity IV, measure the general openness of political institutions. They are scaled from 1 to 7 and vary over time. These institutional barriers are also a proxy for financial development, which is another important determinant of the initial cost of building a container port. The law and finance literature has shown that in countries where legal systems enforce property rights and protect investors' legal rights, savers are more willing to finance firms, and financial markets are more developed. In contrast, legal institutions that fail to support property rights or protect private contracts hinder corporate finance and inhibit financial development (La Porta et al. 1998, 2000, Chinn and Ito 2006).

In the absence of a better and more direct measure, I use oil exports to measure non-containerizable trade. Specifically, I use a dummy variable that takes the value one if a country's oil exports are larger than two thirds of its merchandise exports.

Finally, I measure a country's trade size by its share in world trade. I include additional controls such as country area, trade with early adopters (the United States, Australia, Belgium, the Netherlands, and the United Kingdom), an island dummy, and the length of coastline. Table 3.2 presents descriptive statistics.

[Include Table 3.2 here]

[8] See Levinson (2008), pp. 120–122, for an example of negotiations involving the International Longshoremen's Association (ILA), the New York Shipping Association, and three mediators nominated by President Kennedy.

[9] For example, see Levinson (2008), pp. 203–206, for a description of Tilbury's prolonged closures in the late 1960s, and how Felixstowe, a small ferry port with "no militant unions," profited from London's container service disruptions.

3 Results

3.1 Containerized Trade

Tables 3.3 to 3.5 present the results from estimating equation (3.2), using ordinary least square with fixed effects. Since I estimate the share of containerized trade conditional upon the decision to adopt, I use only observations with positive values for containerized trade. Standard errors are clustered by country, which corrects for residual dependence between observations of the same country in different years.

[Include Table 3.3 here]

Table 3.3 shows that fixed costs have a positive effect on usage of containerization. As discussed before, fixed costs of using containerization are negatively associated with increases in the share of leased boxes and the stock of domestic land transportation infrastructure. The positive and significant coefficients of these variables, therefore, indicate that reductions in the fixed cost increase containerized trade. Even though the density of railway lines is not statistically significant in specifications 1 and 2, it has positive and significant coefficients in specifications 3 and 4, which do not include the density of paved roads as an explanatory variable. This is because the length of paved roads and railway lines are positively correlated (the correlation coefficient is 0.31), resulting in insignificant coefficients for the weaker variable, due to measurement error. Nonetheless, the densities of paved roads and railway lines are jointly significant at the 1% level (see p-values in the last row of Table 3.3).[10]

Distance to the network measures how far a country is from the container network, weighted by the relative importance of each trade partner. If distance is a good measure of transportation costs and containerization's impact on transportation costs increases with distance, firms in countries that are relatively farther away from the container network should have larger transportation cost gains from using containerization.[11] However, distance to the network is not significant in any specification, indicating that the effect of containerization on transportation costs works through a different channel. Alternatively, since most of the variation in the distance to network measure is cross-sectional (any time variation in a country's distance to the network comes only from changes in its trade partners' trade shares, which are slow moving), its effect is possibly absorbed by country fixed effects, which are included in all specifications.[12]

[10] I also present p-values for this joint significance test in subsequent estimations (see Tables 3.4 to 3.8).
[11] See discussion in the previous section.
[12] Specifications 2, 4, and 6 include, additionally, year fixed effects.

Other explanatory variables in Table 3.3 are the number of years since adoption and its squared value, trade openness, population size, and the weighted-average number of countries in the container network (a measure of network effects). The coefficients of the number of years since adoption and its squared value indicate a concave relationship between time and containerized trade: containerized trade grows initially and starts to move more slowly after several years have passed since adoption. Higher levels of trade openness, as well as a larger size of its container network, increase a country's usage of containerization, but its population size has no effect on usage of the technology. The effect of network size is fairly large: a two-standard-deviation increase in the average number of trade partners using containerization, 0.6, increases a country's usage between 1% and 1.4%. The next table explores network effects in more detail.

[Include Table 3.4 here]

Table 3.4 estimates the influence of several measures of network effects on containerized trade. Column 1 replicates specification 2 in Table 3.3, estimating the effect of network size only, and columns 2 to 5 include additional measures of network effects. Network size, network usage, and network income have positive and significant effects on a country's usage of containerization. Specifications 2 to 5 show that, once I control for other network characteristics, the effect of network size becomes slightly smaller. A two-standard-deviation increase in network size increases the share of containerized trade between 0.26% and 1.1%. A similar increase in the average usage level in the network, 0.42 percentage points, increases the share of containerized trade between 0.53% and 0.64%. Similarly, a two-standard-deviation increase in network's average per capita income, 1.85%, increases the share of containerized trade between 1.3% and 2%. It is the number of countries using containerization, and not the number of container ports in these countries, that affects usage of the technology. In specification 3, the coefficient for the number of ports in the network is insignificant, and in specification 5, which includes all measures of network effects, it is even negative. In sum, new adoptions by trade partners, their usage of containerization, and their income are important determinants of a country's share of containerized trade after adoption. Note also that the effect of fixed costs is robust to the inclusion of these different network measures.

[Include Table 3.5 here]

While Table 3.4 investigates how decisions by the entire network of trade partners affect a country's usage of containerization, Table 3.5 investigates the role of its neighbors' decisions (countries that share a land border). The estimations presented in Table 3.5 include the same explanatory variables as the previous table (not shown), and additionally, they include measures of the number of neighboring countries using containerization, their average

usage, and their number of ports. Both adoption and usage by neighboring countries have a positive and significant effect on a country's usage of the technology, even after controlling for the influence of the rest of the network of trade partners. However, the impact is small when compared to that of the entire network. On average, adoption by a neighboring country increases a country's usage of containerization between 0.08% and 0.27%, and a two-standard-deviation increase in neighbors' usage of containerization, 0.45, increases a country's usage of containerization by about 0.18%.

In Tables 3.6 to 3.9, I present several robustness checks which address particular concerns about the strength of the previous results. In Table 3.6, I include additional explanatory variables such as the number of ports per km of coastline, a dummy variable for episodes of banking crisis, and real per capita income. First, the number of ports per km of coastline attempts to control for the extent to which domestic maritime trade matters. Additionally, the number of ports may affect the impact of the domestic transportation network on fixed costs, given that an extensive network of paved roads and railway lines becomes less necessary once there are many ports per km of coastline. Second, by including banking crises as a control variable, I endeavor to exclude the possibility that network effects are being driven by similarity in financial shocks. Episodes of banking crisis create disruptions in credit markets which affect firms' decisions, in particular those related to usage of new technologies. To the extent that banking crises propagate internationally, firms in various countries will be experiencing similar financial shocks. Finally, real per capita income controls for market size and the potential for economies of scale. None of these controls has a significant effect on containerized trade, and all the results presented previously are robust to their inclusion in the estimations.

[Include Table 3.6 here]

In Tables 3.7.(a) and 3.7.(b), I investigate differences across several sub-samples of countries. Column 1 reproduces specification 2 in Table 3.4, and columns 2 and 3 estimate the same regression for high to medium-high income countries and low to medium-low income countries, respectively.[13] While network size matters equally for both types of countries,[14] network usage has a stronger effect on containerized trade in low to medium-low income countries than in high to medium-high income countries. In addition, growth in leasing of container boxes also has a stronger effect on containerized trade in the former than in the

[13] I use the following World Bank income classifications, based on per capita income in 1992: low income, below $675; medium-low income, between $676 and $2,695; medium-high, between $2,696 and $8,355; and high income, above $8,355.

[14] Even though the coefficients of network size are not statistically significant due to an increase in standard errors caused by a smaller sample size, they have the same magnitude as in column 1.

latter countries. On the other hand, the domestic transportation network matters more for high to medium-high income countries. The density of paved roads and railway lines are both jointly statistically significant at the 5% level for this group of countries, but not for low to medium-low income countries.

[Include Tables 3.7.(a) and 3.7.(b) here]

Columns 4 to 7 estimate the same regression excluding island countries, the US, Western Europe, or oil exporters, respectively. All previous results, except for the impact of the density of paved roads, are robust to the exclusion of these countries. When I exclude island countries, the US, or Western Europe from the sample, paved roads are no longer statistically significant *per se* (although the coefficients keep their magnitudes relative to column 1), and while the effect of railway lines remains positive and significant, the density of both paved roads and railway lines are also no longer jointly significant. These results are in line with those in columns 2 and 3, which show that the domestic transportation network matters more for high to medium-high income countries, such as the US, Western Europe, and the United Kingdom (an island country), than for low to medium-low income countries.

So far, I have not considered the potential for endogeneity in my previous results. However, interpretation of the coefficients of network effects may suffer from what Manski calls "the reflection problem."[15] First, network effects may arise from similarity in trade partners' characteristics and institutions. Second, if two countries affect each other simultaneously, it is hard to identify empirically the actual causal effect that the behavior of a country's network of trade partners has on an individual country's behavior.

[Include Table 3.8 here]

I address this problem with two additional robustness tests, presented in Tables 3.8 and 3.9. First, I consider larger lags for the explanatory variables. Two- and five-year lagged values for the network variables, instead of one-year, mitigate the simultaneity problem because a country's decision to increase usage of containerization (an aggregate of its firms' individual decisions) should not influence its trade partners' adoption and usage decisions in the previous two and five years. Table 3.8 shows that previous results are robust to using larger lags. However, while this strategy mitigates the simultaneity problem, it does not address it fully. The identification problem may still be present if countries affect each other through expectations about their future actions. Therefore, I

[15] Manski (1993) is the first formal discussion of identification problems in the context of models with social interactions. In demonstrating the importance of peer effects among Dartmouth roommates, Sacerdote (2001) also discusses in detail the difficulties of interpreting coefficients for social interactions. He solves the reflection problem by exploring freshman random assignment to dorms and roommates.

employ an additional robustness check, which uses the network's domestic transportation infrastructure as an instrument for its usage. This instrument, which is both relevant and exogenous, creates an exogenous source of variation that helps identify network effects. We have seen in previous estimations that a country's density of paved roads and railway lines affects its own usage of containerization. That being the case, the network's density of paved roads and railway lines should also affect the network's usage (the instrument is relevant). The exclusion restriction implies that, conditional on other control variables included in the regression, the network's density of paved roads and railway lines should have no effect on a country's usage of containerization (directly by itself or through an omitted variable), other than its effect through network usage. The main concern with this restriction is that the density of paved roads and railway lines in a country's network could affect the country's usage of containerization directly, either because domestic firms care about the transportation network in trade-partner countries or because expectations about foreign firms' future usage of containerization affect a country's decisions about its domestic transportation network today. Regarding the first concern, it seem unlikely that a seller would care about the costs associated with transporting goods from the port of destination to the final inland destination. This is because the terms of sale between buyers and sellers in international trade usually involve the seller being responsible for the transport of goods either to the port of shipment ("free on board," or "f.o.b.") or to the port of destination ("cost, insurance and freight," or "c.i.f."), and not to their final inland destination. These inland transportation costs at the importer's end are only relevant to the extent that they affect foreign firms' usage of containerization. As for the second concern, investments in roads and railway lines tend to be relatively large and lumpy, and the decision process is usually a long one. Therefore, it seems implausible that expectations about future changes in a foreign country's usage of containerization would affect the average density of roads and railway lines in its network. Nonetheless, and as an additional check for the validity of the exclusion restriction, I regressed the residuals from each IV-2SLS estimation on the instrumental variable(s) and found no statistically significant effects.

[Include Table 3.9 here]

Table 3.9 presents the results from the IV-2SLS estimations, together with their analogous OLS estimations. Using the IV-2SLS method, network effects have an even stronger impact on containerized trade than using OLS. These larger estimates suggest that bias due to measurement error in network usage is likely to be larger in magnitude than the endogeneity bias, which is presumably positive. The IV-2SLS results show that a two-standard deviation increase in network usage increases the share of containerized trade between 2.4% and 3.8%.

To put these numbers into context: the mean share of containerized trade in the sample is 25.5%, thus, a half percentage point increase in the average country's network's usage causes its individual usage to increase to between 32.7% and 37%. The first-stage relationship between network density of paved roads and railway lines and network usage is strongly positive, and the F-statistic in all IV-2SLS estimations is large.

3.2 Hazard of Adoption

Tables 3.10 to 3.14 show the results from estimating the logistic discrete-time hazard presented in equation (3.3). The dependent variable is constructed in two steps. First, I set the adoption indicator variable equal to one in year t if a country has at least one container port and zero otherwise. Second, for each country, I drop all observations corresponding to the years after adoption; that is, once a country adopts containerization, it is dropped from the estimation in the following years. Since imputed containerized trade is measured with sampling error, I estimate the standard errors by bootstrapping the results 1000 times.[16] The explanatory variables are lagged 5 years in order to account for the time it takes to build a container port once the decision to construct it has been made.[17]

[Include Table 3.10 here]

Table 3.10 presents estimates of equation (3.3) where the expected share of containerized trade is computed over different time horizons: 5 years, 20 years, and 50 years. The idea is to test the time-period that policymakers use in their adoption decisions.[18] The coefficients in columns 1 to 3 show that, for all time horizons, the impact of expected containerized trade on the hazard of adoption is very strong. For example, a 1% increase in expected containerized trade over a 20-year period makes a country 4.3 times more likely to adopt containerization (exp(1.459)). These results are in line with the theoretical predictions presented in Chapter 2. Even though the coefficient for expected containerized trade over a 20-year period is

[16] The observations are resampled with replacement, and the number of replications is large enough that the results do not vary substantially across computations.

[17] In the *Containerisation International* yearbooks, there are various notes explaining both the current situation and future plans for each port. For example, they read: "new terminal under construction... operational at (year)," "(y) is to have a container terminal and one berth ready by (year)," "a new terminal was to be completed by the end of (year)." By looking at these notes, I estimate that, on average, a container terminal takes about 3 to 5 years to be ready after the initial notice of its construction. Adding an extra year for the information to be updated in the *Containerisation International* yearbooks makes it an average of 5 years between the decision to build the terminal and it being ready.

[18] Figure 3.1 depicts average expected containerized trade over these different time horizons.

larger than the others, the distinction between time horizons appears not to be noteworthy for policymakers deciding whether or not to adopt containerization.[19]

All specifications include dummies for the four periods identified in the historical analysis in Chapter 2. Instead of a linear specification (or even a polynomial or Weibull) for time, I use this set of dummy variables to allow a more flexible estimation of the baseline logit hazard function. As a group, they identify the baseline hazard, while their individual coefficients allow a different value of the logit hazard in each specific time period. The estimates for these period dummies show that the baseline hazard increases over time; that is, factors affecting all countries together cause the likelihood of adoption to increase over time.

Other explanatory variables in Table 3.10 are per capita income, a country's share in world trade, geographical area, and a dummy for oil exporter. A country's share in world trade has a positive and significant effect on the hazard of adoption: a one percentage point increase in its share in world trade makes a country 30% more likely to adopt. Countries with larger geographical areas are also more likely to adopt containerization: a country that is 10% larger than another is between 7 and 10 times more likely to adopt. Since oil is not containerizable, countries that rely heavily on oil exports should be less likely to adopt containerization; and in fact, estimates show that oil exporters are between 2.5 and 3.4 times less likely to adopt containerization than other countries.

While I would expect per capita income to have a negative impact on adoption, given that richer countries tend to have higher labor costs, its coefficients are positive and insignificant. One possible reason why this is the case is that richer countries also have better institutions which influence political costs associated with building a container port. In Table 3.11, I control for institutional barriers by adding three measures of institutional quality: executive constraints, rule of law, and judicial efficiency.[20] Both rule of law and judiciary efficiency have a positive impact on adoption. Their estimated odds ratio in column 4 are 1.56 and 1.43, respectively, which implies that a one unit increase in either of these institutional indices causes a country to be about 50% more likely to adopt containerization. Notice, also, that the coefficients of per capita income decrease when I add institutional variables, and some even become negative, which suggests that this variable is in fact capturing a mix of labor costs and institutions. All other coefficients remain the same.

In Table 3.12, I include another set of regressors, this time to analyze the role of trade with early adopters (the United States, Australia, Belgium, the Netherlands, and the United Kingdom). These estimates provide a test of these countries' role in leading the international

[19]It would be interesting to run a regression with all three variables, but since they are highly correlated with each other (the correlation coefficients are between 0.87 and 0.97), they would not deliver valid estimates of the partial effect of these variables (Wooldridge, 2009, Chapter 4).

[20]In this and in the following two tables, I focus on estimations using expected containerized trade over a 20-year time period. Section G of the Appendix show similar results using 5- and 50- year horizons.

diffusion of containerization. They evaluate the role of trade as a vehicle for transmission of a new technology and as a measure of the potential for economies of scale. Since the US was the first country to adopt containerization, and the only country using the technology from 1956 to 1965, I start by adding trade with the US only (column 1), and then go on to add trade with other early adopters (columns 2 and 3). Column 3 replicates column 2, but it includes two additional controls, an island dummy and the length of coastline. These variables are meant to control for the importance of domestic maritime trade.[21] Surprisingly, column 1 shows that countries that trade more with the US are less likely to adopt containerization. A possible reason for this result is competition. Countries with less productive firms may want to protect their local markets from American competition by being out of the container network. However, since adding trade with other countries makes this result disappear, it is plausible that trade with the US simply has no effect on adoption. Nevertheless, this is still a surprising result, given that the US is not only the first adopter but is also the largest user of containerization. In Table 3.13, I test if this unexpected result is due to the effect of Canada and Mexico, two countries which trade mainly with the US, but mostly by land. Excluding Canada and Mexico from the estimations does not change the previous results.

Columns 2 and 3 show that trade with Australia and the United Kingdom have strong positive impacts on a country's hazard of adoption. Increasing trade with Australia by one billion dollars makes a country between 427 and 535 times more likely to adopt. This is a very strong effect. Since Australia is geographically one of the most remote countries in the sample, it suggests that containerization allows substantial gains for trade over long distances. The impact of trade with the UK is not nearly as large, but it is still notable. Each extra billion dollar of trade with the UK makes a country between 4 and 5 times more likely to adopt.

Tables 3.13 and 3.14 present the same estimations as in columns 1 and 2 of Table 3.12 using different sub-samples of countries. The idea is to test whether or not particular groups of countries are driving the previous results. Columns 1 and 2 exclude Canada and Mexico, as discussed above, columns 3 and 4 exclude the main Commonwealth countries apart from the UK,[22] columns 5 and 6 exclude Australia's main trade partners (Japan, China, and New Zealand), and columns 7 and 8 exclude oil exporters. Even though there are a few cases in which the coefficients for trade with Australia and the UK are not statistically significant, they keep the same sign and magnitude as in previous estimations. Excluding Australia's main trade partners from the sample raises the impact of trade with Australia, which suggests that Australia's role in the diffusion of containerization is not limited to its

[21] I also added a dummy for the period when the Suez Canal was closed, but nothing changed because the dummy for the period 1966–1974 almost coincides with that closure.

[22] These are Australia, Canada, India, New Zealand, Singapore, and South Africa.

main trade partners.

To summarize, the main findings in this section are that expected future containerized trade, institutions, a country's trade and geographical size, and trade with Australia and the United Kingdom are the main determinants of adoption. Trade with the United States, surprisingly, has no effect.

4 Conclusion

These last two chapters have examined containerization's international diffusion from two perspectives, adoption of container-port infrastructure and effective use of this technology in international trade. In Chapter 2, I developed a theoretical model that is consistent with the diffusion patterns observed in the data and relevant historical features of containerization. Adoption, which follows an S-shaped path, is determined in particular by the cost of adoption, country size, and predicted containerized trade. Fixed costs and network effects determine firms' usage of containerization and therefore the share of trade that is containerized.

In this chapter, I took the predictions of the model to the data. The empirical results are consistent with the model and show that adoption depends on institutional barriers, country size (both in terms of trade and geographical area), trade with Australia and the United Kingdom, and expected future usage of containerization. On the other hand, usage of containerization is determined by fixed costs, which are associated with the spread of leasing companies and the domestic land transportation infrastructure; network effects, measured by network size, network usage, and network income; and neighbor effects. While network usage and the spread of leasing companies have a stronger impact on low to medium-low income countries than high to medium-high income countries, the domestic land transportation infrastructure matters more for the latter than for the former.

These findings have important implications for previous literature and the role of government policy in hastening a country's integration into the global economy. First, my analysis has political economy implications. By highlighting the role of institutional barriers in delaying adoption of containerization, it sheds light on the connection between institutional quality and international trade.

Second, my results emphasize an important barrier to trade: internal trade costs. While the bulk of the international trade literature has focused its attention on international barriers to trade, especially barriers related to geographical frictions and national borders, the role of internal trade costs has been less studied. This paper shows that internal trade costs (associated with the domestic land transportation network) played an important role in accelerating the diffusion of containerization. This suggests that improvements in the domestic

transportation network can have important consequences for not only domestic but also international trade costs. As a result, government policies, which are distinct from the usual trade-policy instruments, can have significant effects on international trade, for example by enhancing intermodality.

Finally, my results also point to the relevance of trade linkages. Network effects are strong, and the diffusion of containerization is faster in countries with substantial trade with containerized countries. In addition, countries trading with rich countries, in particular Australia and the United Kingdom, adopt faster. Trade partners mattered greatly in the diffusion of containerization. This suggests that developing countries seeking to extend their global economic integration can benefit from trading with richer countries and with countries that are in the center of the international trade system.

Figure 3.1: Expected containerized trade over different time horizons

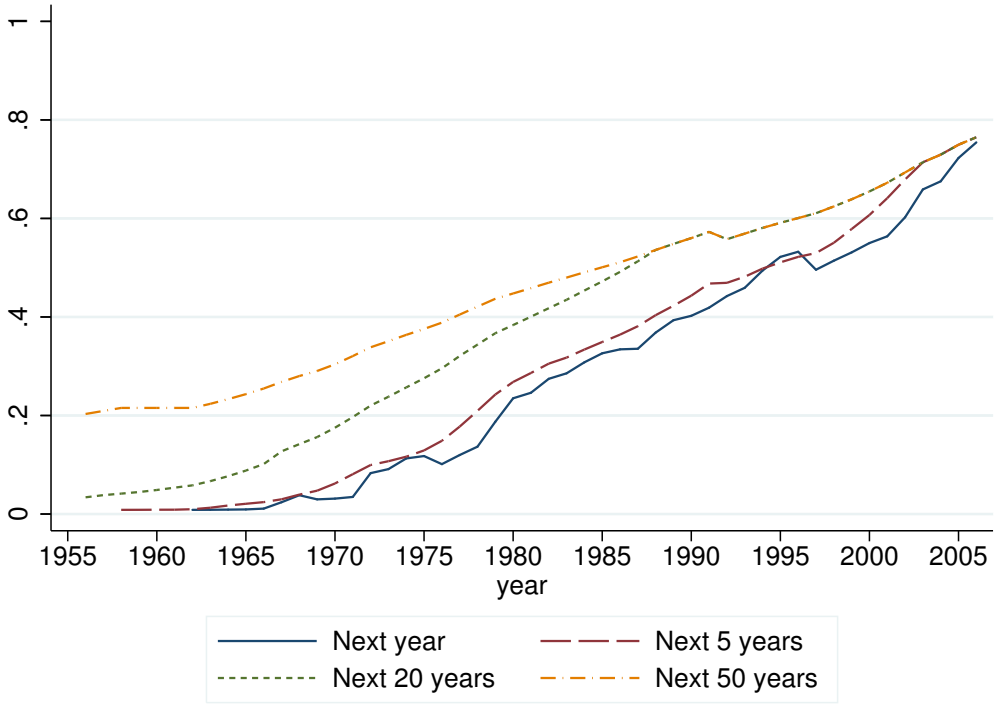


Table 3.1: Network measures

Variable	Definition
Network nr. countries	$\sum_{k \neq j} \omega_{kj,t}\ A_{k,t}$
Network usage	$\sum_{k \neq j} \omega_{kj,t}\ S_{k,t}$
Network ports	$\sum_{k \neq j} \omega_{kj,t}\ cports_{k,t}$
Network real GDPpc	$\sum_{k \neq j} \omega_{kj,t}\ GDP_{k,t}\ A_{k,t}$
Network nr. neighbors	$\sum_{k \neq j} \omega_{kj,t}\ A_{k,t}\ border_{kj}$
Neighbors usage	$\sum_{k \neq j} \omega_{kj,t}\ S_{k,t}\ border_{kj}$
Neighbors ports	$\sum_{k \neq j} \omega_{kj,t}\ cports_{k,t}\ border_{kj}$
where	
$\omega_{kj,t}$	k's share in country j's total trade (average over the period from $t-4$ to t.
$A_{k,t}$	Dummy variable that takes the value one if country k has adopted containerization by year t
$S_{k,t}$	k's share of containerized trade in year t
$cports_{k,t}$	Number of container ports in country k at year t
$GDP_{k,t}$	k's real GDP per capita
$border_{kj}$	Dummy variable that takes the value one if country j has a border with country k

Table 3.2: Descriptive statistics

	N	Mean	St.dev	Min	Max	Median
Share containerized trade	3934	0.255	0.304	0	1	0.092
World share leased boxes	7153	31.307	19.966	0	54.460	43.370
Density of paved roads	4400	0.376	0.797	0	6.328	0.046
Density of railway lines	5082	0.083	0.911	0	12.951	0.005
Distance to network, log	4546	7.734	1.234	0.012	9.195	8.177
Trade openness, log	5772	-2.021	0.822	-9.621	2.773	-2.006
Population, log	6558	15.577	2.032	10.523	20.999	15.799
Network nr. countries	6575	0.772	0.301	0	1	0.919
Network usage	5932	0.313	0.212	0	0.860	0.336
Network ports	6492	12.336	7.825	0.014	44.571	12.345
Network real GDPpc, log	6492	9.450	0.925	3.584	10.552	9.738
Network nr. neighbors	7151	1.256	1.552	0	9	1
Neighbors usage	2724	0.303	0.227	0	0.983	0.255
Neighbors ports	3686	9.654	10.052	1	56	6
Ports/coastline	6888	0.002	0.006	0	0.083	0.001
Banking crisis, 5 yrs	7153	0.089	0.284	0	1	0
Real GDPpc PPP, log	5830	8.508	1.243	4.767	11.917	8.570
Share world trade	6577	1.555	3.795	0	33.434	0.261
Area km2, log	7153	11.495	2.636	1.946	16.654	12.005
Oil exporter	7153	0.096	0.295	0	1	0
Executive constraints	5498	4.262	2.341	1	7	4
Rule of law	2440	6.850	2.625	1.9	10	6.780
Efficiency of judiciary	2440	7.640	2.062	2.5	10	7.250
Trade with USA, real bn.$	6547	2.242	8.538	0	135.550	0.229
Trade with AUS, real bn.$	6229	0.211	0.789	0	14.272	0.011
Trade with BEL, real bn.$	5006	0.402	1.745	0	21.536	0.024
Trade with NLD, real bn.$	6611	0.601	2.464	0	52.379	0.045
Trade with GBR, real bn.$	6670	0.836	2.545	0	34.558	0.104
Island	7047	0.306	0.461	0	1	0
Coastline, log	6888	6.997	1.675	2.485	12.216	7.041

Table 3.3: Fixed costs: leasing and domestic transportation network (ordinary least squares)

	(1)	(2)	(3)	(4)	(5)	(6)
Years since adoption	0.128**	0.026	0.142**	0.062**	0.128**	0.046+
	(0.020)	(0.025)	(0.018)	(0.016)	(0.018)	(0.024)
Years since adoption, sq	-0.002**	-0.002**	-0.002**	-0.002**	-0.002**	-0.002**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
World share leased boxes, t-1	0.008	0.048*	0.013*	0.039*	0.008	0.043*
	(0.006)	(0.021)	(0.006)	(0.019)	(0.006)	(0.021)
Density of paved roads, t-1	0.217*	0.215*			0.202*	0.206*
	(0.097)	(0.101)			(0.094)	(0.093)
Density of railway lines, t-1	5.591	5.794	8.062+	8.867*		
	(4.016)	(4.016)	(4.236)	(4.251)		
Distance to network, log t-1	-0.243	-0.250	-0.241	-0.232	-0.233	-0.245
	(0.234)	(0.246)	(0.233)	(0.245)	(0.231)	(0.246)
Trade openness, log t-1	0.249	0.291	0.283+	0.300+	0.298+	0.337+
	(0.156)	(0.200)	(0.142)	(0.179)	(0.157)	(0.194)
Population, log t-1	0.253	0.272	-0.117	-0.098	0.278	0.272
	(0.322)	(0.346)	(0.316)	(0.333)	(0.307)	(0.331)
Network nr. countries, t-1	2.310**	1.813*	2.138*	1.808*	2.113*	1.646+
	(0.820)	(0.867)	(0.812)	(0.906)	(0.811)	(0.869)
Constant	-5.924	-9.317	0.788	-2.519	-10.000*	-8.439
	(4.833)	(5.694)	(7.025)	(4.961)	(4.601)	(5.436)
Observations	1504	1504	1610	1610	1698	1698
R^2	0.79	0.80	0.79	0.80	0.79	0.80
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	No	Yes	No	Yes	No	Yes
F-test (p-value)	0.007	0.006				

Notes: The dependent variable is the share of containerized trade in logs. The last line presents the p-value of the F-test for the joint significance of the density of paved roads and the density of railway lines. Standard errors in parentheses, clustered by country. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Table 3.4: Network adoption and usage (ordinary least squares)

	(1)	(2)	(3)	(4)	(5)
Years since adoption	0.026	0.043*	0.102**	0.053*	0.096**
	(0.025)	(0.019)	(0.025)	(0.021)	(0.024)
Years since adoption, sq	-0.002**	-0.002**	-0.002**	-0.002**	-0.002**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
World share leased boxes, t-1	0.048*	0.046**	0.029**	0.028	0.009
	(0.021)	(0.013)	(0.011)	(0.020)	(0.018)
Density of paved roads, t-1	0.215*	0.175+	0.202+	0.117	0.133
	(0.101)	(0.103)	(0.107)	(0.099)	(0.106)
Density of railway lines, t-1	5.794	7.803+	6.889+	7.815+	6.265
	(4.016)	(4.108)	(3.762)	(4.258)	(3.831)
Distance to network, log t-1	-0.250	-0.315	-0.361	-0.285	-0.347
	(0.246)	(0.283)	(0.287)	(0.272)	(0.271)
Trade openness, log t-1	0.291	0.266	0.328	0.212	0.290
	(0.200)	(0.188)	(0.199)	(0.179)	(0.189)
Population, log t-1	0.272	0.256	0.245	0.378	0.422
	(0.346)	(0.344)	(0.330)	(0.353)	(0.335)
Network nr. countries, t-1	1.813*	1.575+	1.774*	0.602	0.431
	(0.867)	(0.897)	(0.889)	(1.094)	(1.100)
Network usage, t-1		1.465*	1.505*	1.287+	1.261+
		(0.682)	(0.663)	(0.675)	(0.637)
Network ports, t-1			-0.028		-0.048+
			(0.022)		(0.025)
Network real GDPpc, log t-1				0.735+	1.120*
				(0.399)	(0.470)
Observations	1504	1501	1501	1501	1501
R^2	0.80	0.80	0.80	0.80	0.81
F-test (p-value)	0.006	0.009	0.006	0.036	0.041

Notes: The dependent variable is the share of containerized trade in logs. All specifications include a constant, country fixed effects, and year fixed effects. The last line presents the p-value of the F-test for the joint significance of the density of paved roads and the density of railway lines. Standard errors in parentheses, clustered by country. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Table 3.5: Neighbors' adoption and usage (ordinary least squares)

	(1)	(2)	(3)	(4)	(5)
Network nr. countries (excl. neigh), t-1	1.433	1.784^{+}	1.060	1.250	1.150
	(1.498)	(0.990)	(1.764)	(1.170)	(1.778)
Network usage (excl. neigh), t-1				1.650^{+}	
				(0.938)	
Network ports (excl. neigh), t-1					-0.022
					(0.021)
Network nr. neighbors, t-1	0.274*	0.108	0.186*	0.079	0.187*
	(0.123)	(0.102)	(0.087)	(0.111)	(0.085)
Neighbors usage, t-1		0.385**		0.391*	
		(0.145)		(0.154)	
Neighbors ports, t-1			0.004		0.004
			(0.015)		(0.015)
Observations	1207	1029	1192	1029	1192
R^2	0.81	0.78	0.80	0.79	0.80
F-test (p-value)	0.252	0.584	0.263	0.443	0.365

Notes: The dependent variable is the share of containerized trade in logs. All specifications include a constant, country and year fixed effects, and the same controls as in table 3.4 ("years since adoption," "years since adoption squared," "world share leased boxes," "distance to network," "density of paved roads," "density of railway lines," "trade openness," and population), not shown. The last line presents the p-value of the F-test for the joint significance of the density of paved roads and the density of railway lines. Standard errors in parentheses, clustered by country. $+$ $p < 0.10$, $*$ $p < 0.05$, $**$ $p < 0.01$.

Table 3.6: Robustness checks: additional controls (ordinary least squares)

	(1)	(2)	(3)	(4)
World share leased boxes, t-1	0.046**	0.049*	0.049*	0.034+
	(0.013)	(0.020)	(0.020)	(0.017)
Density of paved roads, t-1	0.175+	0.178+	0.180+	0.095
	(0.103)	(0.104)	(0.102)	(0.143)
Density of railway lines, t-1	7.803+	7.533+	7.565+	6.724+
	(4.108)	(4.332)	(4.293)	(3.900)
Distance to network, log t-1	-0.315	-0.314	-0.309	-0.321
	(0.283)	(0.283)	(0.284)	(0.287)
Trade openness, log t-1	0.266	0.266	0.274	0.216
	(0.188)	(0.188)	(0.193)	(0.213)
Population, log t-1	0.256	0.252	0.249	0.421
	(0.344)	(0.357)	(0.355)	(0.405)
Network nr. countries, t-1	1.575+	1.549	1.506	1.714+
	(0.897)	(0.953)	(0.972)	(0.977)
Network usage, t-1	1.465*	1.469*	1.493*	1.215
	(0.682)	(0.687)	(0.690)	(0.768)
Ports/coastline, t-1		-2.650	-2.718	1.677
		(12.819)	(12.850)	(13.545)
Banking crisis, 5 yrs			0.042	0.049
			(0.046)	(0.045)
Real GDPpc PPP, log t-1				0.359
				(0.257)
Observations	1501	1501	1501	1501
R^2	0.80	0.80	0.80	0.80
F-test (p-value)	0.009	0.012	0.010	0.102

Notes: The dependent variable is the share of containerized trade in logs. All regressions include "years since adoption," "years since adoption squared," a constant, country fixed effects, and year fixed effects (not shown). The last line presents the p-value of the F-test for the joint significance of the density of paved roads and the density of railway lines. Standard errors in parentheses, clustered by country. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Table 3.7: (a) Robustness checks: sub-samples (ordinary least squares)

	(1)	(2)	(3)
World share leased boxes, t-1	0.046**	0.016	0.041**
	(0.013)	(0.015)	(0.010)
Density of paved roads, t-1	0.175+	0.336*	0.323
	(0.103)	(0.134)	(0.504)
Density of railway lines, t-1	7.803+	1.794	10.958
	(4.108)	(2.945)	(8.155)
Distance to network, log t-1	-0.315	0.046	-0.549
	(0.283)	(0.292)	(0.851)
Trade openness, log t-1	0.266	0.381+	0.392
	(0.188)	(0.191)	(0.302)
Population, log t-1	0.256	0.381	0.297
	(0.344)	(0.439)	(0.686)
Network nr. countries, t-1	1.575+	1.533	1.163
	(0.897)	(0.988)	(1.676)
Network usage, t-1	1.465*	0.136	2.237*
	(0.682)	(0.647)	(0.907)
Observations	1501	791	710
R^2	0.80	0.87	0.78
Nr.countries	77	36	41
F-test (p-value)	0.009	0.013	0.295
Sub-sample	All	High med-high income	Low med-low income

Notes: The dependent variable is the share of containerized trade in logs. All regressions in parts (a) and (b) include "years since adoption," "years since adoption squared," a constant, country fixed effects, and year fixed effects (not shown). The penultimate line presents the p-value of the F-test for the joint significance of the density of paved roads and the density of railway lines. Standard errors in parentheses, clustered by country. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Table 3.7: (b) Robustness checks: sub-samples (ordinary least squares)

	(4)	(5)	(6)	(7)
World share leased boxes, t-1	0.086**	0.052**	0.033*	0.049**
	(0.030)	(0.016)	(0.015)	(0.014)
Distance to network, log t-1	-0.268	-0.307	-0.324	-0.517+
	(0.314)	(0.281)	(0.362)	(0.300)
Density of paved roads, t-1	0.200	0.124	0.108	0.145
	(0.229)	(0.125)	(0.170)	(0.107)
Density of railway lines, t-1	8.237+	7.871+	11.334	7.507+
	(4.621)	(4.485)	(9.393)	(4.327)
Trade openness, log t-1	0.291	0.272	0.370+	0.112
	(0.246)	(0.190)	(0.215)	(0.160)
Population, log t-1	0.323	0.270	0.081	0.281
	(0.460)	(0.384)	(0.377)	(0.362)
Network nr. countries, t-1	1.375	1.565+	1.230	2.132*
	(1.004)	(0.932)	(1.196)	(0.912)
Network usage, t-1	1.837*	1.341*	1.831*	1.050+
	(0.896)	(0.658)	(0.836)	(0.576)
Observations	1147	1463	1164	1415
R^2	0.80	0.80	0.79	0.83
Nr.countries	62	76	64	71
F-test (p-value)	0.213	0.106	0.251	0.035
Sub-sample	Excl. islands	Excl. US	Excl. Western Europe	Excl. oil exporters

Table 3.8: Robustness checks: increased time lags (ordinary least squares)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		2-year lags				**5-year lags**		
World share leased boxes	0.036**	0.050**	0.052**	0.015	0.026+	0.062**	0.029*	0.025
	(0.013)	(0.016)	(0.015)	(0.023)	(0.015)	(0.015)	(0.011)	(0.021)
Density of paved roads	0.148	0.117	0.146	0.054	0.084	0.070	0.115	0.032
	(0.111)	(0.117)	(0.121)	(0.112)	(0.128)	(0.136)	(0.141)	(0.139)
Density of railway lines	5.139	6.639+	5.695	7.002+	7.010+	7.976*	7.388*	7.687+
	(3.921)	(3.653)	(3.430)	(3.884)	(3.770)	(3.535)	(3.345)	(3.870)
Distance to network, log	-0.265	-0.340	-0.386	-0.302	-0.486+	-0.539+	-0.592*	-0.508
	(0.229)	(0.286)	(0.293)	(0.275)	(0.255)	(0.305)	(0.296)	(0.313)
Network nr. countries	1.905*	1.733+	1.935*	0.733	1.867*	1.801*	2.109*	1.074
	(0.920)	(0.960)	(0.964)	(1.078)	(0.823)	(0.852)	(0.859)	(0.878)
Network usage		1.289+	1.330*	1.047		0.884	0.905	0.628
		(0.673)	(0.660)	(0.662)		(0.698)	(0.692)	(0.675)
Network ports			-0.029				-0.039	
			(0.023)				(0.026)	
Network real GDPpc, log				0.785+				0.574
				(0.424)				(0.447)
Observations	1546	1543	1543	1543	1545	1542	1542	1542
R^2	0.80	0.80	0.80	0.80	0.80	0.79	0.80	0.79
F-test (p-value)	0.076	0.058	0.054	0.141	0.136	0.076	0.071	0.145

Notes: All specifications include a constant, country and year fixed effects, "years since adoption," "years since adoption squared," "trade openness," and population (not shown). The last line presents the p-value of the F-test for the joint significance of the density of paved roads and the density of railway lines. Standard errors in parentheses, clustered by country. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Table 3.9: Robustness checks: IV-2SLS estimation

	(1) OLS	(2) IV-2SLS	(3) IV-2SLS	(4) IV-2SLS	(5) OLS	(6) IV-2SLS
Years since adoption	0.043*	-0.007	-0.041	-0.011	0.051**	-0.023
	(0.019)	(0.093)	(0.090)	(0.073)	(0.018)	(0.065)
Years since adoption, sq	-0.002**	-0.002**	-0.002**	-0.002**	-0.002**	-0.002**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
World share leased boxes, t-1	0.046**	0.087+	-0.313+	-0.260+	0.065**	-0.289**
	(0.013)	(0.046)	(0.166)	(0.142)	(0.008)	(0.111)
Distance to network, log t-1	-0.315	-0.433	-0.540	-0.490	-0.164	-0.479
	(0.283)	(0.307)	(0.343)	(0.319)	(0.234)	(0.323)
Density of paved roads, t-1	0.175+	0.055	-0.043	0.002	0.161	-0.023
	(0.103)	(0.151)	(0.193)	(0.168)	(0.098)	(0.168)
Density of railway lines, t-1	7.803+	14.255+	19.486+	17.054+	5.460	17.671*
	(4.108)	(7.476)	(10.557)	(8.728)	(3.722)	(8.752)
Trade openness, log t-1	0.266	0.202	0.148	0.173	0.318+	0.173
	(0.188)	(0.165)	(0.192)	(0.174)	(0.182)	(0.184)
Population, log t-1	0.256	0.227	0.206	0.216	0.150	0.186
	(0.344)	(0.373)	(0.458)	(0.414)	(0.338)	(0.432)
Network nr. countries, t-1	1.575+	0.844	0.248	0.525		
	(0.897)	(1.140)	(1.116)	(1.088)		
Network usage, t-1	1.465*	5.665	9.062+	7.482*	1.792**	8.340**
	(0.682)	(3.601)	(4.635)	(3.770)	(0.628)	(2.941)
First-stage (dependent variable: Network usage, t-1)						
Network rail density, t-2		1.357*		0.941		1.168*
		(0.567)		(0.600)		(0.500)
Network roads density, t-2			0.069*	0.051+		0.055+
			(0.028)	(0.029)		(0.030)
Observations		1497	1497	1497		1497
F-stat		143.218	40.366	43.335		34.947

Notes: All regressions include a constant, country fixed effects, and year fixed effects. Standard errors in parentheses, clustered by country. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Table 3.10: Adoption of containerization (logistic discrete-time hazard)

	(1)	(2)	(3)
Exp. containerized trade, avg. first 5-years, log t-5	0.767**		
	(0.235)		
Exp. containerized trade, avg. first 20-years, log t-5		1.459**	
		(0.307)	
Exp. containerized trade, avg. first 50-years, log t-5			1.317**
			(0.386)
Real GDPpc PPP, log t-5	0.099	0.092	0.091
	(0.154)	(0.153)	(0.154)
Share world trade, real t-5	0.299**	0.288**	0.257**
	(0.091)	(0.091)	(0.080)
Area km2, log	0.194*	0.230**	0.214*
	(0.087)	(0.087)	(0.092)
Oil exporter	-0.919	-1.226	-1.002
	(0.790)	(0.816)	(0.794)
Dummy 1956-1965	-1.668	-1.602	-3.430**
	(1.518)	(1.630)	(1.322)
Dummy 1966-1974	2.388**	2.805**	1.254*
	(0.870)	(0.771)	(0.621)
Dummy 1975-1983	2.964**	3.322**	2.409**
	(0.712)	(0.674)	(0.600)
Constant	-5.226**	-5.289**	-5.283**
	(1.731)	(1.781)	(1.734)
Observations	875	997	997
Log-likelihood	-221.564	-214.910	-222.813

Notes: The dependent variable is an indicator variable that takes the value one at the year of adoption and zero otherwise. For each country, I drop all observations corresponding to the years after adoption; that is, once a country adopts containerization, it is dropped from the estimation in the following years. Standard errors, computed by bootstrapping the results 1000 times, are in parentheses. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Table 3.11: Additional controls (20-year horizon)

	(1)	(2)	(3)	(4)
Exp. containerized trade, 20 yrs	1.452**	1.877**	1.662**	1.968**
	(0.315)	(0.435)	(0.332)	(0.477)
Real GDPpc PPP, log t-5	0.084	-0.236	-0.037	-0.263
	(0.163)	(0.180)	(0.172)	(0.184)
Share world trade, real t-5	0.276**	0.107	0.172+	0.076
	(0.092)	(0.101)	(0.093)	(0.096)
Area km2, log	0.235*	0.270*	0.291*	0.313**
	(0.095)	(0.119)	(0.113)	(0.115)
Oil exporter	-1.256	-1.662+	-1.248	-1.587
	(0.781)	(0.921)	(0.818)	(1.009)
Executive constraints, log t-5	0.041	0.047	-0.034	-0.003
	(0.062)	(0.077)	(0.076)	(0.075)
Rule of law		0.560**		0.440**
		(0.155)		(0.156)
Efficiency of judiciary			0.550**	0.358*
			(0.179)	(0.159)
Dummy 1956-1965	-1.617	-1.293	-1.492	-1.363
	(1.685)	(1.226)	(1.309)	(1.134)
Dummy 1966-1974	2.759**	3.115**	2.909**	3.250**
	(0.819)	(0.900)	(0.823)	(0.960)
Dummy 1975-1983	3.277**	3.834**	3.576**	4.004**
	(0.704)	(0.767)	(0.724)	(0.846)
Observations	997	997	997	997
Log-likelihood	-214.590	-202.221	-206.009	-198.727

Notes: The dependent variable is an indicator variable that takes the value one at the year of adoption and zero otherwise. For each country, I drop all observations corresponding to the years after adoption; that is, once a country adopts containerization, it is dropped from the estimation in the following years. All specifications include a constant and period dummies (not shown). Standard errors, computed by bootstrapping the results 1000 times, are in parentheses. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Table 3.12: Additional controls (20-year horizon)

	(1)	(2)	(3)
Exp. containerized trade, 20 yrs	1.927**	1.871**	1.854**
	(0.463)	(0.652)	(0.649)
Real GDPpc PPP, log t-5	-0.067	-0.065	-0.249
	(0.184)	(0.229)	(0.259)
Share world trade, real t-5	0.175*	-0.698	-0.815+
	(0.088)	(0.465)	(0.468)
Area km2, log	0.306**	0.210	-0.015
	(0.106)	(0.140)	(0.235)
Oil exporter	-1.276	-1.179	-1.111
	(1.017)	(1.358)	(1.438)
Executive constraints, log t-5	0.026	-0.098	-0.136
	(0.082)	(0.098)	(0.110)
Rule of law	0.425**	0.289	0.245
	(0.150)	(0.210)	(0.211)
Efficiency of judiciary	0.293+	0.217	0.321+
	(0.160)	(0.177)	(0.194)
Trade with USA, t-5	-0.265+	0.035	0.036
	(0.140)	(0.236)	(0.219)
Trade with AUS, t-5		6.283+	6.057*
		(3.233)	(3.025)
Trade with BEL, t-5		-0.624	0.002
		(6.232)	(5.580)
Trade with NLD, t-5		6.881	6.840
		(5.169)	(5.031)
Trade with GBR, t-5		1.413+	1.564*
		(0.770)	(0.777)
Island			-0.505
			(0.832)
Km of coastline, log			0.408+
			(0.245)
Observations	980	579	536
Log-likelihood	-186.980	-149.043	-144.578

Notes: See Table 3.11.

Table 3.13: Robustness checks: sub-samples (20-year horizon)

	(1)	(2)	(3)	(4)
Exp. containerized trade, 20 yrs	2.025**	1.795**	1.999**	1.784*
	(0.505)	(0.670)	(0.549)	(0.698)
Real GDPpc PPP, log t-5	-0.088	-0.057	-0.149	-0.015
	(0.181)	(0.248)	(0.178)	(0.251)
Share world trade, real t-5	0.149	-0.718	0.208	-0.935
	(0.118)	(0.683)	(0.177)	(0.677)
Area km2, log	0.319**	0.203	0.209	0.167
	(0.110)	(0.146)	(0.131)	(0.143)
Oil exporter	-1.929	-0.908	-1.678	-1.009
	(1.891)	(2.827)	(1.235)	(1.637)
Executive constraints, log t-5	0.025	-0.094	-0.015	-0.131
	(0.079)	(0.094)	(0.083)	(0.097)
Rule of law	0.450**	0.272	0.448*	0.247
	(0.169)	(0.235)	(0.194)	(0.269)
Efficiency of judiciary	0.305+	0.211	0.296+	0.169
	(0.164)	(0.192)	(0.171)	(0.190)
Trade with USA, t-5	-0.009	-0.052	-0.036	0.013
	(0.391)	(0.583)	(0.237)	(0.289)
Trade with AUS, t-5		6.720		7.758+
		(4.162)		(4.187)
Trade with BEL, t-5		-0.694		0.115
		(6.432)		(6.042)
Trade with NLD, t-5		7.375		6.307
		(5.989)		(5.827)
Trade with GBR, t-5		1.366+		2.441
		(0.776)		(1.859)
Observations	951	560	706	559
Log-likelihood	-180.858	-145.012	-173.094	-139.975
Sub-sample	Excl. CAN & MEX	Excl. CAN & MEX	Excl Common-wealth	Excl Common-wealth

Notes: See Table 3.11.

Table 3.14: Robustness checks: sub-samples (20-year horizon)

	(1)	(2)	(3)	(4)
Exp. containerized trade, 20 yrs	1.883**	1.702**	2.204**	2.316**
	(0.512)	(0.645)	(0.403)	(0.534)
Real GDPpc PPP, log t-5	0.067	0.117	-0.035	-0.025
	(0.200)	(0.253)	(0.183)	(0.250)
Share world trade, real t-5	0.163+	-0.838+	0.171+	-0.814
	(0.089)	(0.499)	(0.094)	(0.515)
Area km2, log	0.198+	0.163	0.325**	0.264+
	(0.112)	(0.160)	(0.116)	(0.140)
Oil exporter	-1.267	-1.078		
	(0.988)	(1.297)		
Executive constraints, log t-5	0.005	-0.116	0.017	-0.099
	(0.074)	(0.100)	(0.080)	(0.102)
Rule of law	0.387**	0.272	0.505**	0.419*
	(0.148)	(0.225)	(0.150)	(0.199)
Efficiency of judiciary	0.223	0.241	0.270	0.210
	(0.157)	(0.188)	(0.165)	(0.182)
Trade with USA, t-5	-0.238	0.069	-0.272+	0.094
	(0.151)	(0.225)	(0.156)	(0.270)
Trade with AUS, t-5		13.139+		6.682*
		(7.514)		(3.339)
Trade with BEL, t-5		-0.730		-0.217
		(5.971)		(6.314)
Trade with NLD, t-5		6.459		6.972
		(5.057)		(5.497)
Trade with GBR, t-5		1.219		1.277+
		(0.846)		(0.744)
Observations	958	567	948	557
Log-likelihood	-177.680	-141.583	-172.785	-135.694
Sub-sample	Excl NZL, CHN & JPN	Excl NZL, CHN & JPN	Excl. oil exp.	Excl. oil exp.

Notes: See Table 3.11.

Chapter 4

Exchange Rates and Global Rebalancing

1 Introduction

Everyone agrees that global rebalancing is needed. They just don't agree on what it entails. American commentators talk about the need for increases in consumption spending in Asia without equal emphasis on the need for more saving in the United States. Asian commentators emphasize the need to raise saving in the U.S. without acknowledging that it needs to be accompanied by an increase in spending in other regions in order to avoid a shortfall in global demand. Some point to the need for the United States to produce additional traded goods without acknowledging that this implies the need for other regions to produce less of the same, absent a significant change in relative prices. Some commentators insist that exchange rate changes are central to the adjustment process, while others insist that they are peripheral. This inability to agree does not exactly enhance the regard with which practitioners of the dismal science are held in the policy community.

Confusion and disagreement frequently stem from the fact that the problem is inadequately specified. In some cases the question is posed as: what would be the impact on global imbalances of an increase in China's exchange rate without at the same specifying what other variables are to be taken as endogenous if the exchange rate is treated as exogenously set. In other cases the question posed is: how would the exchange rate have to adjust to accommodate a change in the level of spending? In some cases the formulation distinguishes inadequately between spending on Chinese- and U.S.-produced goods. In others it distinguishes inadequately between changes in spending on traded and nontraded goods. The substitutability of U.S.- and foreign-produced traded goods and of traded and nontraded goods produced within the U.S. is not specified. With the question underspeci-

fied, the answer is underspecified: it fails to distinguish between equilibrating changes in the real exchange rate (relative overall price levels in the two economies) and the single factoral terms of trade (the relative price, exchange rate adjusted, of traded goods produced in the two countries).

Then there is disagreement stemming from confusion over which countries and regions are involved in this rebalancing process. Are we talking about the United States and China, where the Chinese economy is only 30 per cent the size of the U.S. economy – a fact that may have important implications for the changes in relative prices that would have to accompany, say, an exogenously-specified increase in U.S. savings rates?[1] Are we talking about a process of rebalancing where the U.S. is on one side and all of Asia is on the other – in which case the size imbalance is considerably less? Or are we talking about rebalancing between the U.S. and the rest of the world, in which case the U.S. is the smaller economy by a considerable margin?

Finally, there is confusion over the circumstances in which different categories of countries can contribute to the process of global rebalancing. The empirical literature has focused on adjustment by deficit countries. It asks: under what circumstances have such countries been able to eliminate large and persistent current account deficits? This literature has identified a useful set of stylized facts about the circumstances under which adjustment has occurred. But this emphasis fails to acknowledge that the coin has two sides. It is equally important to ask: under what circumstances have countries with large and persistent current account surpluses been able to eliminate these successfully? What with large surpluses heavily concentrated in emerging markets and petroleum-producing countries, it is further important to ask: are the circumstances in which these countries have succeeded in eliminating large current account surpluses different from those of advanced countries and non-oil exporters finding themselves in this position? It may be unwarranted to assume that findings about the characteristics of countries that have succeeded in eliminating large deficits carry over, up to a sign change, to countries that have eliminated large surpluses. It may be similarly reckless to simply assume that findings that apply to advanced countries and non-oil exporters mechanically carry over to emerging markets and oil exporters.

In this paper we seek to clarify these questions. In its first part we use the simplest model capable of shedding light on the exchange-rate and terms-of-trade implications of various rebalancing scenarios, the Obstfeld-Rogoff two-country endowment model (Obstfeld and Rogoff 2007). In this model each country possesses an endowment (produces a fixed quantity) of traded and nontraded goods that are imperfect substitutes in consumption.[2]

[1] The comparison is at market exchange rates, which is presumably what is relevant for an experiment in which relative prices adjustments eliminate initial imbalances in markets for traded goods.

[2] We add more precision to this statement below.

Given an assumption about the level of spending in both countries, it is possible to solve for the relative prices (the real exchange rate and terms of trade) that clear markets. And this makes it possible, in turn, to solve for the changes in relative prices (the exchange rate and terms of trade changes) needed to clear markets when levels of spending change.

This is the question, in our view, that is most central to global rebalancing and to the role of the exchange rate in that process. Starting from a situation where the U.S. is in current account deficit and the rest of the world is in surplus, what is the effect on the real exchange rate and other relative prices of, inter alia, an increase in U.S. savings owing to a financial crisis that vaporizes households' retirement accounts? What is the effect of an increase in Chinese spending owing to financial reforms that eliminate households' credit constraints and to the development of a social safety net that reduces the need for precautionary saving?

This initial analysis simply replicates the findings of the Obstfeld-Rogoff study. But we then apply the same model to further questions. How dramatically do relative price effects differ when it is only China, or all of Asia, or the entire rest of the world minus China on the other side of the U.S. rebalancing process? What difference does it make when the increase in spending in China falls mainly on traded or nontraded goods? How is the relative-price and adjustment impact affected when the increase in spending in China takes the form of investment in infrastructure and capacity that can then be used to produce traded or nontraded goods?

In the second part of the paper we turn to the circumstances under which countries have eliminated persistent current account surpluses. We start with a review of the literature on the elimination of large deficits. We then apply similar methods to constructing a sample of cases where large surpluses were eliminated. We compare the results with those in the mirror-image (large deficit) cases. And we contrast the findings for advanced countries with those for emerging markets and oil exporters.

We argue that this is an important extension of the earlier literature focusing on circumstances under which large deficits are eliminated. When the deficit country is small, the circumstances under which its external imbalance is eliminated can reasonably be considered in isolation. But when that country is large, there also has to be significant adjustment on the surplus side. In this case analyzing the circumstances in which large deficits are eliminated makes little sense without also analyzing the circumstances under which large surpluses are eliminated. The previous literature having addressed the first question, we add evidence on the second. Putting the pieces together, we are then able to say something about the likelihood that we will now see a sustained reduction in global imbalances.

2 Overview of Global Imbalances

The debate over global imbalances is of long standing, reflecting the persistence of those imbalances themselves. Figure 4.1, following Blanchard and Milesi-Ferretti (2009), summarizes their evolution, expressing the imbalances of different regions as shares of global GDP. The figure highlights two facts. First, the United States accounts for the largest share of global current account deficits; any explanation for imbalances and their evolution will have to account for its behavior. 2009 was the first time in years when the U.S. did not account for the majority of the world's deficits, the question of course being whether its deficit share is likely to expand again as the U.S. and global economies recover.

Second, while China is prominent on the surplus side, it is not alone. In most years the contribution of oil exporters and Surplus-Europe countries like Germany is even greater, and in some years (early in the period) China's contribution is matched by those of Other Emerging Asia and Japan. Only in 2009 was the global surplus heavily a Chinese surplus. While any explanation for global imbalances clearly will have to reckon with the behavior of China, an analysis limited to the bilateral U.S.-China imbalance will not adequately capture the problem.

[Include Figure 4.1 here]

Some years ago one of us (Eichengreen, 2006) published an article distinguishing several classes of explanations for global imbalances. The first of these was the "new economy" or "relative profitability" interpretation emphasizing the contrast between the rapid productivity growth associated with the rollout of new information and communications technologies in the United States and slower growth and lower profitability in crisis-ridden Other East Asia and Japan. This plausibly accounts for some widening of global imbalances in the late 1990s but less so after the Tech Bubble burst and Other East Asia recovered from its crisis.

The second explanation, the "standard analysis," focused on declining U.S. saving and corresponding increases in saving in Asia (Governor Bernanke's global savings glut).[3] The initial decline in U.S. savings was ascribed mainly to growing government dissaving following the Bush tax cut of 2001 (Figure 4.2). After 2004 the focus shifted to household dissaving associated with the boom in asset prices, home prices in particular (Figure 4.3). On the surplus side, different explanations applied to different economies. The oil exporters ran large net surpluses in the period of strong global growth and high energy prices around mid-decade. High internal and external savings in Surplus Europe reflected policies of restraint

[3] Bernanke (2005).

(restraint of wages and of the impulse to consume).[4] In Other Emerging Asia, net external savings reflected stagnant investment more than surging saving.[5] High saving in China was a function of high growth.[6] It was a function of the strong demand for precautionary saving in the presence of capital market imperfections and absence of a well-developed social-safety net. It was a function of lack of pressure on profitable state-owned enterprises to pay out dividends.

[Include Figures 4.2 and 4.3 here]

The third class of explanation focused on the characteristics of international assets and liabilities. The "dark matter" or "exorbitant privilege" views emphasized the tendency for the United States to earn a higher return on its external assets than it paid on its liabilities, enabling it to run current account deficits without increasing its net indebtedness to the rest of the world. One interpretation of this differential was that U.S. investors were savvier. A more plausible variant was that they had greater risk tolerance: they were willing to hold relatively risky foreign direct investments, while foreigners preferred relatively safe U.S. debt securities. Gourinchas and Rey (2007) documented the existence of this rate-of-return differential and established the linkage with the composition of external assets and liabilities. Caballero (2010) is an influential statement of the view that the demand in emerging markets for relatively safe debt securities, which the U.S. has a comparative advantage in producing, could rationalize the existence not just of rate-of-return differentials but also of growing imbalances, as larger and more rapidly growing emerging markets sought to import additional safe assets from the United States.

While these three interpretations are different, there is no necessary incompatibility among them, in general and insofar as they apply to different periods and economies in particular.

Each class of explanation can shed some light on what is likely to happen next. The "new economy" view does not predict the rapid reemergence of global imbalances insofar as the post-crisis U.S. economy is unlikely to be characterized by high levels of investment.[7]

[4]This can be understood as reflecting the absence of a housing boom in countries like Germany and that only a small fraction of the population holds a significant share of their savings in the form of stocks; hence the effects of the asset boom were less.

[5]A thorough analysis is *Asian Development Outlook 2009: Rebalancing Asia's Growth* (2009).

[6]This is understood in terms of the predictions of the life-cycle model: with younger generations saving out of higher current incomes and older generations dissaving out of lower former incomes, national saving will be high in fast growing economies (see Modigliani & Cao, 2004).

[7]Rapid productivity growth there has of course been in recent quarters, but there is reason to think this was a one-off event, as firms laid off their least productive workers and closed down their least efficient plant. The difficulty of structural change, the likelihood of a credit-less recovery, and the growing debt overhang are all reasons to worry that U.S. investment rates will lag (Goldman Sachs, 2010).

The "standard analysis" points to the importance of higher U.S. savings rates which, recent research suggests, will continue to run in the mid single digits.[8] It points similarly to the likelihood that Chinese household savings will begin to decline with better public provision of health care and a more effective social safety net generally.[9] But it also suggests that adjustment in China will remain slow insofar as household savings are inertial and there is still little pressure on Chinese enterprises to reduce their retained earnings.[10] Finally, to the extent that the United States is no longer viewed as a reliable supplier of safe assets, emerging markets wishing to accumulate them may now turn to other sources, which will mean less foreign finance for U.S. current account deficits.

Note that this analysis has been presented entirely without reference to the exchange rate. Indeed, how exchange rates (shown in Figure 4.4) fit into this story is not entirely clear. It is to this issue that we now turn.

[Include Figure 4.4 here]

3 Implications of Various Rebalancing Scenarios

3.1 Obstfeld-Rogoff Model

In this subsection we describe Obstfeld-Rogoff model. We describe first the structure of preferences, then the equilibrium conditions, and finally the parameter values used for simulation. We then show the impact on exchange rates (real exchange rates and the terms of trade) of eliminating the imbalance between the U.S. and the rest of the world.

The model here is Obstfeld-Rogoff's two-country model with exogenous endowments. It assumes that prices are flexible and the law of one price holds for individual tradable goods. There is home consumption bias within tradable goods which may be different between countries. This is captured by the parameters α and α^*. Countries may also assign different preference weights to tradable goods relative to nontradable goods. This is captured by the two parameters γ and γ^*. The values of θ and η correspond to (constant) elasticities

[8] This according to Carroll and Slacalek (2009), Lee, Rabanal, and Sandri (2010) and Mody and Ohnsorge (2010).

[9] Barnett and Brooks (2010) find that one additional yuan of government spending on health care produces a two yuan increase in consumption spending; in contrast, they find little impact on consumption of increases in education spending.

[10] It is on these grounds that the IMF projects the reemergence of large surpluses in China by 2012 (Blanchard & Milesi-Ferretti, 2009). The decline in household savings rates in China will presumably accelerate after 2015 with the rapid rise in old-age dependency ratios, but this is still far in the future from the perspective of policy analysis.

of substitution between tradable and nontradable goods and domestically-produced and imported tradables, respectively.

The Home consumption index is expressed in the nested form

$$C = \left[\gamma^{\frac{1}{\theta}} C_T^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_N^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \tag{4.1}$$

and the Home consumer price index (CPI) corresponding to the preceding Home consumption index C is

$$P = \left[\gamma P_T^{1-\theta} + (1-\gamma) P_N^{1-\theta}\right]^{\frac{1}{1-\theta}} \tag{4.2}$$

with tradables and nontradables consumption given by

$$C_T = \left(\frac{P}{P_T}\right)^{\theta} \gamma\ C \tag{4.3}$$

$$C_N = \left(\frac{P}{P_N}\right)^{\theta} (1-\gamma)\ C \tag{4.4}$$

Similarly, tradables consumption index C_T is expressed as

$$C_T = \left[\alpha^{\frac{1}{\eta}} C_H^{\frac{\eta-1}{\eta}} + (1-\alpha)^{\frac{1}{\eta}} C_F^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{4.5}$$

and the price index for tradables given by

$$P_T = \left[\alpha P_H^{1-\eta} + (1-\alpha) P_F^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{4.6}$$

with Home and Foreign tradables consumption

$$C_H = \left(\frac{P_T}{P_H}\right)^{\eta} \alpha\ C_T \tag{4.7}$$

$$C_F = \left(\frac{P_T}{P_F}\right)^{\eta} (1-\alpha)\ C_T \tag{4.8}$$

In Foreign there are isomorphic indices but with the parameters α^* and γ^*.

The terms of trade, τ, and the real exchange rate, q, are[11]

$$\tau = \frac{P_F}{P_H} = \frac{P_F^*}{P_H^*} \qquad q = \frac{\varepsilon P^*}{P}$$

[11] Discussion here is in terms of the real exchange rate, this being a real rather than a monetary model. Readers preferring to think in terms of the nominal rate can assume that central banks in each country target a stable price level.

Even though the law of one price holds for individual tradable goods, purchasing power parity does not hold for the differing preferred baskets of tradable goods in each country. This means that $P_T \neq \varepsilon P_T^*$, where ε is the nominal exchange rate.

Given this structure, market-clearing conditions for the Home produced good H, the Foreign tradable good F, Home nontradables N and Foreign nontradables N^* are

$$\begin{aligned}
Y_H &= C_H + C_H^* \qquad \Leftrightarrow \\
Y_H &= \alpha \left(\frac{P_H}{P_T}\right)^{-\eta} \underbrace{\gamma \left(\frac{P_T}{P}\right)^{-\theta} C}_{C_T} + (1-\alpha^*) \left(\frac{P_H/\varepsilon}{P_T^*}\right)^{-\eta} \underbrace{\gamma^* \left(\frac{P_T^*}{P^*}\right)^{-\theta} C^*}_{C_T^*} \qquad (4.9) \\
Y_F &= C_F + C_F^* \qquad \Leftrightarrow \\
Y_F &= (1-\alpha)\gamma \left(\frac{P_F}{P_T}\right)^{-\eta} \left(\frac{P_T}{P}\right)^{-\theta} C + \alpha^*\gamma^* \left(\frac{P_F/\varepsilon}{P_T^*}\right)^{-\eta} \left(\frac{P_T^*}{P^*}\right)^{-\theta} C^* \qquad (4.10) \\
Y_N &= C_N \qquad \Leftrightarrow \qquad Y_N = (1-\gamma)\left(\frac{P_N}{P}\right)^{-\theta} C \qquad (4.11) \\
Y_N^* &= C_N^* \qquad \Leftrightarrow \qquad Y_N^* = (1-\gamma^*)\left(\frac{P_N^*}{P^*}\right)^{-\theta} C^* \qquad (4.12)
\end{aligned}$$

Finally, the current account is

$$\begin{aligned}
\text{Home:} \qquad & CA = P_H Y_H + iF - P_T C_T \qquad (4.13) \\
\text{Foreign:} \qquad & \varepsilon CA^* = P_F Y_F - iF - P_T C_T^* = -CA \qquad (4.14)
\end{aligned}$$

where F is Home net foreign assets and i is the interest rate, in Home-currency units, and the real exchange rate is

$$q = \underbrace{\frac{\left[\alpha^* \tau^{1-\eta} + (1-\alpha^*)\right]^{\frac{1}{1-\eta}}}{\left[\alpha + (1-\alpha)\tau^{1-\eta}\right]^{\frac{1}{1-\eta}}}}_{\frac{\varepsilon P_T^*}{P_T}} \times \frac{\left[\gamma^* + (1-\gamma^*)(P_N^*/P_T^*)^{1-\theta}\right]^{\frac{1}{1-\theta}}}{\left[\gamma + (1-\gamma)(P_N/P_T)^{1-\theta}\right]^{\frac{1}{1-\theta}}} \qquad (4.15)$$

In our calibration we initially adopted Obstfeld and Rogoff's (2007) parameter values. We set the dollar value of tradable goods output to GDP at $\frac{P_H Y_H}{P_H Y_H + P_N Y_N} \approx 0.25$. Assuming that U.S. current external deficit is about 5% of GDP, this implies a current account deficit-to-tradables ratio of $ca = \frac{CA}{P_H Y_H} = -0.05/0.25 = -0.2$. We set net U.S. foreign assets over the dollar value of traded goods output at $f = \frac{F}{P_H Y_H} = 0.8$, and the nominal interest rate at $i = 0.05$ per year. We also set $Y_N/Y_H = Y_{N^*}/Y_F = 1$, $\eta = 2, \theta = 1, \gamma = \gamma^* = 0.25, \alpha = 0.7$

and $\alpha^* = 0.925$. Under the assumption that $\sigma_T = Y_H/Y_F = 0.22$, the U.S. accounts for 21% of the world economy.

We assume a decline in U.S. spending and an increase abroad sufficient to eliminate the U.S. deficit. Suppose, for example, that a financial crisis depresses the value of U.S. households' retirement accounts and that financial reforms eliminate credit constraints in China. Eliminating the imbalance would cause the dollar to depreciate by 32.3%. On the one hand, there will be a shift in global demand away from the U.S. which causes a relative drop in demand for U.S.-produced tradable goods. This is because U.S. citizens are assumed to have a relatively strong preference for U.S.-produced tradables. The U.S. terms of trade will fall by 15.76%. On the other hand, because eliminating the U.S. current account deficit implies a 20% fall in demand for traded goods, there needs to be a fall in the relative price of nontraded goods in the United States. In parallel with the effect in the U.S. there will also be a rise in the price of nontraded goods abroad. Given the large share of nontradables in the CPI, this magnifies the overall real exchange rate response beyond terms of trade changes.

Changing the two elasticity parameters θ and η has important effects in the adjustment. Higher elasticities of substitution between tradable and nontradable goods and domestically-produced and imported tradables lead to a smaller impact on the terms of trade and the real exchange rate.

3.2 Participation in Global Rebalancing

In this second subsection we explore alternative assumptions about what countries participate, along with the United States, in the process of global rebalancing. Our benchmark assumption was that all countries participate, both the U.S., which is 21 percent of the world economy, and the rest of the world. Here we ask how much difference it makes if China does not participate – if it prevents its imports and exports from moving. Removing China from the picture, the rest of the world is now smaller relative to the United States. The U.S. is 21% of the world, while we take China as 7% of the world. Hence the relative economic size of the U.S. is now approximately 23%. Accordingly, we assume that $\sigma_T = Y_H/Y_F = 0.2579$ instead of 0.22.[12] For different combinations of the two elasticity parameters, Table 4.1 shows how the impact on exchange rates (the terms of trade and the real exchange rate) of eliminating the imbalance between the U.S. and the rest of the world varies with different U.S. sizes. Since U.S. citizens have a relatively strong preference for Home goods, the fall in the terms of trade increases with the size of the U.S relative to the world economy. Furthermore, the larger the relative size of the U.S. the larger the initial current account surplus in the rest of the world. For example, a U.S. current account

[12]See Appendix H for details.

deficit of 5% of GDP corresponds to a current account surplus in the rest of the world of $\frac{CA^*}{GDP^*} = -\frac{CA}{GDP} \times \frac{P_H Y_H}{P_F Y_F} = -(-0.05 * 0.2579/0.8843) = 1.46\%$ when the U.S. is 23% of the world economy and of $\frac{CA^*}{GDP^*} = -(-0.05 * 6.71/2.2357) = 15\%$ when the U.S. is 75%. Adjustment abroad causes the rise in the relative price of foreign nontraded goods, in parallel to the fall in the relative price of domestic nontraded goods, which magnifies the effect on the real exchange rate. Therefore, if China does not participate in eliminating the imbalances, there will have to be a larger dollar depreciation.

Alternatively, we explore the cases where the U.S. is on one side of the rebalancing process and either all of Asia or only China is on the other. In the first case all non-Asian countries prevent any movement in their imports and exports from occurring, while in the second all of Asia except China joins the non-Asian group by excluding itself from the process of rebalancing. Since the U.S. is one and a half times the economic size of Asia and three times the economic size of China on its own, its share in the collective output is 0.5 and 0.75, respectively.

It follows that the impact on the terms of trade and the real exchange rate would be much bigger. For example, when only the U.S. and China participate in the rebalancing, the dollar depreciation is above 69% for any reasonable combination of the two elasticity parameters.

[Include Table 4.1 here]

The conclusion is that it matters greatly how many countries are on the other side of the U.S. current account adjustment. If there is only one, China, the real exchange effects are extremely large. All of Asia and they are smaller. The rest of the world minus China and they are even smaller. The entire rest of the world including China and they are smaller still.

3.3 Sectoral Productivity Shocks

In this third subsection we return to our benchmark model where the U.S. accounts for 21% of the world economy and explore the effects of productivity shocks in the rest of the world. First, we look at an increase in foreign production of tradable goods (think of this as the additional infrastructure investment undertaken by China in 2008-9 as increasing the supply of exportable goods). We also explore the effect of assuming an increase in foreign capacity to produce nontradable goods. The real exchange rate changes needed to accommodate these different patterns of increased output are, not surprisingly, very different.

The real exchange rate response is determined by changes in both the terms of trade and in the relative prices of domestic and foreign nontradable goods (see equation 4.15). Given

the large share of nontradable goods in the CPI, changes in the relative prices of nontradable goods have a higher weight in the determination of the overall exchange rate response than do changes in the terms of trade.

An increase in foreign production of tradable goods causes the relative prices of both domestic tradable goods and foreign nontradable goods to rise. The former relative price change corresponds to an improvement in the U.S. terms of trade, and the combination of both causes the dollar to depreciate. When the increase in foreign production is concentrated in the nontradable goods sector there is no change in the terms of trade. Nevertheless, the drop in the relative price of foreign nontradable goods causes the dollar to appreciate. Table 4.2 reports parameter values and exchange rate changes (the terms of trade and the real exchange rate) for 20 percent variations in foreign production.

[Include Table 4.2 here]

It thus matters tremendously whether surplus countries like China as they continue to grow concentrate their investment in productive capacity in traded or nontraded goods. In the first case, the U.S. terms of trade would have to increase and the dollar would depreciate in real terms. In the second case, in contrast, there would be no change in the terms of trade and the dollar would appreciate in real terms.

3.4 Preference Shocks

In this final subsection we imagine structural reforms (a social safety net, financial market reforms, etc.) that change spending patterns. First, we assume an increase in the foreign preference for U.S. exports. This is, in effect, an increase in the foreign preference weight on U.S. tradable goods, $1 - \alpha^*$, or, equivalently, a reduction in foreign home bias in tradables. As can be seen from the second row of Table 4.3, raising $1 - \alpha^*$ from 0.075 to 0.2 causes the U.S. terms of trade to rise by about 35 percent and the dollar exchange rate to appreciate by 31 percent.[13] This reflects the shift in global demand towards U.S. exports. If foreign home bias were to increase to the level of the U.S., $\alpha = \alpha^* = 0.7$, the rise in the terms of trade would be larger than 50 percent and the dollar real exchange rate would appreciate by 45 percent.

Next we assume a reduction in U.S. home bias in tradables from 0.7 to 0.4. In the fourth row of the table we can see that this causes the terms of trade to fall by 37 percent and the dollar to depreciate 33 percent in real terms. This happens because lower U.S. home bias causes global demand for U.S. tradable goods to fall.

[13] We assume the size of the U.S. to be 21% of the world economy and the elasticity parameters θ and η to equal 1 and 2, respectively.

Finally we look at changes in foreign preferences for tradables. This corresponds to the foreign preference weight on tradable goods, γ^*. Because this parameter affects only relative consumption of tradable and nontradable goods – see equations 4.1 to 4.4 – it has no effect on the terms of trade. However, because it has an impact in the price of foreign nontradable goods (relative to tradable goods) the real exchange rate changes. We can see this from equation 4.15 above – the dollar depreciates in real terms when γ^* falls and appreciates when it increases. Lowering γ^* from 0.25 to 0.19 causes the dollar real exchange rate to depreciate by about 35 percent. A real appreciation of the same magnitude can be generated by raising γ^* from 0.25 to 0.33, as can be seen from the fifth and sixth rows of the table. The effect of raising the U.S. preference for tradables, γ, is similar to that of lowering the foreign preference for tradables, γ^*. An increase in γ from 0.25 to 0.32 causes the real exchange rate to depreciate by 33 percent – see the seventh row of the table.

[Include Table 4.3 here]

This shows that changes in spending patterns can result in significant changes in the real exchange rate and terms of trade. Stronger foreign taste for U.S. exports or for tradable goods cause the dollar to appreciate, while declines in U.S. home bias in tradables, declines in foreign preference for tradable goods or increases in U.S. preference for tradable goods cause the dollar to depreciate. As expected, changes in domestic or foreign preferences for tradable goods have no effect in the terms of trade, while changes in home bias in tradables do. A decline in U.S. home bias causes U.S. terms of trade to fall, while a decline in foreign home bias (or, equivalently, an increase in foreign preference for U.S. tradable goods) causes U.S. terms of trade to rise.

4 Current Account Surplus Reductions

While there is little literature on how large current account surpluses end, especially in emerging markets, there is a large literature on the elimination of large current account deficits ("current account reversals"). Table 4.4 summarizes this literature. Most studies identify "reversals" following the criteria proposed by Milesi-Ferretti and Razin (1998).[14] These criteria identify, inter alia, the initial current account ratio, the size of the adjustment (in percent of GDP and as a fraction of the initial deficit) and its duration. Algieri and Bracke (2007) relax earlier criteria using sensitivity analysis in order to maximize the number of episodes. International Monetary Fund (2007) shift the emphasis of previous studies toward both deficit and surplus reversals and propose a set of criteria applicable to both.

[14] With the exceptions of Algieri and Bracke (2007) and International Monetary Fund (2007): see below.

Additionally, they estimate the duration of episodes instead of setting a fixed adjustment period.

Most papers focus on industrial/OECD countries, namely Freund (2005), Croke, Kamin, and Leduc (2005), Freund and Warnock (2007), Debelle and Galati (2007) and de Haan, Schokker, and Tcherneva (2008).[15] A few papers consider current account reversals in low- and middle-income economies (Milesi-Ferretti and Razin (1998)), or in both industrial and emerging economies (Adalet and Eichengreen (2007), Algieri and Bracke (2007) and International Monetary Fund (2007)).

[Include Table 4.4 here]

While there is dispute about the main determinants of reversals, there is nonetheless some agreement regarding what variables to consider. Most studies include the current account ratio, macroeconomic variables such as domestic growth, GDP per capita and the fiscal balance, external sector variables such as the trade balance, trade openness, the real exchange rate, the terms of trade and the exchange regime, and world variables such as world growth, OECD growth or U.S. real interest rates. The last column of the table reports the effect of the variables used in each study.

Although these papers focus on current account deficit reversals,[16] which may differ beyond a sign change from reductions in current account surpluses, they are nonetheless a logical starting point in our study.

4.1 Data and Variable Definitions

Our analysis uses data for 46 emerging countries[17] and 26 advanced countries[18] over the period 1980-2008. The main sources are the IMF World Economic Outlook Database (October 2009) and the World Bank's World Development Indicators (2009). We start by identifying

[15] This is evidence of the recent interest in the U.S. situation as a few of them use the analysis of the OECD's experience to draw inferences for the U.S. case.

[16] Except International Monetary Fund (2007).

[17] Argentina, Bahrain, Bangladesh, Botswana, Brazil, Bulgaria, Chile, China, Colombia, Côte d'Ivoire, Croatia, Cyprus, Czech Republic, Egypt, Estonia, Hungary, India, Indonesia, Jordan, Kenya, Lithuania, Macedonia, Malaysia, Mauritius, Mexico, Morocco, Nigeria, Oman, Pakistan, Peru, Philippines, Poland, Qatar, Romania, Russia, Serbia, Slovak Republic, Slovenia, South Africa, Sri Lanka, Taiwan, Thailand, Tunisia, Turkey, United Arab Emirates, and Vietnam.

[18] Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hong Kong, Ireland, Israel, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Singapore, Korea, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

persistent reductions in current account surpluses. Because the defining criteria have important implications in episode selection and thereby for the results, we consider three different sets of criteria inspired by the above-mentioned literature on deficit reversals.

Our first definition, EP1, is a variant of the measure proposed by Algieri and Bracke (2007). In order for a country to have an episode that qualifies as a persistent reduction in the current account surplus, it must meet the following five criteria:

i. The current account is in surplus before the reduction;

ii. Adjustment takes place within 4 years;

iii. Within 4 years the current account decreases by at least one standard deviation of the country's current account ratio;

iv. The current account reduction is sustained over 5 years, that is, the maximum current account ratio in the 5 years after the adjustment should remain below the minimum current account ratio in the 3 years before the adjustment;

v. There is not another reduction in the following 4 years.

Alternatively, we construct EP2 following, with necessary modifications, Milesi-Ferretti and Razin (1998) and the subsequent studies that adopted their criteria:[19]

i. The current account surplus exceeded 2 percent of GDP before the reduction;

ii. The average surplus was reduced by at least 2 percent of GDP over 3 years (from the maximum to the 3 year average);

iii. The maximum current account ratio in the 5 years after the reduction was not larger than the minimum current account ratio in the 3 years before the reduction;

iv. The current account ratio decreased by at least 1/3 of the initial surplus value;

v. There is not another reduction in the following 3 years.

Finally, we construct EP3 using the four criteria adopted by International Monetary Fund (2007), to which we add a fifth:

i. *Beginning of the reduction (year 0)*: the average reduction in the imbalance over the next 3 years must be at least 1/2 percentage point of GDP;

[19] Freund (2005), Croke et al. (2005), Freund and Warnock (2007), Adalet and Eichengreen (2007), Debelle and Galati (2007), and de Haan et al. (2008).

ii. *End of the reduction (year T)*: the episode finishes when a local minimum is reached, that is, when the current account ratio ca_t remains above ca_T for 3 consecutive years, and 1/2 percent or more of the reduction is overturned: $|ca_T - ca_{T-1}|/|ca_0 - ca_{T-1}| \geq 0.005$;

iii. Compared with the initial year, the current account ratio in T must fall by at least 2.5 percentage points of GDP, and by at least one-half of the initial level;

iv. In each of the 5 years after the beginning of the episode, the current account ratio must be smaller than the initial level;

v. There is not another reduction while one is still ongoing, where the duration of each reduction is determined in criterion ii.

Unlike the first two measures, which look at adjustments over a fixed period of 3 to 4 years, EP3 allows for longer-lived reductions in current account surpluses and estimates the duration of each episode. It is less restrictive than EP1 and EP2 as it requires only a 1/2 percent of GDP reduction as opposed to one standard deviation for EP1 and 2 percent of GDP for EP2. We therefore refer to EP1 and EP2 as capturing "substantial surplus reductions" and EP3 as identifying both "substantial" and "moderate" surplus reductions. EP3 generates many more episodes (69 in emerging countries and 26 in advanced countries) than EP1 (28 episodes in emerging countries and 13 in advanced countries) and EP2 (34 episodes in emerging countries and 13 in advanced countries).[20]

Table 4.5 lists all episodes identified by each set of criteria, and tables 4.6 and 4.7 report the current account ratio at the beginning of the episode, its change during the adjustment and the duration of the reduction.

[Include Tables 4.5, 4.6, and 4.7 here]

If we compare episodes picked up by EP1 and EP2 we notice some cases where the same episode is captured by both but with a divergence of several years, and others where episodes are captured by only one definition. One way of choosing between these definitions would be to select the one that has the highest fraction of episodes also picked up by the other two, allowing for 3 years of divergence with regards to the starting year. Table 4.8 reports this information. Of the 47 episodes identified by EP1, 28 were also picked up by EP2 and 39 by EP3. On average, 71.3% of its episodes were also identified by the other two definitions.

[20] After this paper was drafted, International Monetary Fund (2010) published a study of the consequences (as opposed to the causes, our concern here) of ending sustained current account surpluses. Their methodology is similar to our definition EP2, and of the 20 episodes they list after 1980, 7 are also included in our measure EP1, 9 in our measure EP2, and 14 in our measure EP3, which provides something of an independent check on our methodology.

Since this fraction equals 70.7% for EP2, EP1 does the best job in identifying a consistent set of episodes in this sense.

[Include Table 4.8 here]

4.2 Univariate Patterns

We now turn to the choice of explanatory variables, guided by the literature on current account deficit reversals. We list and describe these variables and their sources in Table 4.9, and in Table 4.10 we show their means, differences in means and significance in a two-tailed t-test. We divide the sample in emerging and advanced countries to allow for different determinants of reductions between these countries.[21]

[Include Tables 4.9 and 4.10 here]

For emerging markets, the univariate comparisons suggest that reductions occur in countries with higher initial current account surpluses and with slower domestic growth. Reductions in surpluses appear also to be associated with earlier decreases in trade balances, higher real appreciation, and higher public savings. "Substantial reductions" happen when oil prices are higher, while "substantial and moderate reductions" happen when they are lower. In advanced countries, similarly, reductions seem to occur in economies with higher current account ratios and higher public savings. They are also associated with faster growth, higher openness to trade, earlier decreases in trade balances, and higher world growth.

Figures 4.5–4.10 provide a graphical depiction of the behavior of the current account ratio and various correlates during episodes of surplus reductions in emerging and advanced countries, where year zero is when the reduction starts. The first graph reports the median and average current account ratio over all countries 5 years before and after reductions, and the other seven graphs compare averages for domestic growth, trade openness, trade balance, the real exchange rate, fiscal balance, world growth and the real oil price between countries that experienced reductions and those that did not in the 5 years before and after they occur.

[Include Figures 4.5–4.10 here]

These variables behave very differently in emerging and advanced economies. In emerging countries, reductions happen after increases in the current account ratio. In advanced countries, in contrast, this ratio does not show much variation before reductions. Domestic

[21] We exclude Germany from the advanced country subsample since the current account reduction identified after the reunification in 1989 has its own historical reasons.

growth accelerates in the years preceding reductions in emerging countries, perhaps reflecting demand-driven growth that translates into increased domestic absorption, while it decelerates slightly in advanced countries. In both emerging and advanced countries, reductions seem to occur after a deceleration in a previously growing trade balance. Openness to trade moves in tandem with the trade balance in its improving phase but does not follow its deceleration in the following years. This behavior may possibly be caused by the rise in imports due to exchange rate appreciation.

The real exchange rate is defined such that an increase represents an appreciation. In line with the earlier theoretical model, reductions seem to be preceded by 2 years of significant real appreciation in emerging countries, and by 1 year of mild appreciation in advanced countries. The fiscal balance is very volatile before reductions in emerging countries, whereas in advanced countries it is more stable. In advanced countries, public savings fall in the year immediately preceding reductions following 2 to 3 years of growth. In both emerging and advanced economies fiscal savings deteriorate markedly in the year of the reduction.

Reductions occur after 1 to 3 years of decelerating world growth, in both emerging and advanced countries. "Substantial reductions" tend to be preceded by 2 to 3 years of improving oil prices, whose subsequent fall seems to trigger these reductions. This may reflect the impact of falling oil prices on oil producers' export receipts. "Substantial and moderate reductions" in advanced countries occur after smaller increases in oil prices without a subsequent fall, while in emerging countries they seem to be preceded by 2 years of falling oil prices. The distinct behavior exhibited by several variables before "substantial reductions" and before "substantial and moderate reductions" shows that it matters greatly how we define current account reductions.[22]

The one clear conclusion from this univariate analysis is that the behavior of macroeconomic variables around the time of reductions in large current account surpluses is very different in emerging and advanced countries. We therefore disaggregate them in the multivariate analysis to which we now turn.

4.3 Multivariate Analysis

We use logit analysis to determine which variables help to predict whether a country experiences a substantial, or substantial and moderate, reduction in its current account surplus. Our dependent variable takes a value of 1 if there is a current account reduction and 0 otherwise. Given the similarities between logit and probit models with binary dependent variables, both models would deliver qualitatively similar conclusions. However, fixed effects

[22]For the case of current account deficit reversals, Algieri and Bracke (2007) show, similarly, that small modifications to the criteria used in the literature can considerably change the selection of reversals and significantly affect the results.

probit analysis introduces what Wooldridge (2002) calls an "incidental parameters problem." Because the fixed effects logit maximum likelihood estimator does not treat the fixed effects as parameters to be estimated along with the betas, it produces consistent estimators.

To avoid problems of endogeneity and for consistency with prior studies, we used three-year-lagged averages for the current account ratio, domestic growth, and the change in the trade balance.[23] Since observations for the same country in different years are not independent, we cluster standard errors by country. However, this does not control for unobserved country-specific characteristics, for which we use country fixed effects. We also add year fixed effects to control for unobserved factors that affect all countries in each given year. When we include year fixed effects, we can compare the effects of various factors across countries. When we instead include country fixed effects, effectively dummying out cross-country differences, we are focusing on the effects of changes in an explanatory variable within a country over time on the probability of a surplus reduction.

Results are in tables 4.11 and 4.12. While we would have liked to have a consistent set of explanatory variables in the two subsamples, we had to exclude the fiscal balance from the emerging country subsample and the dummy for oil exporters from the advanced country subsample. Fiscal balance data is available for most advanced countries but not for many emerging countries, especially in earlier years, causing a large number of missing observations in the regressions that use the emerging country subsample. We dropped the dummy for oil exporters from the advanced country subsample because there is only one country that is classified as an oil exporter, Norway.

[Include Tables 4.11 and 4.12 here]

The first regression in each group considers several domestic determinants of reductions and two external variables.[24] The second regression controls for unobservable country-specific characteristics and the third for year-specific factors. A schematic summary of the signs of the significant coefficient estimates is presented in Table 4.13. In discussing the results, we focus on "substantial surplus reductions" identified by EP1, which for the reasons presented above dominates EP2, and on "substantial and moderate surplus reductions" identified by EP3.

[Include Table 4.13 here]

[23] Other explanatory variables are trade openness, real appreciation, fiscal balance, world growth, the real oil price, and a dummy for oil exporters. World growth and the real oil price are meant to capture the effect of external (and exogenous) factors on the probability of a current account reduction.

[24] This corresponds to columns 1, 4, and 7 in tables 4.11 and 4.12.

Not surprisingly, both groups of reductions are more likely to occur in countries with higher current account surpluses (columns 3, 6, and 9). "Substantial and moderate reductions" are also more likely after periods of increase in the current account ratio (column 8). Fast-growing emerging economies are less likely to experience both groups of reductions than slow-growing emerging economies, but differences in growth among advanced economies have no significant effects on the likelihood of reductions.

Reductions are less likely in more open emerging economies. More open economies have larger exportables-producing sectors, making policies designed to shift resources toward the production of nontradables more difficult politically. Comparable evidence for advanced economies is weaker, even though there is some evidence that increasing trade openness reduces the probability of current account reductions. In both emerging and advanced countries "substantial reductions" are more likely after a deceleration in the growth of the trade balance, which may be associated with slower export growth or an acceleration in import growth. There is similar evidence for "substantial and moderate reductions" in advanced countries, but not for emerging countries.

In section 3, Obstfeld and Rogoff's theoretical model shows that real appreciations accompany reductions in the current account surplus, and figures 4.5–4.10 show that this is mostly the case in emerging countries. In the multivariate regression analysis we verify this evidence for emerging countries, finding positive coefficient estimates for one-period lagged real appreciations.[25]

"Substantial reductions" are more likely to occur in advanced countries with smaller fiscal surpluses. Because current account surpluses may be fed by increases in fiscal savings, these reductions are more likely after increases in the fiscal balance. This is a variant of the "twin deficits hypothesis," if you will. We do not find any effect of the fiscal balance on "substantial and moderate reductions."[26]

In sum, we find that large current account surpluses do not last forever: the larger the surplus, the more likely it is to eventually be wound down. This adjustment is more likely in less open economies, where political resistance is likely to be less. It is more likely in emerging market economies whose period of exceptionally high growth comes to an end, when the supply of exportables presumably begins to expand more slowly and demand is rebalanced toward domestic goods, and in these economies it is also associated with real appreciation. Finally, in advanced economies, it is more likely after reductions in budget

[25] International Monetary Fund (2010) also finds that the ending of sustained current account surpluses tends to be associated with real exchange rate appreciation, although they provide no explicit hypothesis tests.

[26] Additionally, we find no significant effect of the two external variables, world growth and real oil prices, even after controlling for the potentially different effect of oil prices on oil exporters, which does not validate our previous univariate analysis.

surpluses.

We checked the robustness of our results against outliers by removing current account reductions that may have a significant impact on the results. We reestimated all regressions twice: (1) after removing reductions with very low initial current account ratio (smaller than 0.5% of GDP) from our list of episodes,[27] and (2) after removing reductions with very large initial current account ratio (two standard deviations higher than the period average for each country).[28] All coefficient estimates keep their sign and magnitude. However, some coefficients that were previously significant at 10% become insignificant. This occurs because there are more countries and years in the sample with only zeros (i.e., no reductions), and these observations will therefore be dropped from the estimates with fixed effects.

Given the nonlinearity of the empirical model, it is difficult to interpret the coefficient estimates in terms of discrete changes. We calculate the marginal effect of each regressor using all observations in the sample and present their average values in Table 4.14.[29] As we have seen before, countries with larger surpluses have a higher likelihood of experiencing a reduction. The second, forth and sixth columns show that, for each additional percentage point increase in the current account ratio, the likelihood of a reduction increases by between 1.46 and 1.84 percentage points in emerging countries and between 1.1 and 1.2 percentage points in advanced countries. For example, the current account ratio in China in 2007 was 10.9% of GDP. The likelihood of China experiencing a reduction was, on average, 7 to 12 percentage points higher than that of Chile, the Philippines, Russia or Japan in the same year.[30]

[Include Table 4.14 here]

We can see from the fifth row of the table the magnitude of the real appreciations that accompany reductions. Each percentage point increase in the rate of real appreciation raises the likelihood of a reduction by 0.2 to 0.7 percentage points, on average. For example, the rates of appreciation of the Malaysian ringgit, the Philippine peso, and the Chinese yuan in 2006 increased between 3 and 4 percentage points. This corresponds to a 1 to 3 percentage point higher likelihood of a significant reduction in their current account surpluses.

[27] This corresponds to 3 episodes picked up by EP1 (1 from the emerging country subsample and 2 from the advanced country subsample) and 12 episodes picked up by EP3 (4 from the emerging country subsample and 8 from the advanced country subsample).

[28] This corresponds to 4 episodes picked up by EP1 (all from the emerging country subsample), 7 episodes picked up by EP2 (all from the emerging country subsample), and 7 episodes picked up by EP3 (6 from the emerging country subsample and 1 from the advanced country subsample).

[29] Notice that this is different than looking at the marginal effects at the average of all regressors or at some other point in the space of regressors.

[30] In 2007, the current account ratio in Chile was 4.4%, in the Philippines 4.9%, in Russia 6%, and in Japan 4.8%.

Because the marginal effect of a specific regressor depends on the values of other regressors, we ask, in Figure 4.11, how this response varies with the level of other regressors. We focus on the emerging country subsample. We can see from the first four graphs that faster currency appreciation increases the marginal effect of changes in the current account ratio and of accelerations in appreciation itself. For "substantial reductions," the marginal effect of changes in the current account is significantly different from zero when real appreciation is strong (between 10 and 28 percent) and for "substantial and moderate reductions" even when appreciation is weak. For both groups of reductions, the marginal effect of accelerations in real appreciation is significantly different from zero for levels of currency appreciation below 15 percent.

[Include Figure 4.11 here]

The remaining four graphs show that output growth has a different impact on the marginal effect of these variables on the likelihood of "substantial reductions" and the likelihood of "substantial and moderate reductions." For the former, the response to changes in the current account ratio is significantly different from zero when countries grow between 5 and 10 percent and remains stable at around 0.05 in this interval. The response to faster real appreciation increases with the rate of growth and is significantly different from zero when growth is between zero and 5 percent. By contrast, the response to changes in the current account ratio and to accelerations in real appreciation increases with reductions in domestic growth. It is significantly different than zero when growth is between -5 and 7 percent.

In sum, higher rates of currency appreciation increase the impact of other determinants, such as the current account ratio and real appreciation itself, on the likelihood of reductions. Slower growth increases the impact of these determinants on the likelihood of "substantial and moderate reductions" but not on the likelihood of "substantial reductions."

5 Conclusion

Economists disagree about the role of the exchange rate in the process of global rebalancing. Some argue that the imbalances problem is fundamentally an imbalance between saving and investment in the U.S. and a mirror-image imbalance in China, and that since there is no reason to think that a change in the exchange rate should have a first-order impact on saving or investment there is no reason to advocate a Chinese revaluation/dollar devaluation as part of the rebalancing process.[31] Others insist, to the contrary, that exchange rate adjustments are indispensable to rebalancing. The resulting controversy has been a source of confusion.

[31] Examples of this point of view include Laurenceson and Qin (2005) and McKinnon and Schnabl (2006).

That confusion has not aided the adoption of policies conducive to rebalancing. Looking forward, there is the danger that it may continue to disrupt efforts to put in place the policies needed for a sustainable resolution of imbalances.

In this paper we have attempted to reduce the confusion by making some simple points and drawing out their implications. First, the exchange rate is not a primitive. The exchange rate is an endogenously-determined relative price that adjusts to clear markets in response to shocks. In thinking about global rebalancing, it is more productive to think in terms of primitives: what is the shock in response to which rebalancing must occur (an increase in Chinese spending, a reduction in U.S. spending, something else)? What are the behavioral parameters that shape the impact of the shock on prices and quantities? Given assumptions about these primitives, it is then possible to ask whether and by how much the exchange rate must adjust. Where the debate over global imbalances has gone wrong is by focusing on the exchange rate, which is better thought of as one of a number of endogenous relative prices that must adjust in response to policy initiatives or other events precipitating the rebalancing process. The simulation exercises undertaken in this paper underscore this point.

The empirical literature, for its part, tends to forget that it takes two to tango. The literature on large current account deficits has been used to ask: are circumstances in the U.S. such that we can now expect a persistent fall in the deficit? But for a large economy like the U.S., this question makes sense only if one also asks: are circumstances in other countries now such that we can expect a persistent fall in the surplus? Is this the case in a sufficient number of other countries to match the adjustment in the United States? In this paper we have added an analysis of the second set of dance partners in an effort to gain a better sense of the overall choreography.

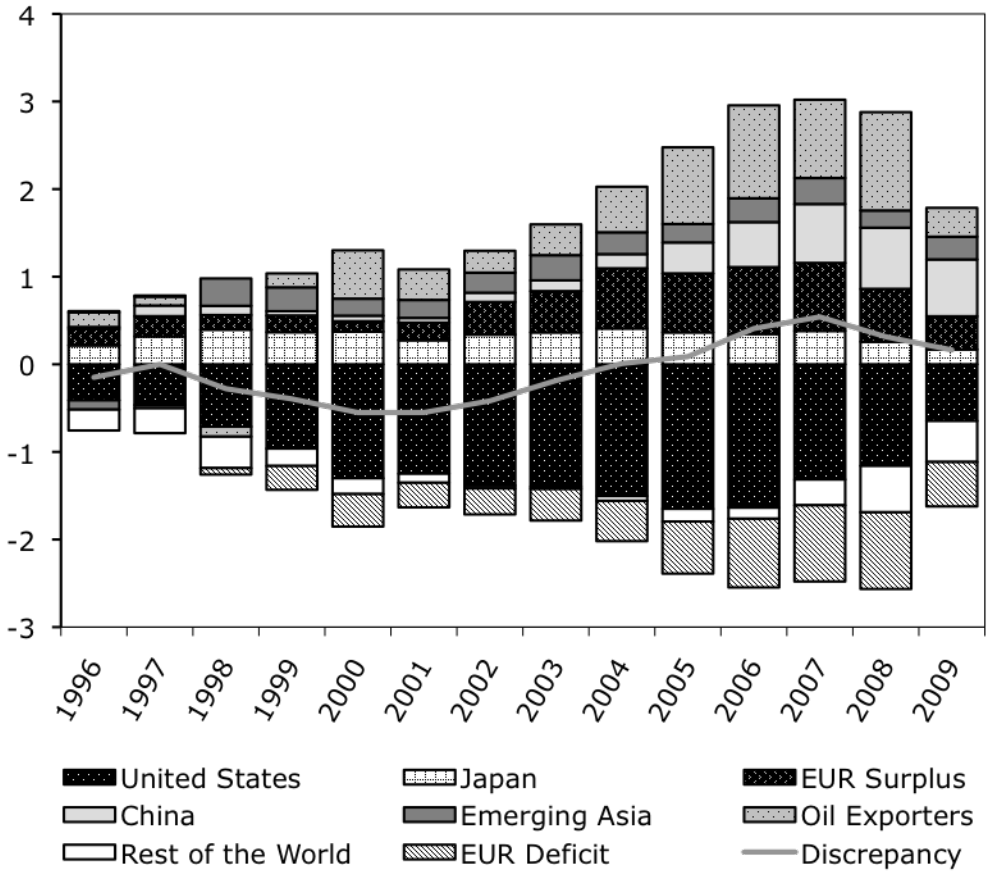
We find that large current account surpluses tend to come to an end when they have been allowed to rise previously to exceptionally high levels, when the economy doing the reducing is less open (reducing political resistance to resource reallocation), when an earlier period of rapid growth comes to an end (presumably both moderating the rate of growth of the capacity to produce tradables and some rebalancing toward domestic goods), and in the case of oil-exporting emerging markets when the price of oil is unusually low. While our data on government budgets are more limited, what we have suggest that smaller budget surpluses can also help to bring large current account surpluses to an end.

Potentially, some of these patterns bode well for reductions in China's large current account surplus. That surplus has risen to extraordinary high levels, something that the cross-country evidence suggests is unlikely to continue forever. Both domestic and foreign pressures make some reduction of the country's extraordinarily large surpluses likely. That Chinese economic growth will decelerate with more spending on social programs and with the country's demographic transition similarly augers the likelihood of some reduction in its

current account surplus. Similarly, that China has been ramping up social spending, and government spending in general, points in a helpful direction. On the other hand, the fact that the Chinese economy is so open, making output and employment growth dependent on exports, is likely to create political resistance to adjustment.

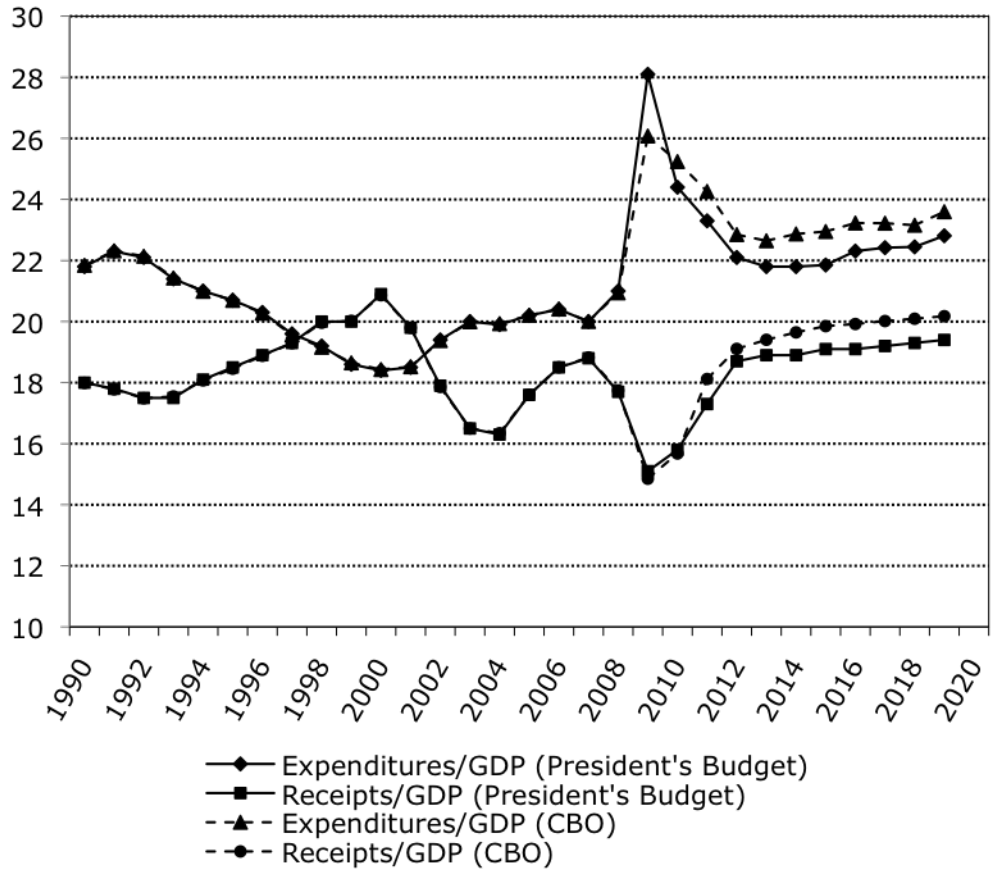
All this underscores the fact that the requisite adjustments are not guaranteed. They are unlikely to occur automatically. Appropriate policy action would greatly increase the likelihood that countries on the surplus side of global imbalances contribute constructively to global rebalancing.

Figure 4.1: Global imbalances (percent of global GDP)



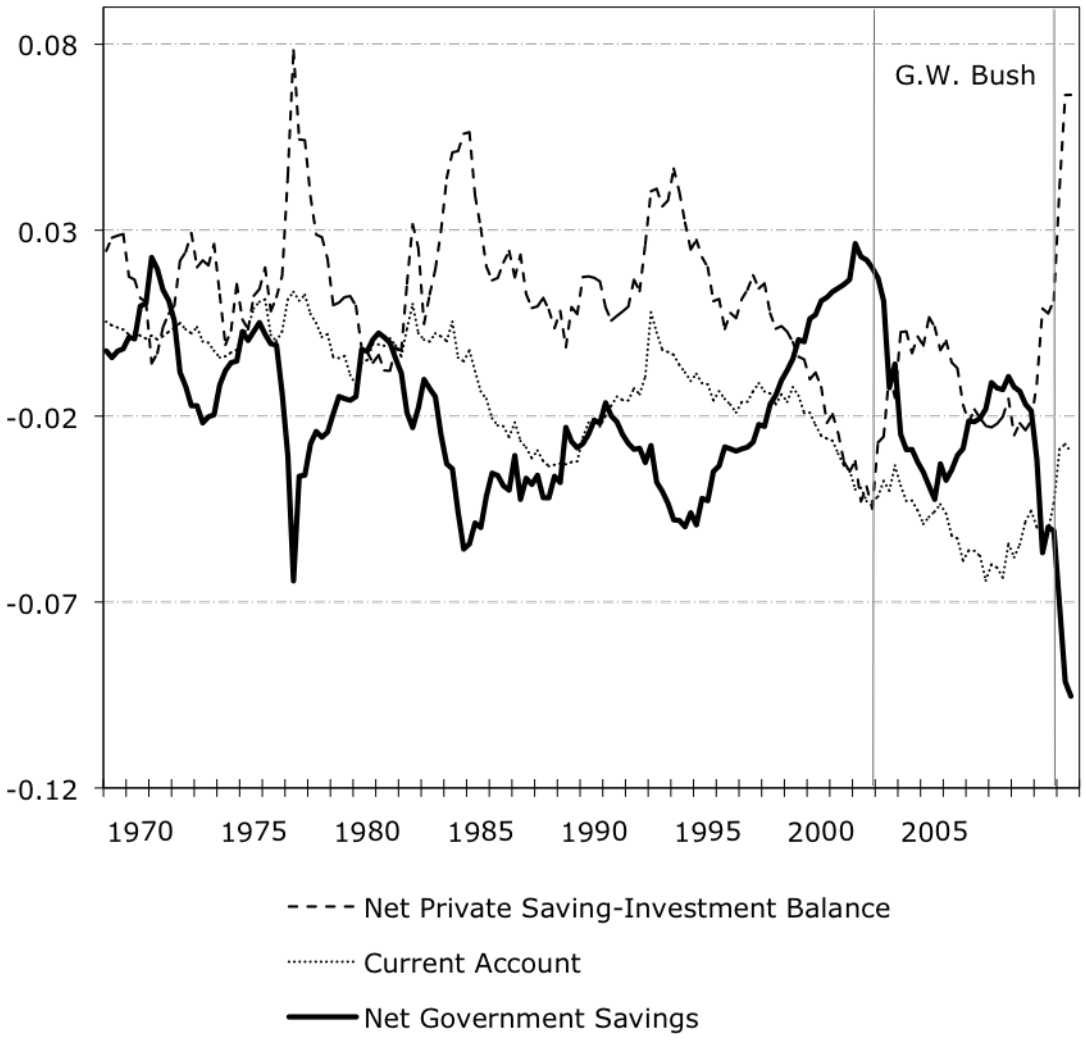
Source: World Economic Outlook, October 2009

Figure 4.2: Federal expenditures and revenues (percent of GDP)



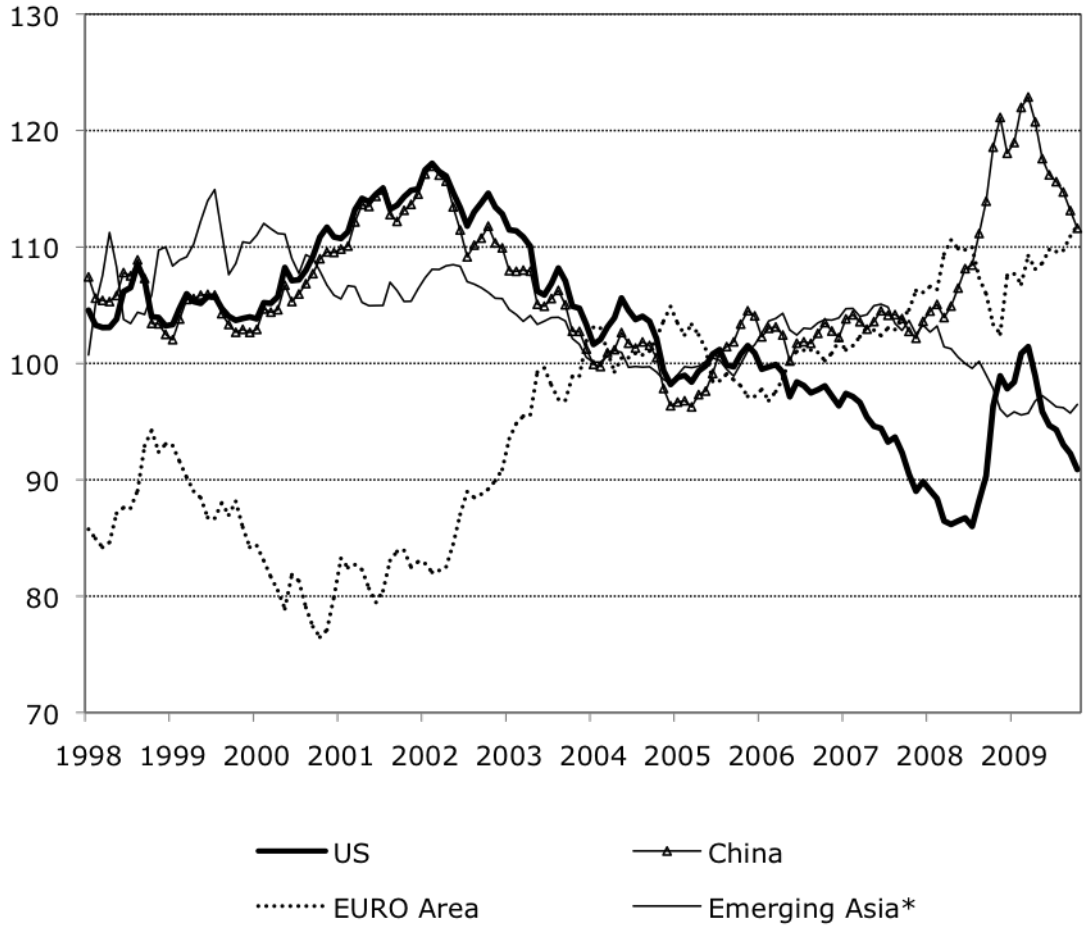
Sources: Office of Management and Budget (White House) and Congressional Budget Office

Figure 4.3: U.S. savings and investment (normalized by nominal GDP)



Source: Bureau of Economic Analysis

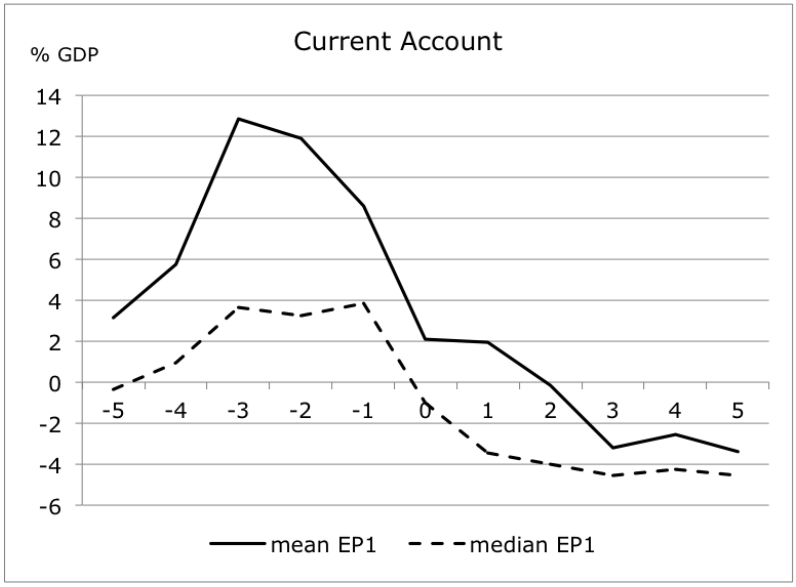
Figure 4.4: Effective exchange rate, 2005=100 (broad index, monthly averages)



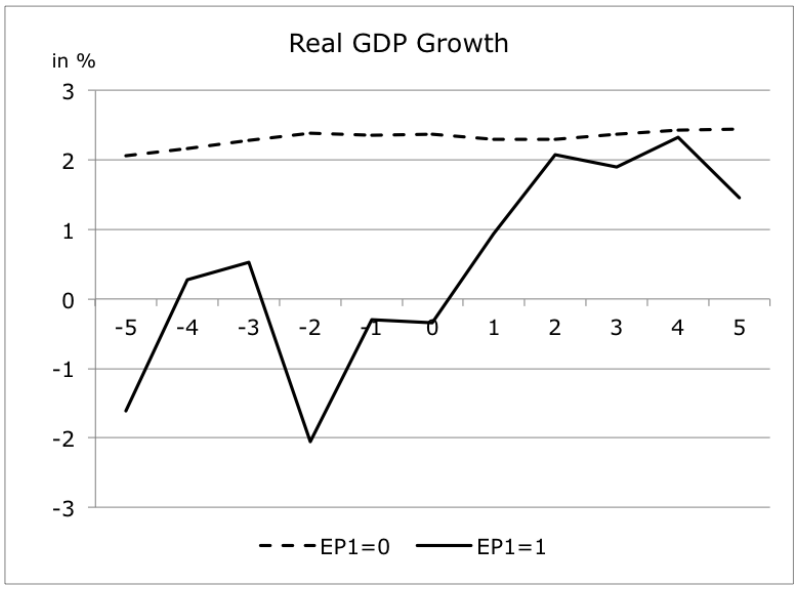
Source: Bank of International Settlements

* Hong Kong, Indonesia, Korea, Malaysia, Philippines, Singapore, Taiwan and Thailand

Figure 4.5: Dynamics of key variables before and after substantial reductions in current account surpluses (EP1), Emerging countries

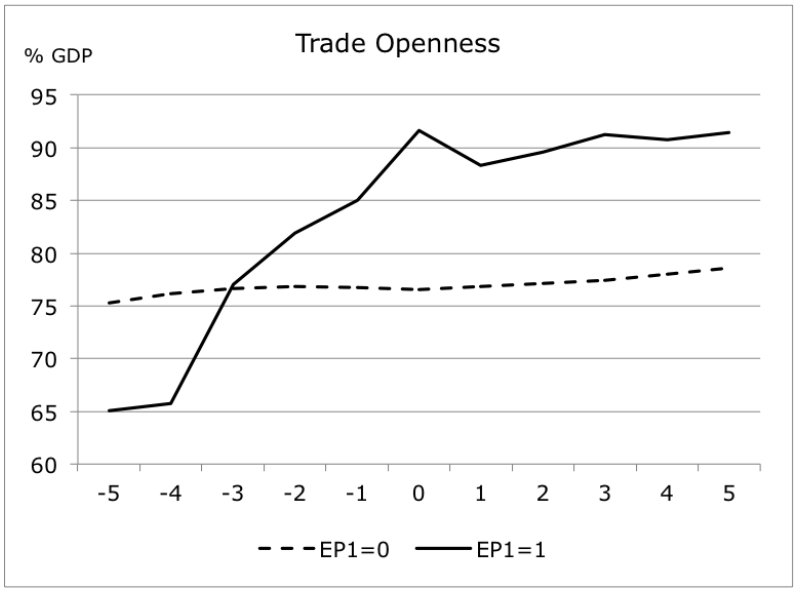


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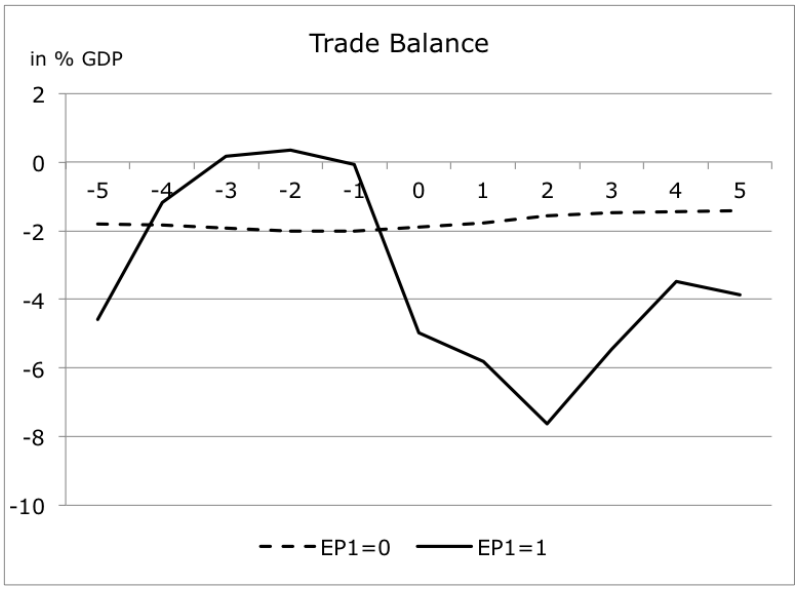


(b)

Figure 4.5: Dynamics of key variables before and after substantial reductions in current account surpluses (EP1), Emerging countries (cont.)

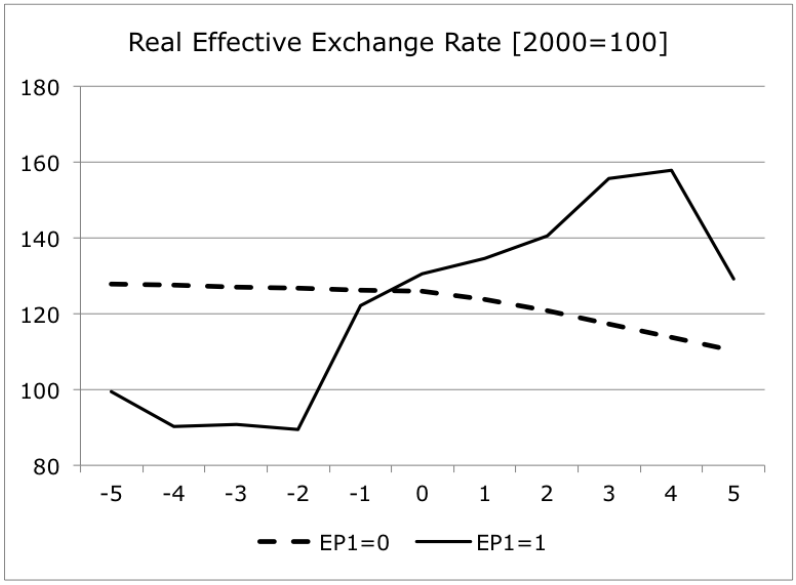


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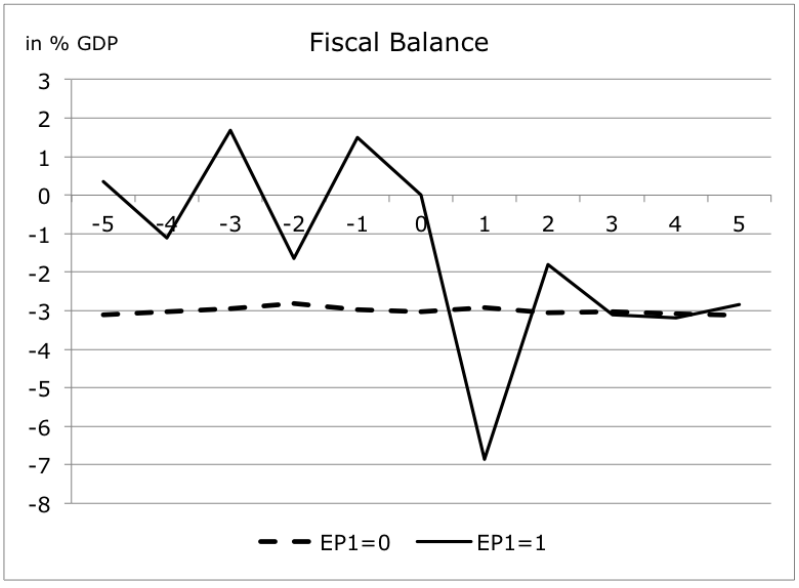


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Figure 4.5: Dynamics of key variables before and after substantial reductions in current account surpluses (EP1), Emerging countries (cont.)

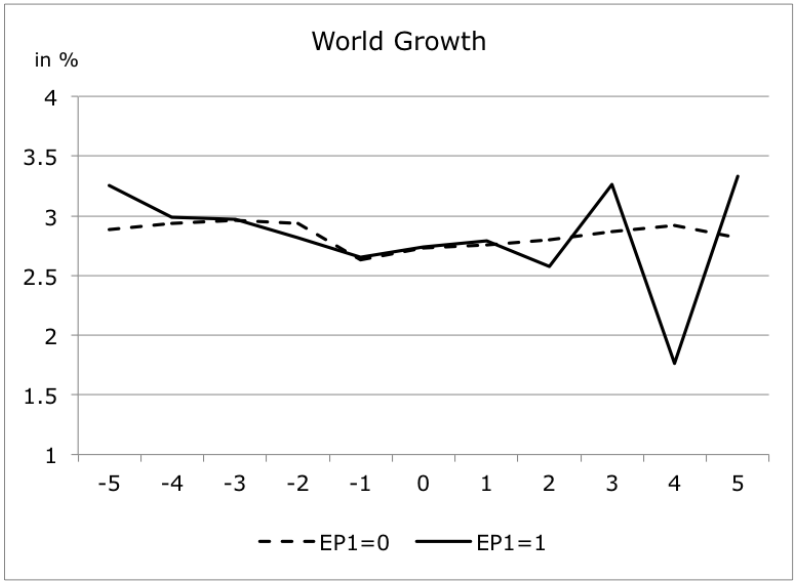


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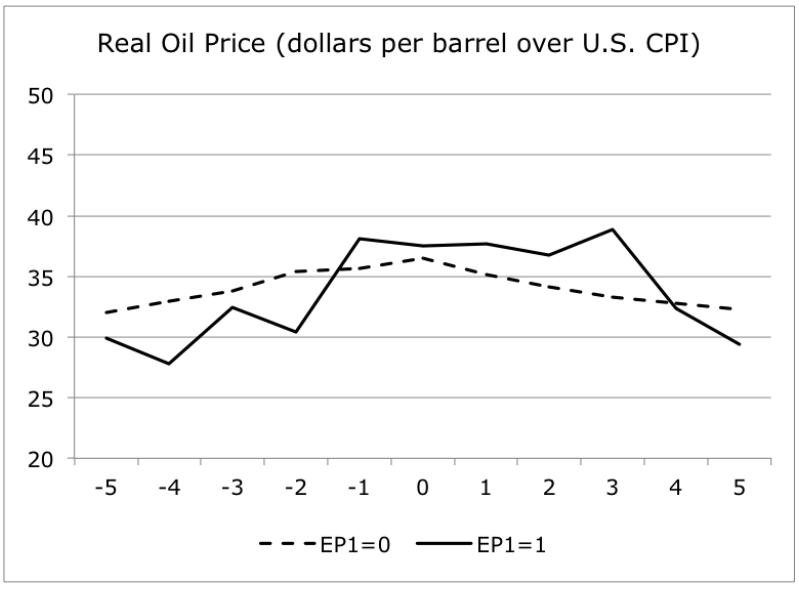


(b)

Figure 4.5: Dynamics of key variables before and after substantial reductions in current account surpluses (EP1), Emerging countries (cont.)

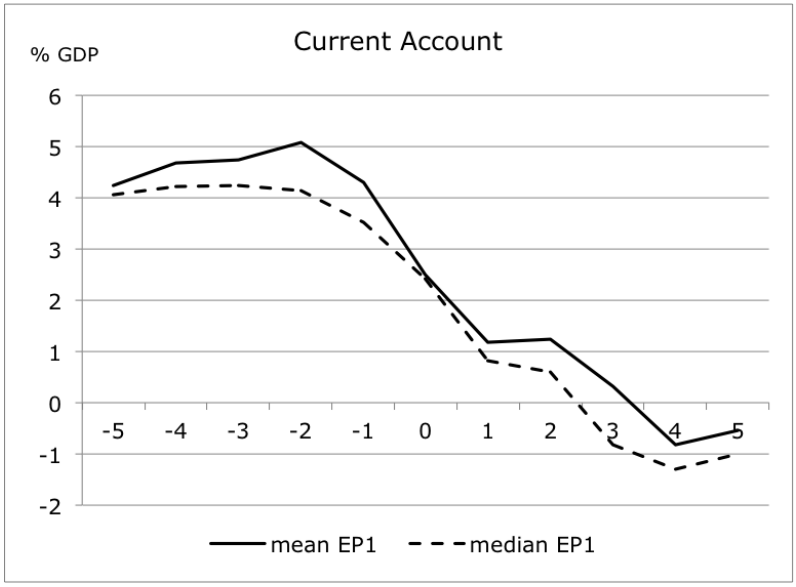


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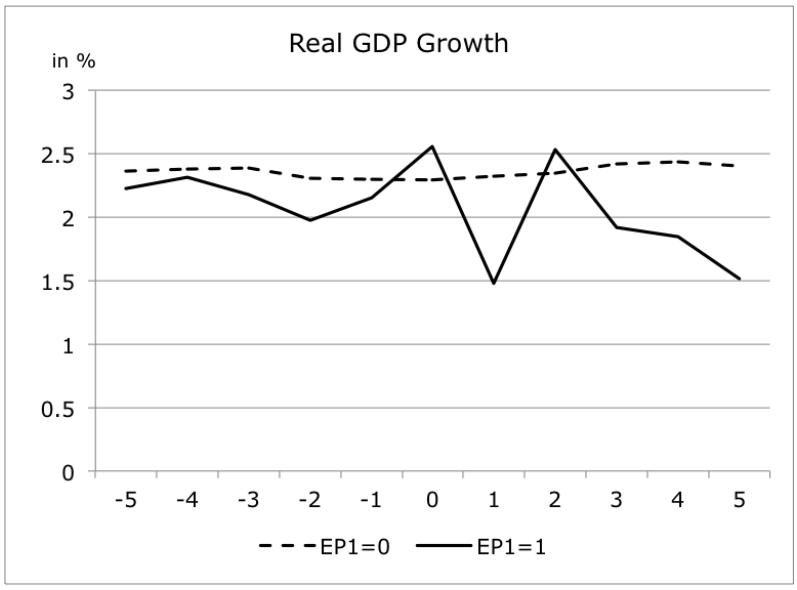


(b)

Figure 4.6: Dynamics of key variables before and after substantial reductions in current account surpluses (EP1), Advanced countries

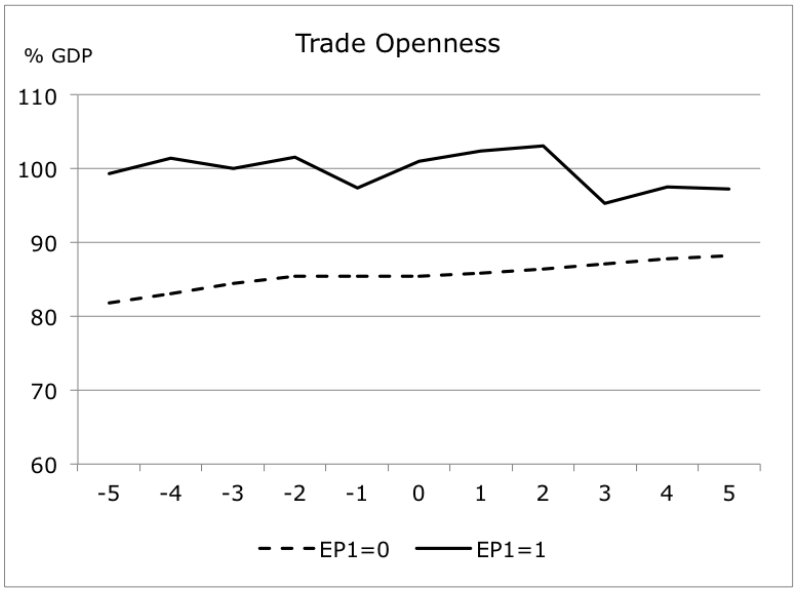


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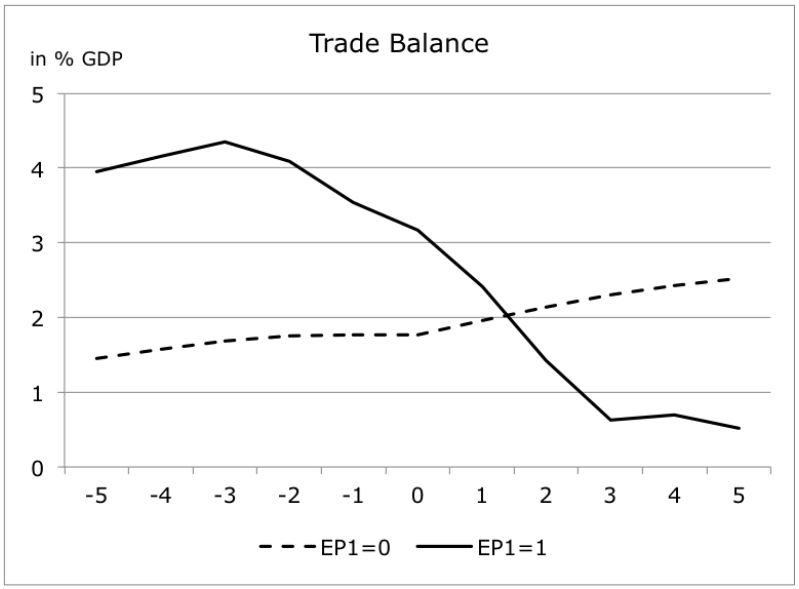


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Figure 4.6: Dynamics of key variables before and after substantial reductions in current account surpluses (EP1), Advanced countries (cont.)

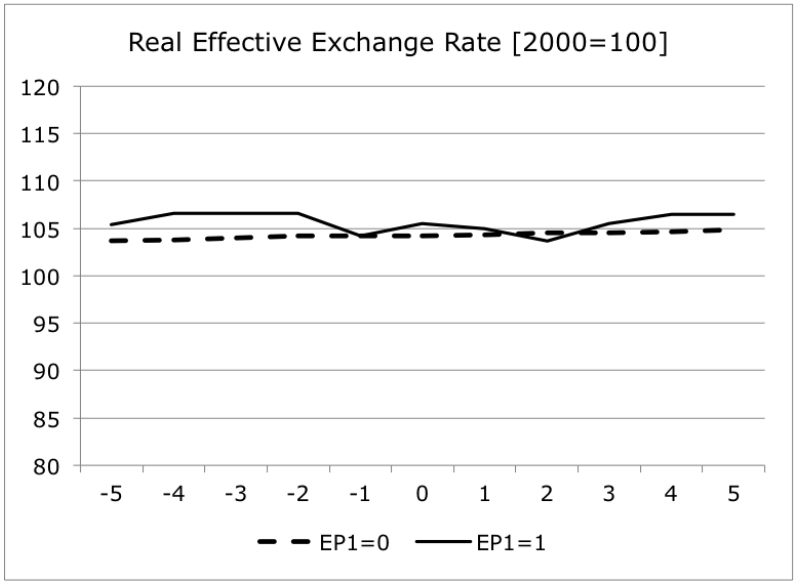


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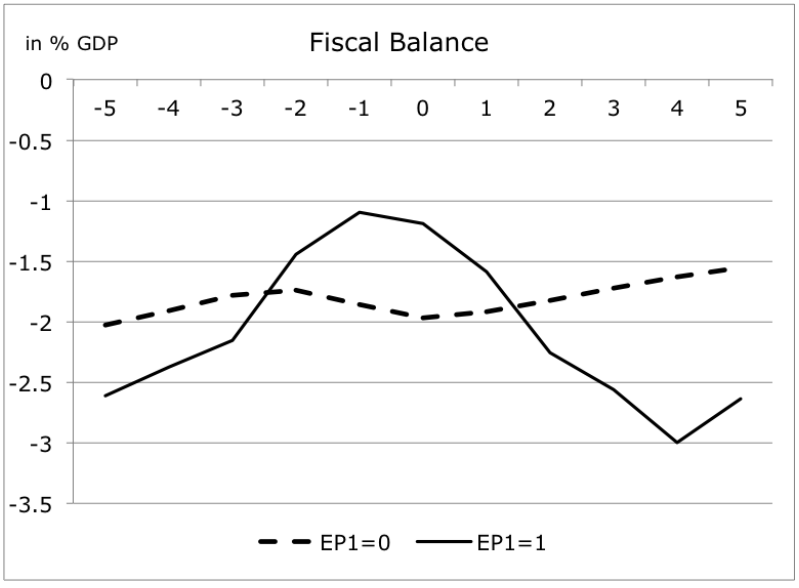


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Figure 4.6: Dynamics of key variables before and after substantial reductions in current account surpluses (EP1), Advanced countries (cont.)

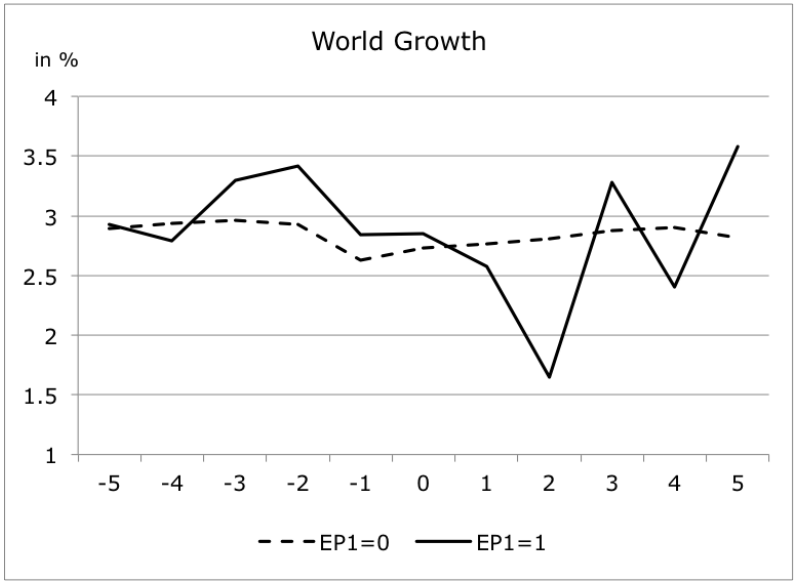


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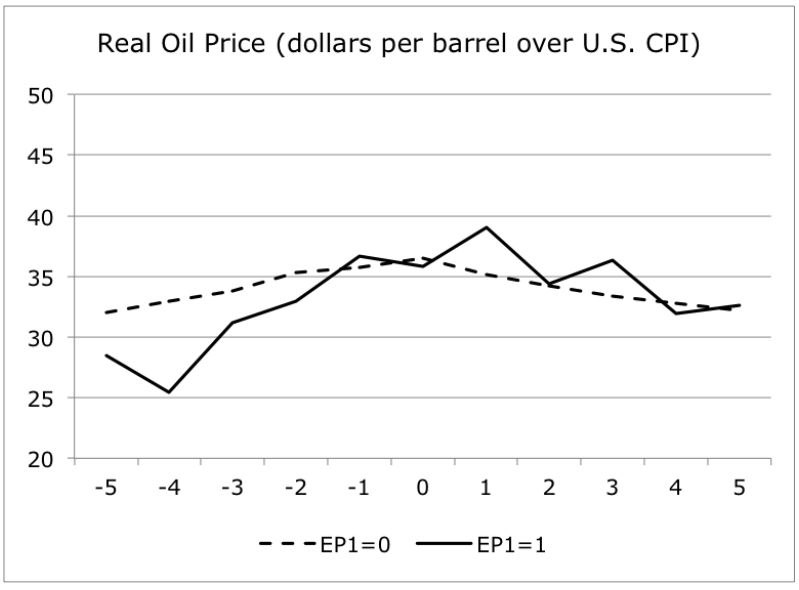


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Figure 4.6: Dynamics of key variables before and after substantial reductions in current account surpluses (EP1), Advanced countries (cont.)

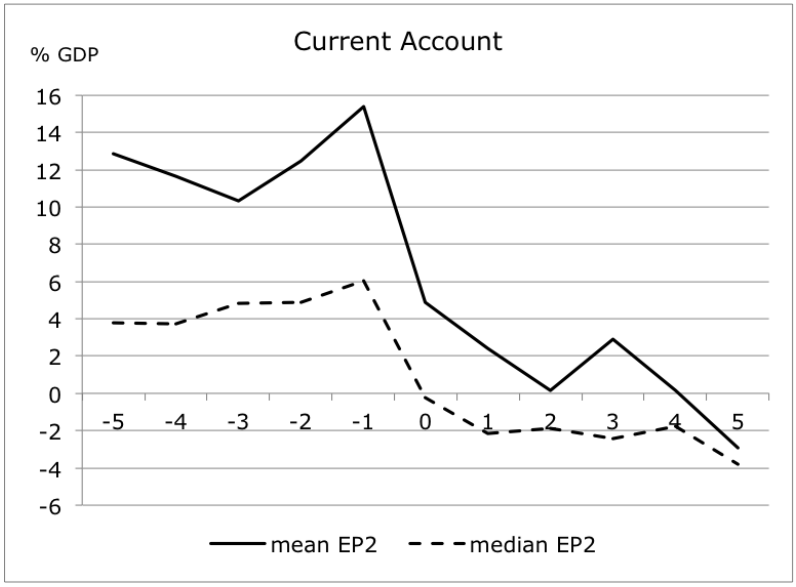


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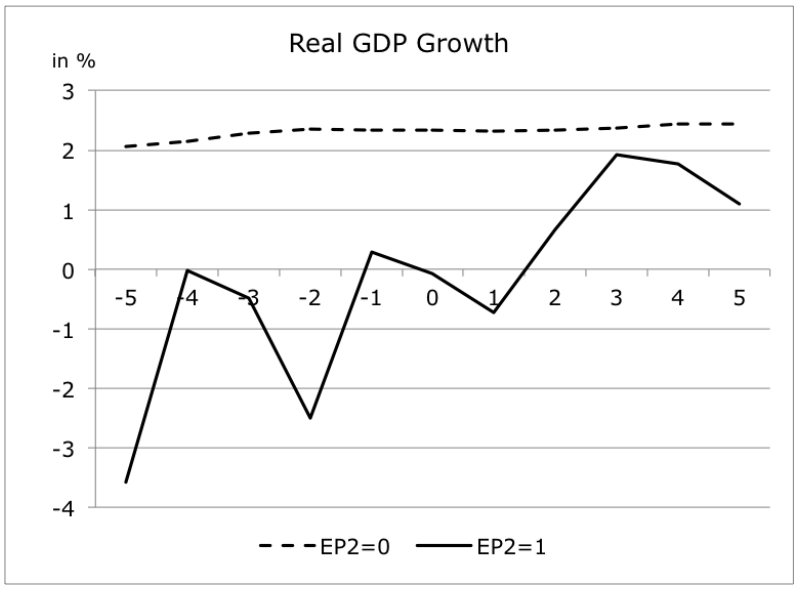


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Figure 4.7: Dynamics of key variables before and after substantial reductions in current account surpluses (EP2), Emerging countries

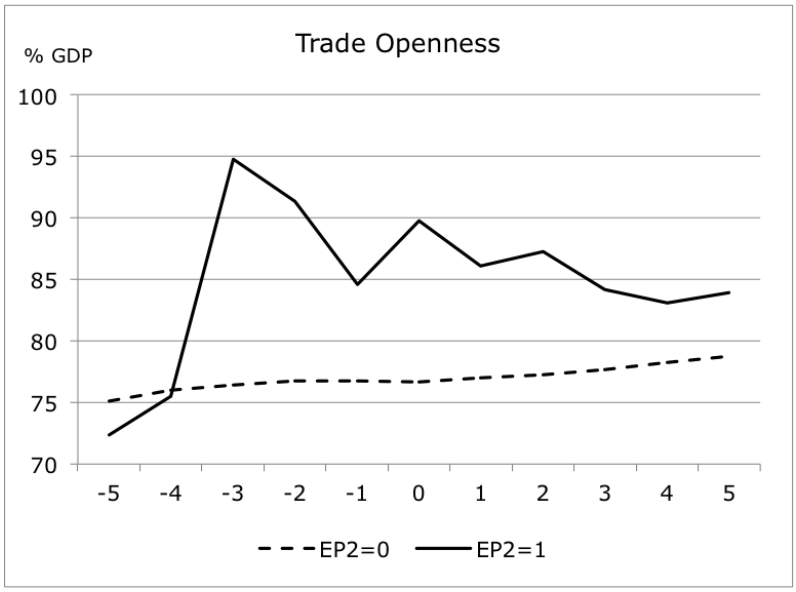


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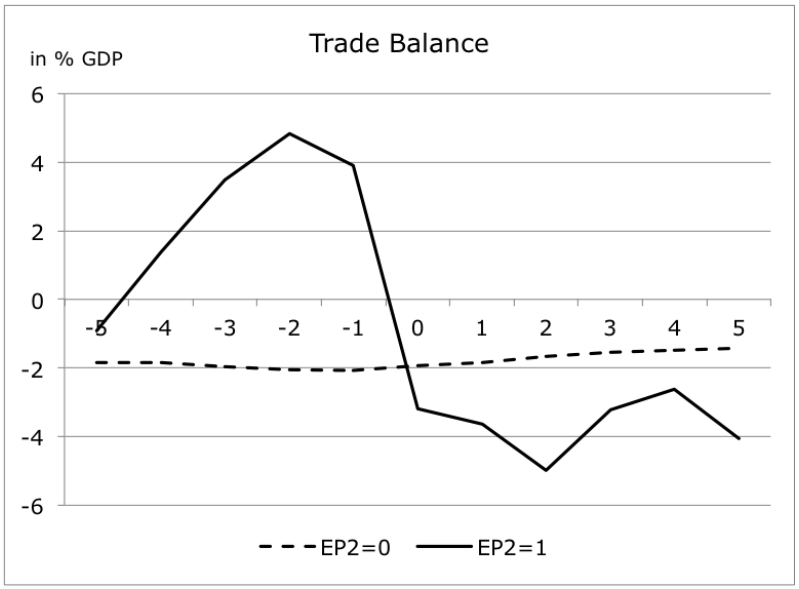


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Figure 4.7: Dynamics of key variables before and after substantial reductions in current account surpluses (EP2), Emerging countries (cont.)

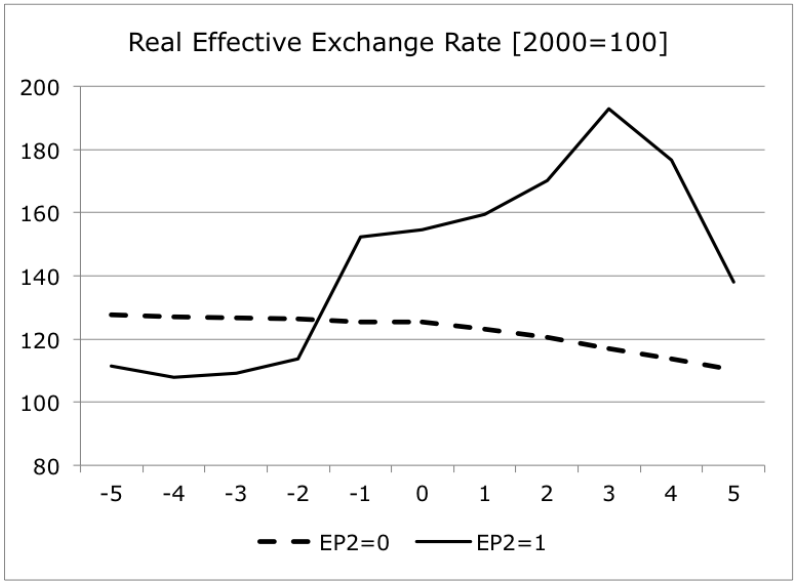


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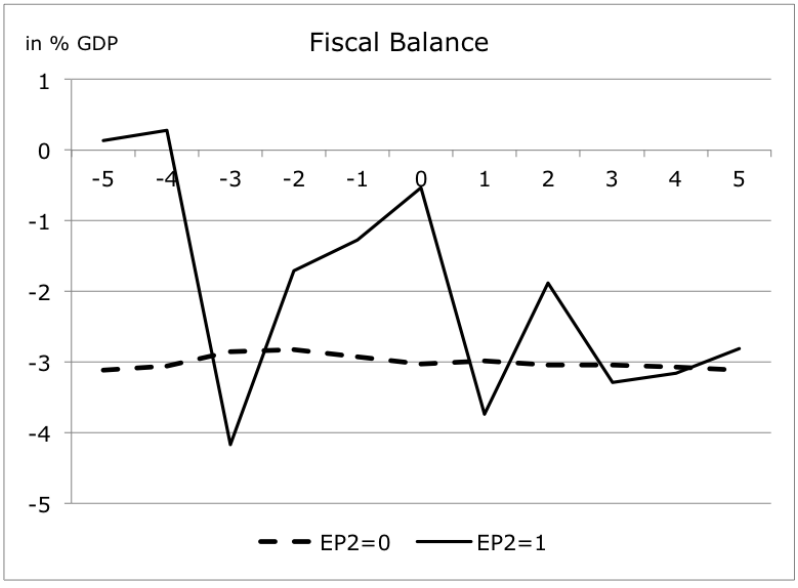


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Figure 4.7: Dynamics of key variables before and after substantial reductions in current account surpluses (EP2), Emerging countries (cont.)

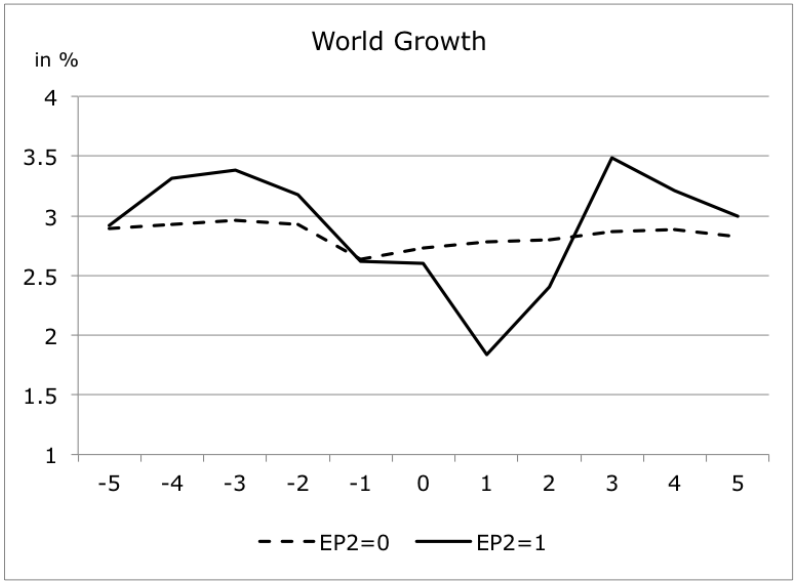


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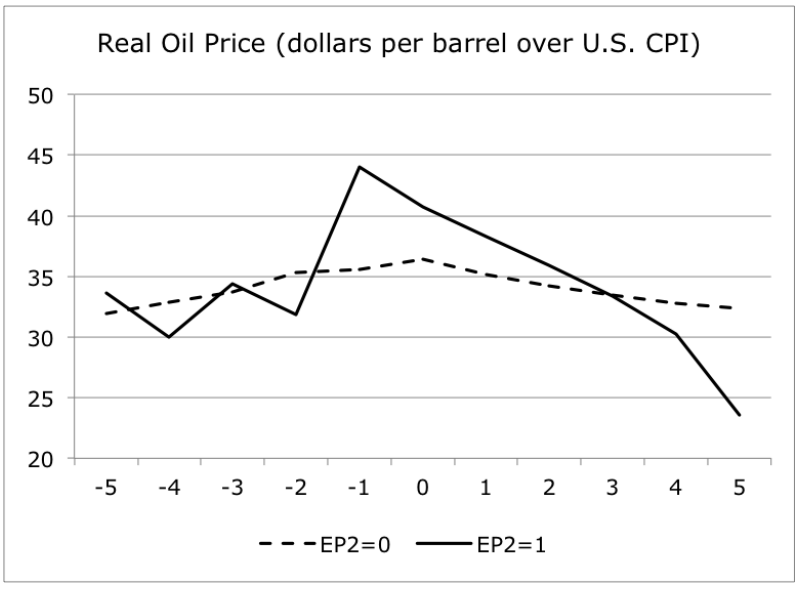


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Figure 4.7: Dynamics of key variables before and after substantial reductions in current account surpluses (EP2), Emerging countries (cont.)

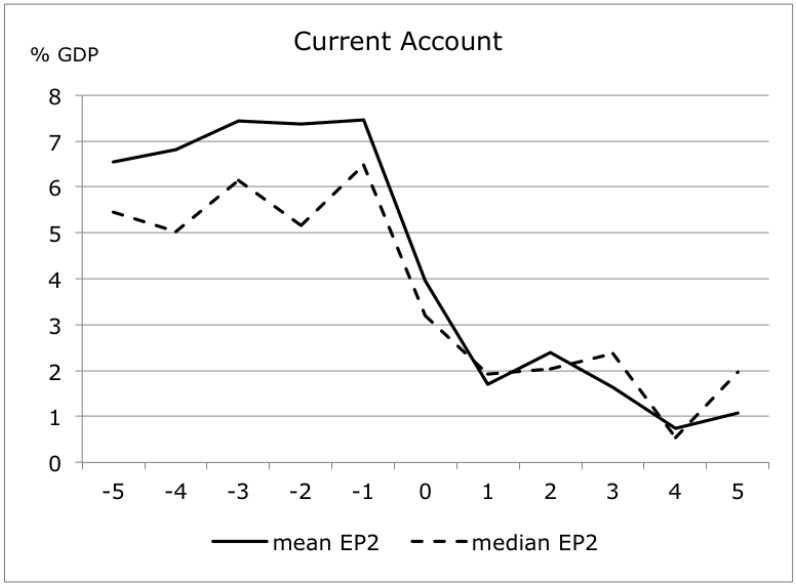


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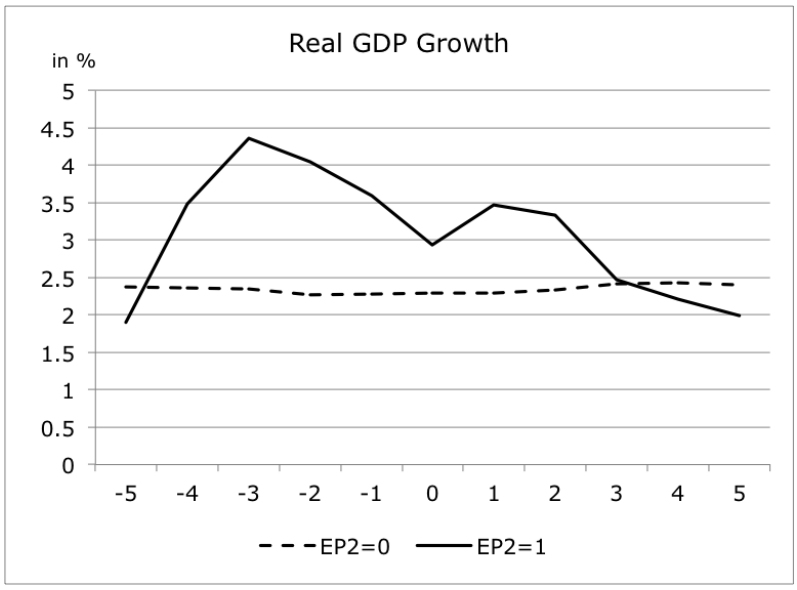


(b)

Figure 4.8: Dynamics of key variables before and after substantial reductions in current account surpluses (EP2), Advanced countries

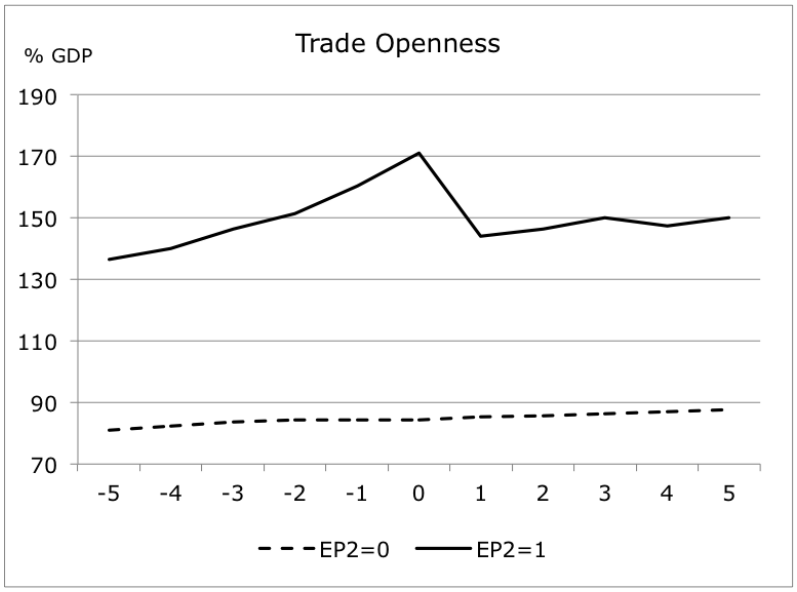


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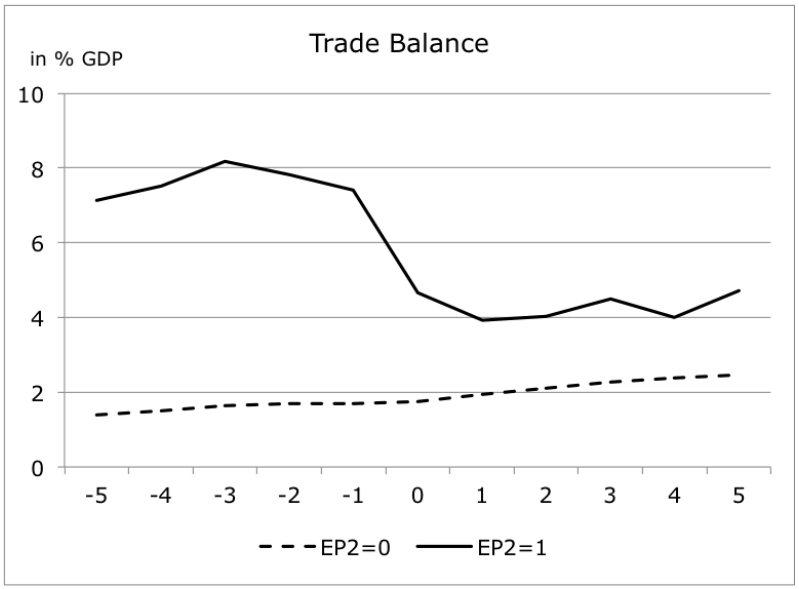


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Figure 4.8: Dynamics of key variables before and after substantial reductions in current account surpluses (EP2), Advanced countries (cont.)

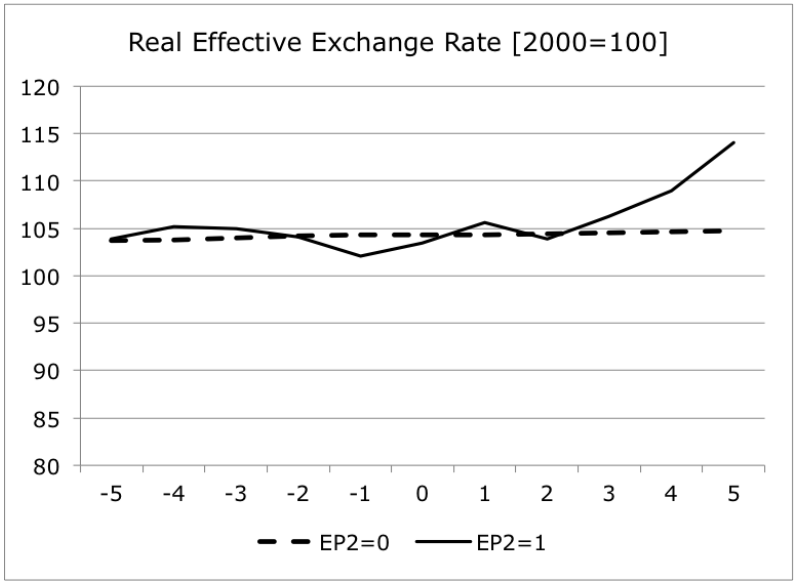


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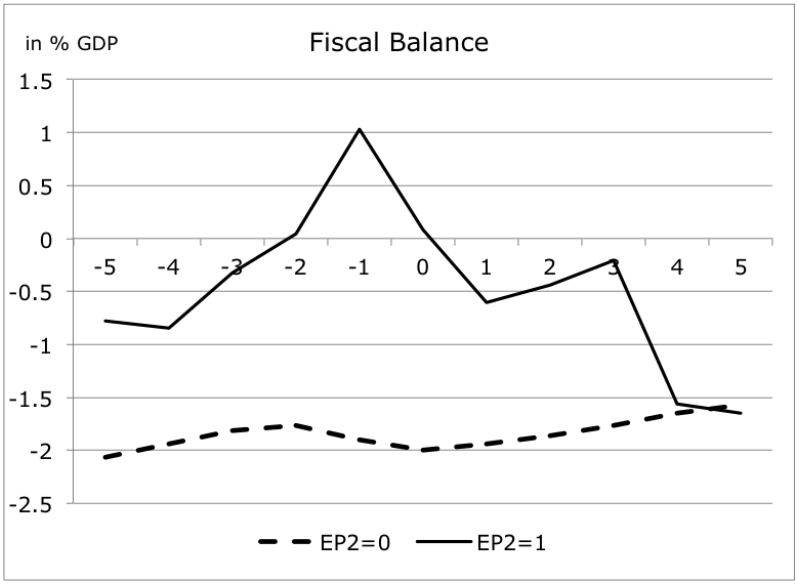


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Figure 4.8: Dynamics of key variables before and after substantial reductions in current account surpluses (EP2), Advanced countries (cont.)

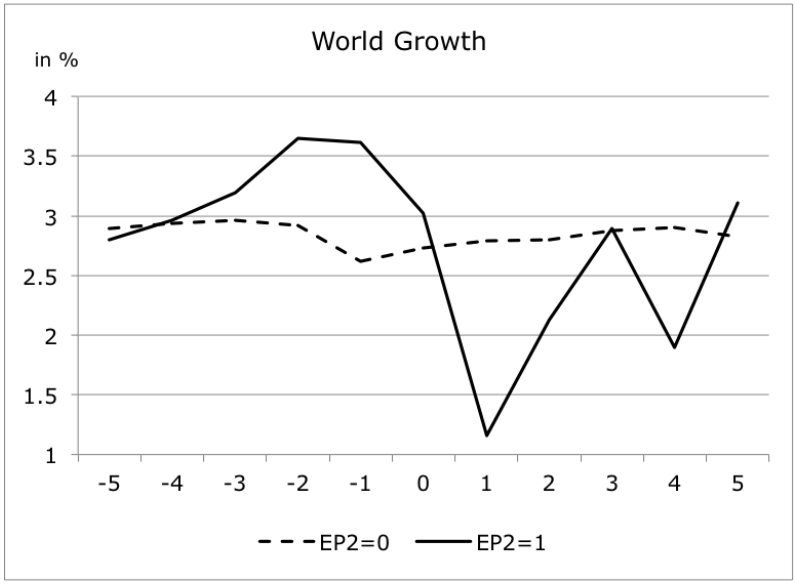


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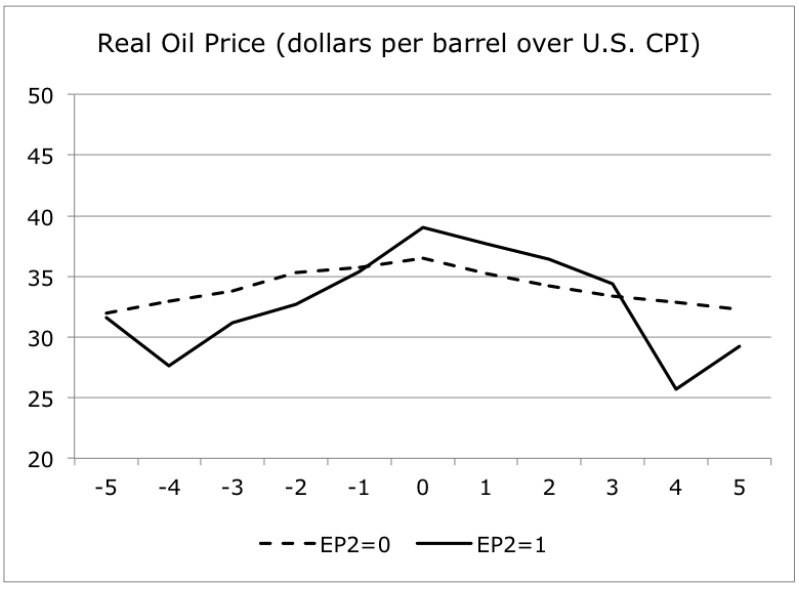


(b)

Figure 4.8: Dynamics of key variables before and after substantial reductions in current account surpluses (EP2), Advanced countries (cont.)

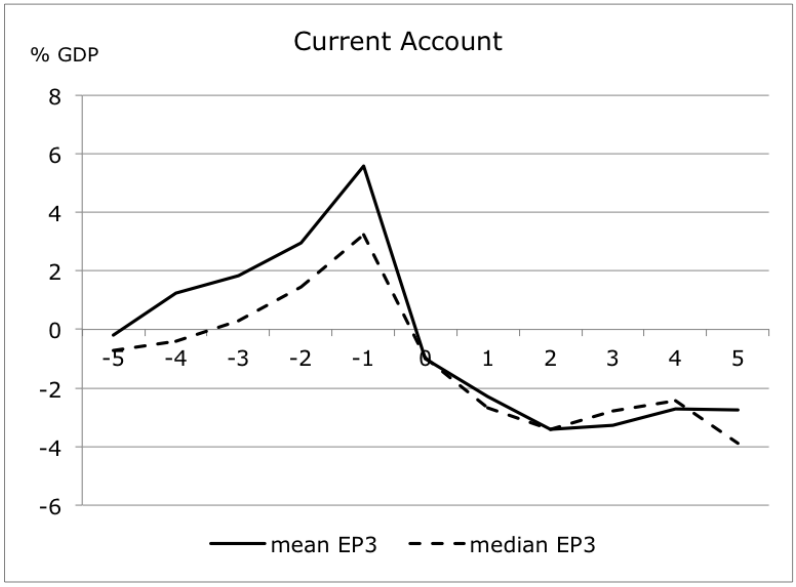


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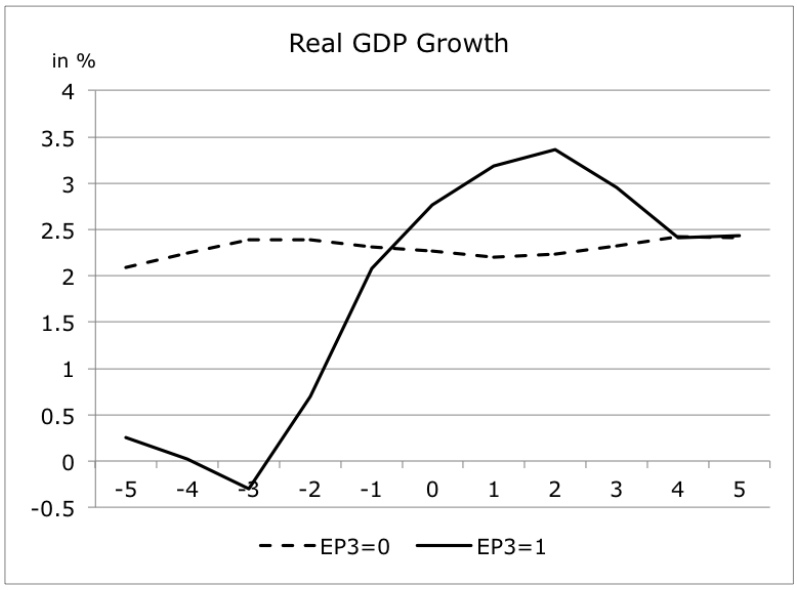


(b)

Figure 4.9: Dynamics of key variables before and after substantial and moderate reductions in current account surpluses (EP3), Emerging countries

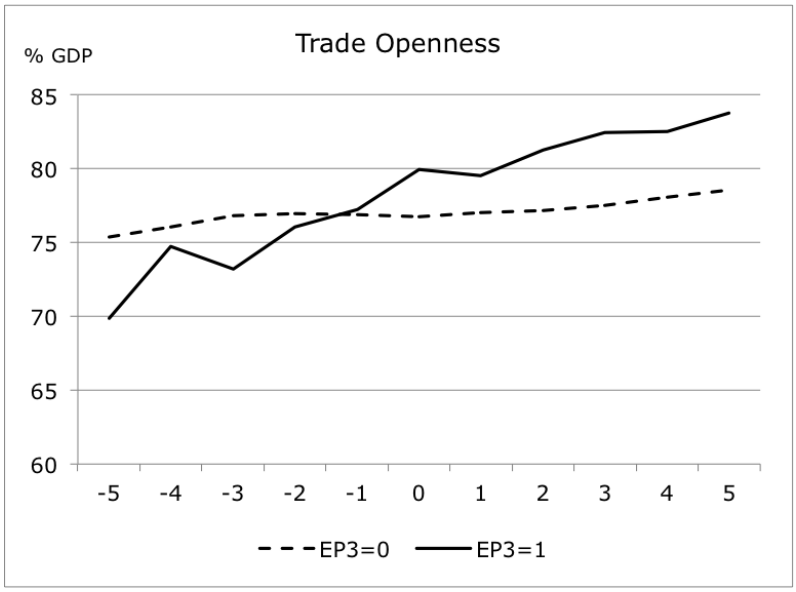


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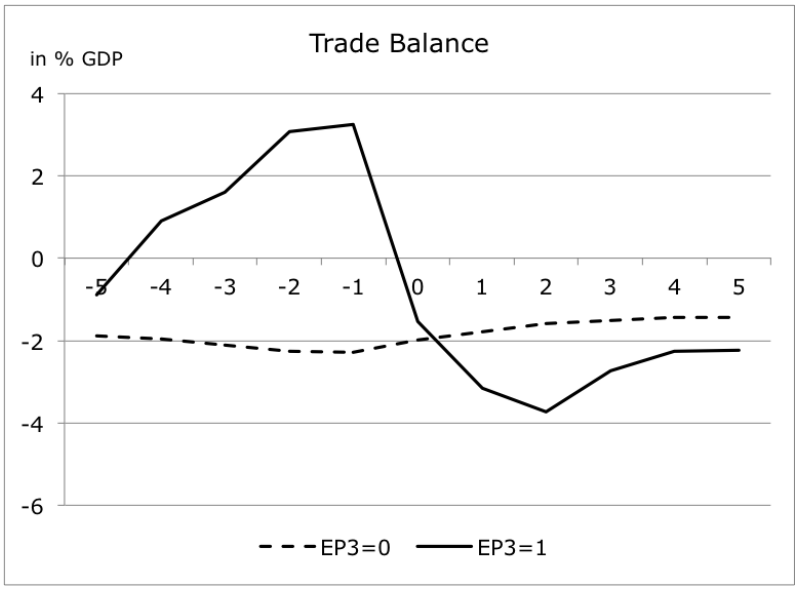


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Figure 4.9: Dynamics of key variables before and after substantial reductions in current account surpluses (EP3), Emerging countries (cont.)

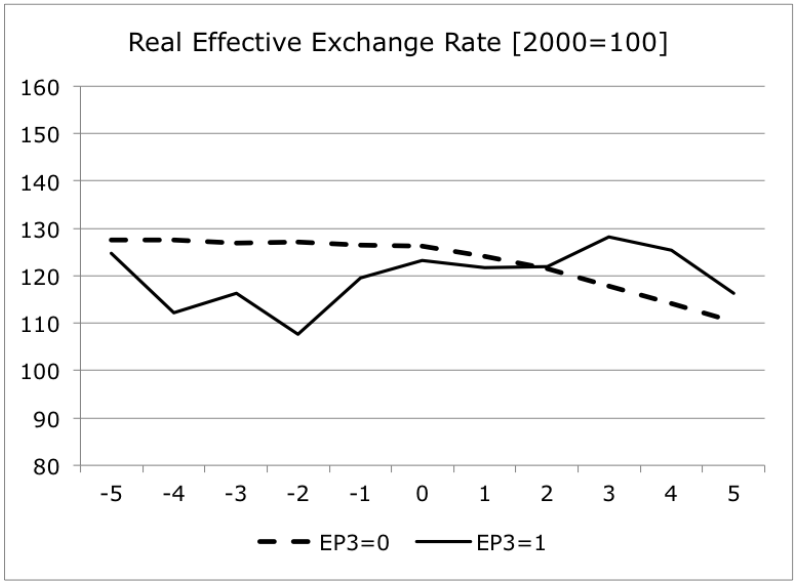


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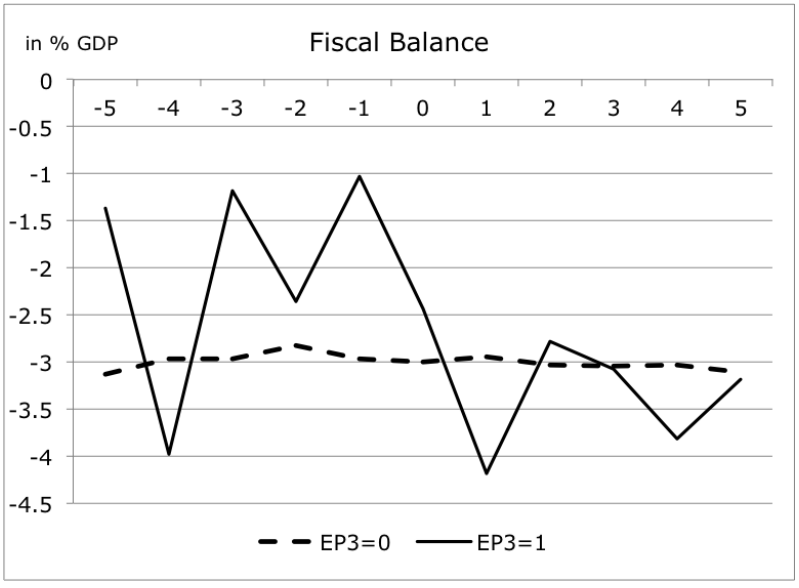


(b)

Figure 4.9: Dynamics of key variables before and after substantial reductions in current account surpluses (EP3), Emerging countries (cont.)

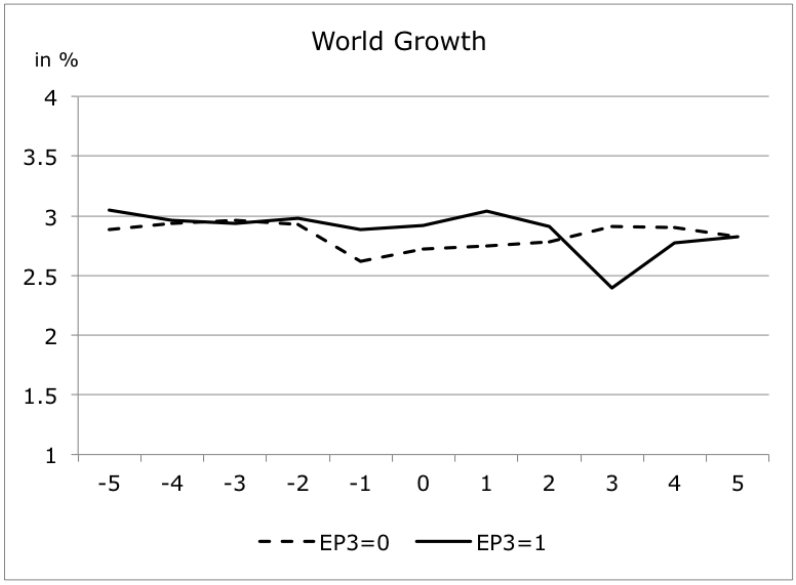


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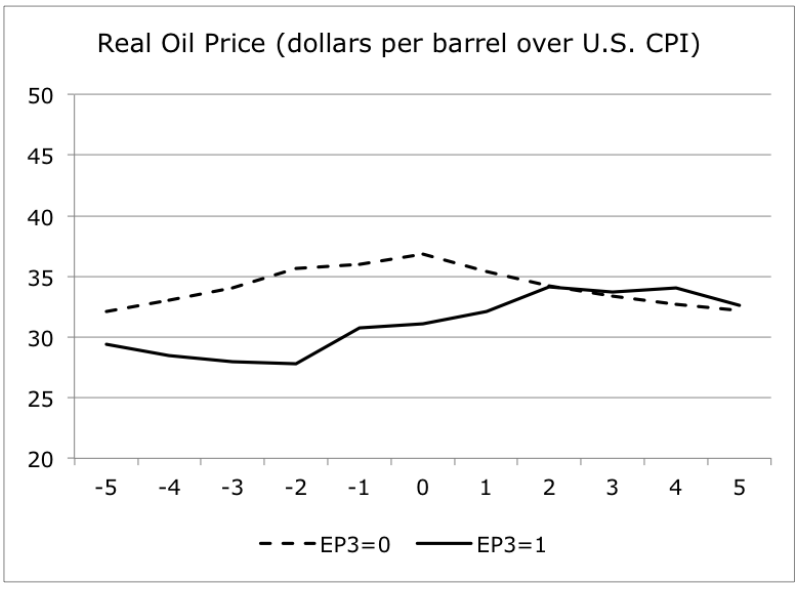


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Figure 4.9: Dynamics of key variables before and after substantial reductions in current account surpluses (EP3), Emerging countries (cont.)

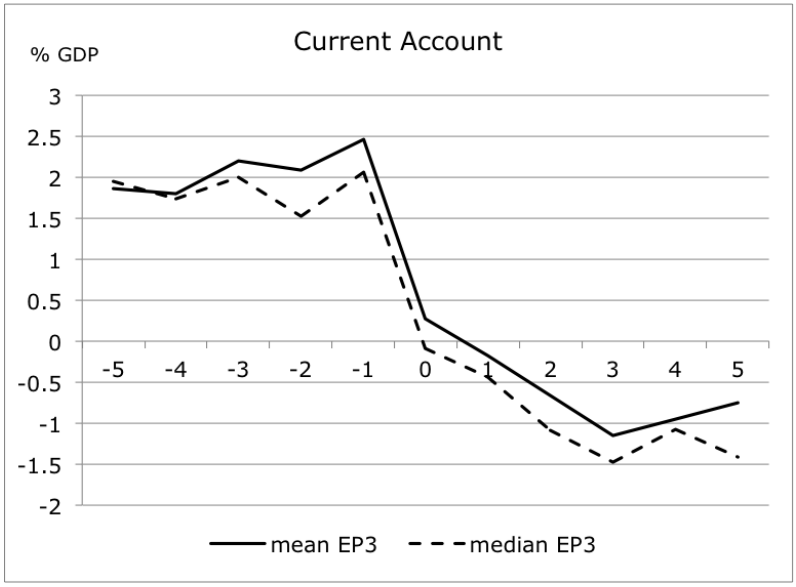


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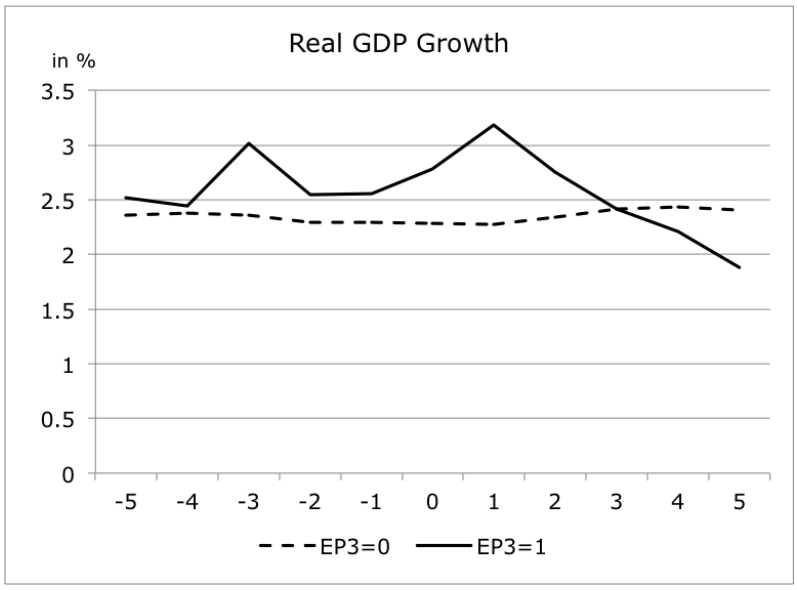


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Figure 4.10: Dynamics of key variables before and after substantial and moderate reductions in current account surpluses (EP3), Advanced countries

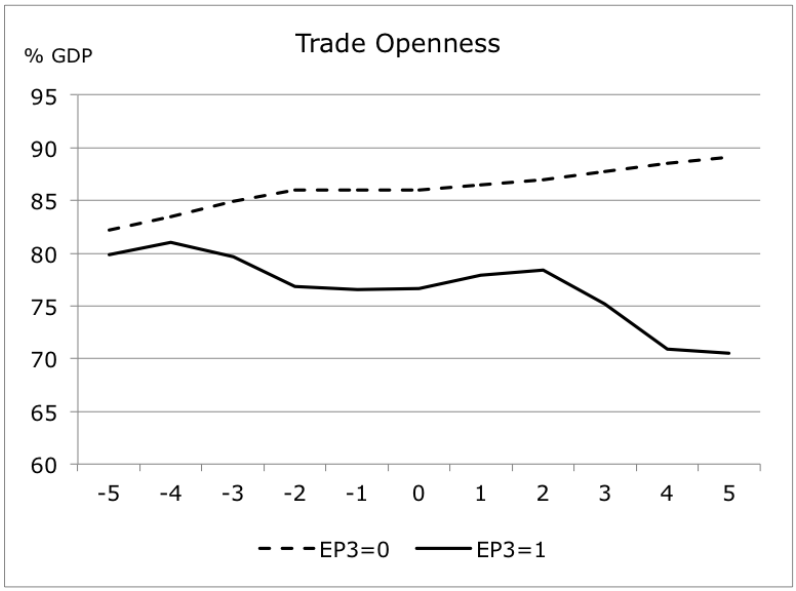


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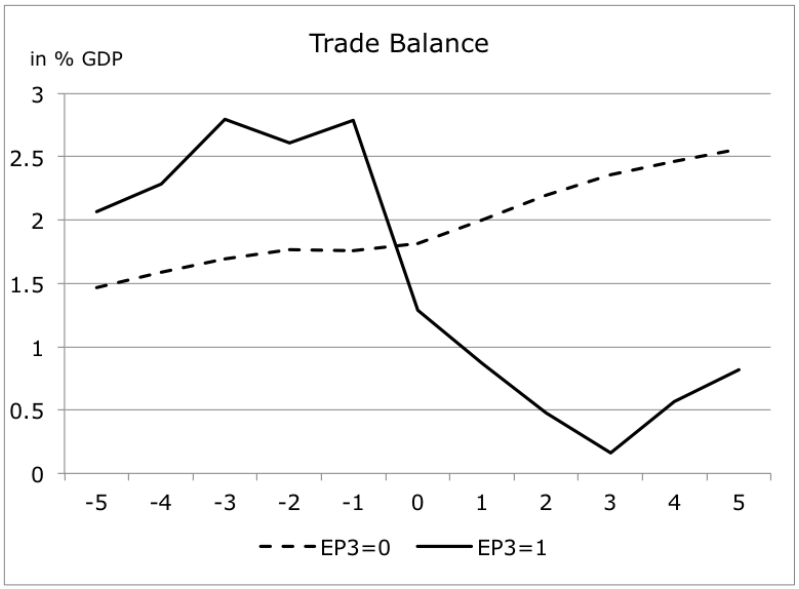


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Figure 4.10: Dynamics of key variables before and after substantial reductions in current account surpluses (EP3), Advanced countries (cont.)

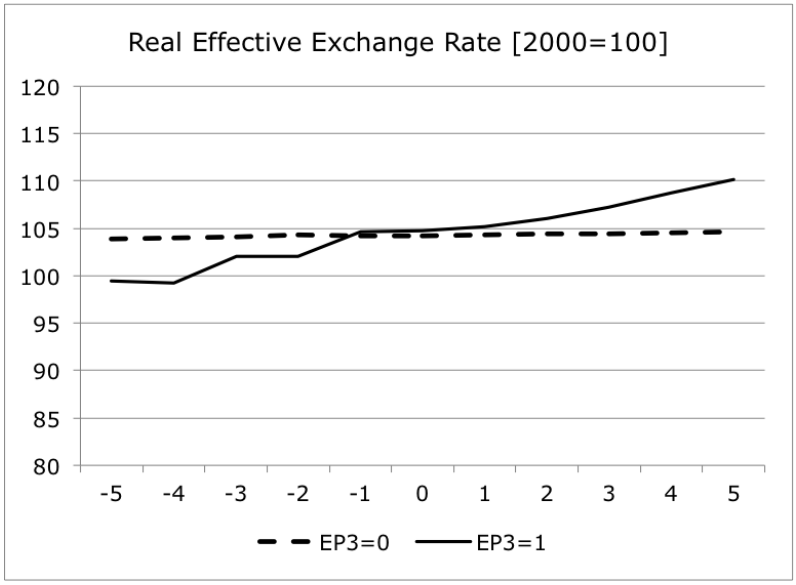


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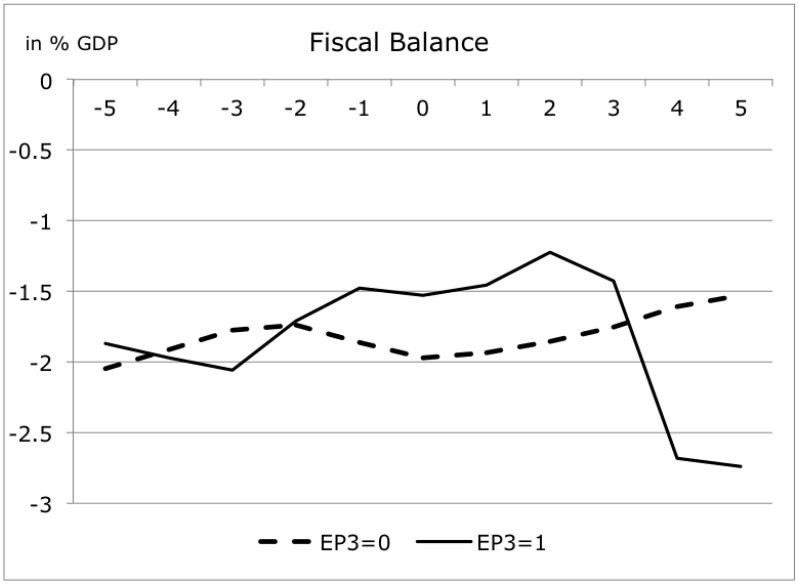


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Figure 4.10: Dynamics of key variables before and after substantial reductions in current account surpluses (EP3), Advanced countries (cont.)

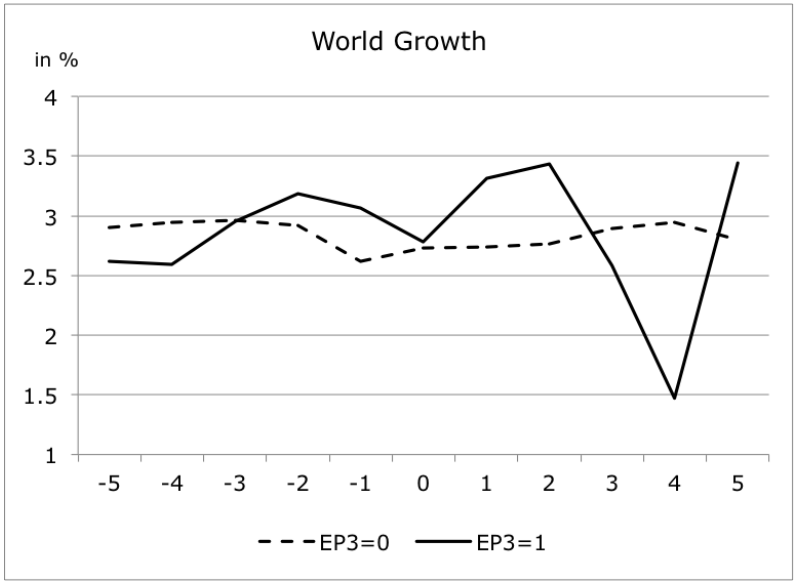


(a)

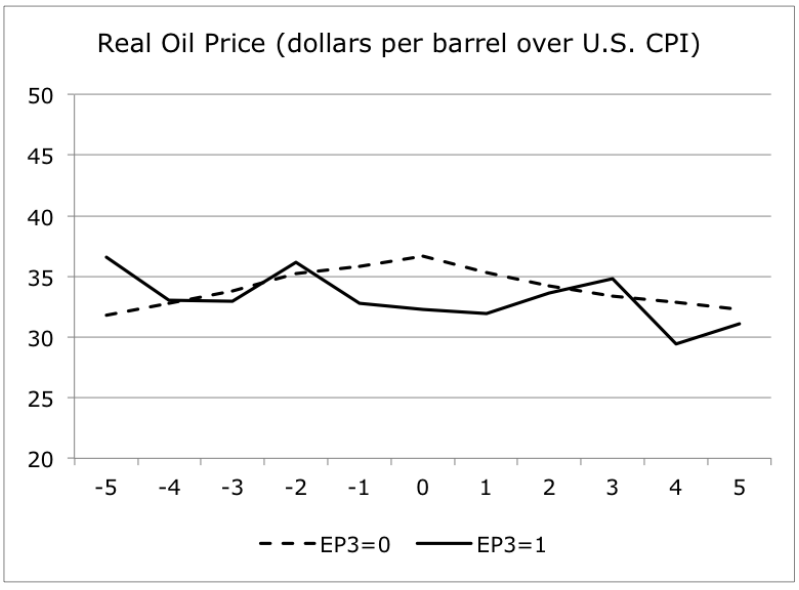


(b)

Figure 4.10: Dynamics of key variables before and after substantial reductions in current account surpluses (EP3), Advanced countries (cont.)

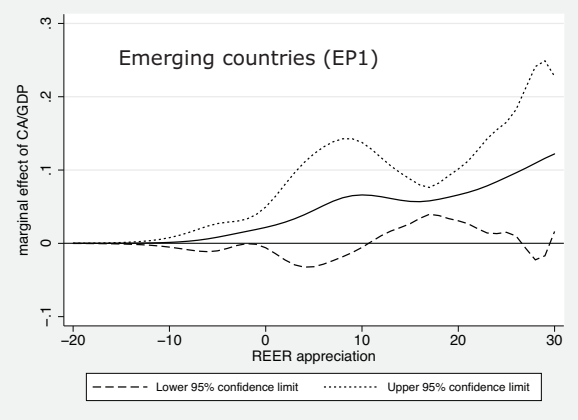


(a)

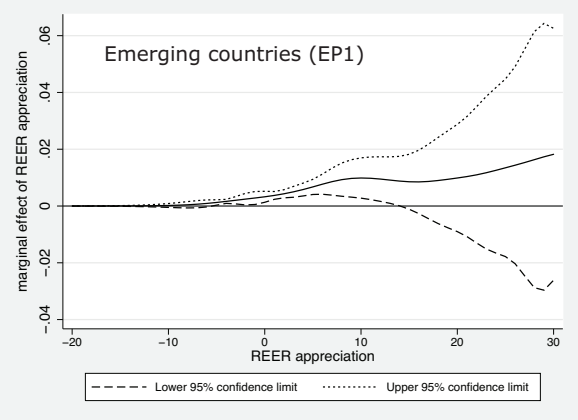


(b)

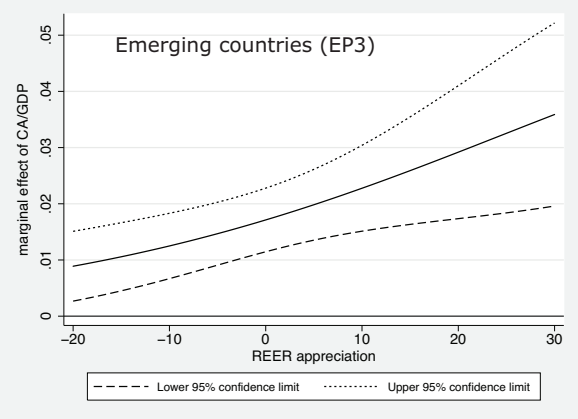
Figure 4.11: Evaluating marginal effects over the response surface



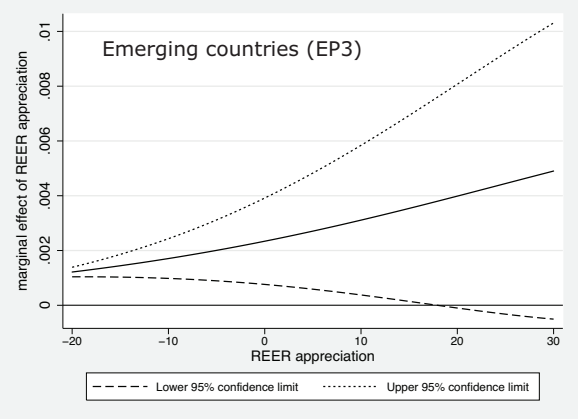
(a)



(b)

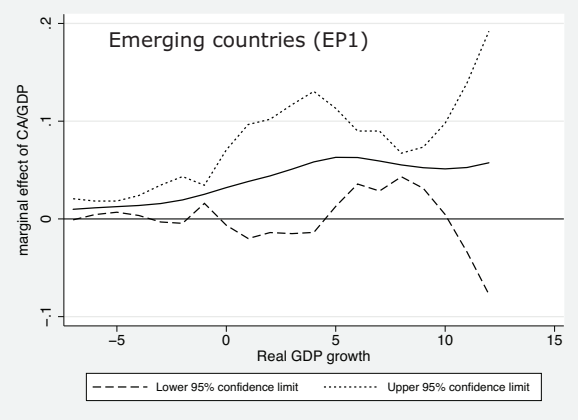


(c)

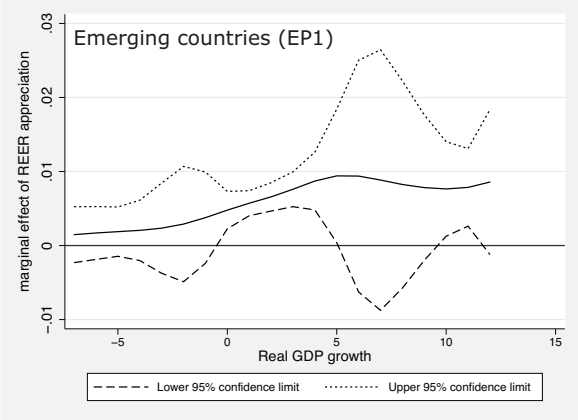


(d)

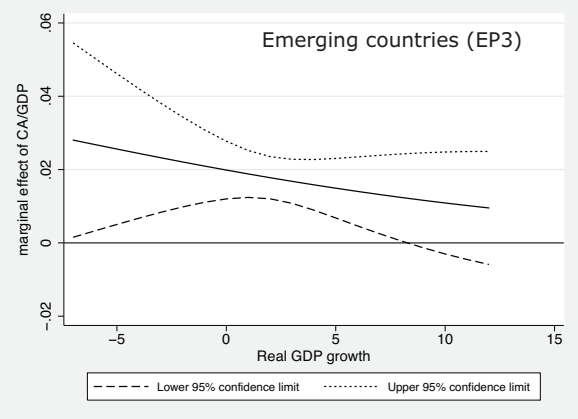
Figure 4.11: Evaluating marginal effects over the response surface (cont.)



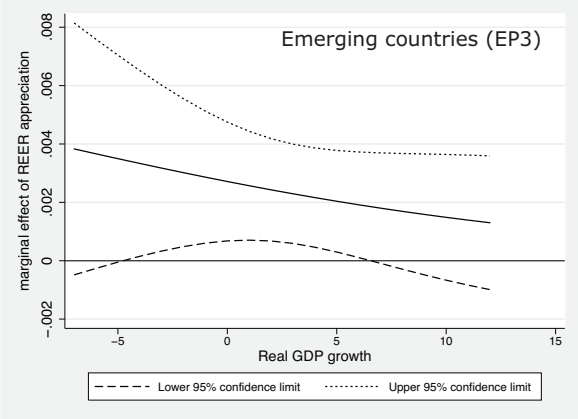
(a)



(b)



(c)



(d)

Table 4.1: Rebalancing with different participants

Countries involved	**Size of the U.S.**	θ	η	**Fall in TOT** $\Delta\tau$	**Real depreciation** Δq
U.S. and the rest of the world	0.21	1	2	15.76	32.30
		1	3	9.44	26.37
		2	2	15.76	19.09
		2	3	9.44	14.37
		0.5	2	15.76	64.36
U.S. plus the rest of the world minus China	0.23	1	2	16.65	33.58
		1	3	10.09	27.47
		2	2	16.65	20.06
		2	3	10.09	15.14
		0.5	2	16.65	66.41
U.S. and all Asia	0.5	1	2	30.87	57.83
		1	3	20.91	52.26
		2	2	30.87	36.69
		2	3	20.91	30.45
		0.5	2	30.87	108.97
U.S. and China	0.75	1	2	51.34	115.66
		1	3	37.57	143.47
		2	2	51.34	69.96
		2	3	37.57	78.27
		0.5	2	51.34	225.18

Table 4.2: Exchange rate responses to productivity shocks

	20% increase in foreign production of tradables	**20% increase in foreign production of nontradables**
σ_T	0.2	0.22
σ_N	1	1
σ_N^*	5/6	1.2
ca	-0.2	-0.2
f	-0.8	-0.8
Fall in TOT: $\Delta\%\tau$	-3.22	0
Real dep.: $\Delta\%q$	10.97	-13.68

Table 4.3: Exchange rate responses to changes in preference parameters

#	**U.S. (Home) preference weight on**		**Foreign preference weight on**		**Adjustment**	
	U.S. tradables	tradables	U.S. tradables	tradables	Fall in TOT	Real depreciation
	α	γ	$1-\alpha^*$	γ^*	$\Delta\%\tau$	$\Delta\%q$
1	0.7	0.25	0.075	0.25		
2	0.7	0.25	**0.2**	0.25	-34.71	-30.99
3	0.7	0.25	**0.3**	0.25	-51.43	-44.82
4	**0.4**	0.25	0.075	0.25	37.10	33.19
5	0.7	0.25	0.075	**0.19**	0.00	34.72
6	0.7	0.25	0.075	**0.33**	0.00	-34.52
7	0.7	**0.32**	0.075	0.25	0.00	32.56

Table 4.4: Literature review

Article	Period	Countries	Definiton of current account reversals						Main	Sign
			Initial	Size of Adjustment		Years of	Sustainability	Nr.	Determinants	
			CA to GDP	GDP	Share of initial deficit	Adjustment	of Adjustment	Episodes	of reversals	
Milesi-Ferretti and Razin (1998)	1974-1990	86 low and middle income	-	3% or 5%	1/3	3	-	72 or 48	CA/GDP Trade openness Reserves/Imports GDP per capita Fiscal Balance Terms of trade Ch. ToT U.S. real interest rates OECD growth Official transfers	- - - + + - + + + -
Freund (2005)	1980-1997	25 industrial	-2%	2%	1/3	3	5	25	CA/GDP Reserve growth Real GDP growth REER appreciation Government Balance Real interest rates	- - -
Croke et al (2005)	1980-1999	21 industrial	-2%	2%	1/3	3	5	23	N/A	
Freund and Warnock (2007)*	1980-2003	25 OECD	-2%	2%	1/3	3	5	26	N/A	
Algieri and Bracke (2007) **	1973-2006	45 industrial and emerging	<0%	1 std. dev.	-	4	5	71	CA/GDP Import expansion variable Exch. Rate overvaluation Output gap Credit expansion Real oil price***	

Table 4.4: Literature Review (cont.)

Article	Period	Countries	Definiton of current account reversals					Nr. Episodes	Main Determinants of reversals	Sign
			Initial CA to GDP	Size of Adjustment GDP	Size of Adjustment Share of initial deficit	Years of Adjustment	Sustainability of Adjustment			
IMF (2007)	1960-2006	47 advanced, emerging and oil exporters	-	2.5	1/2	estimated	5	119	N/A	
Adalet and Eichengreen (2007)	1880-1998	56 all	<0%	2% or 3%	1/3	3	3	194	CA deficit Trade Balance/GDP Government Balance U.S. interest rates GDP per capita U.S. real GDP growth Openness	+ - - - + +
Debelle and Galati (2007)	1974-2003	21 industrial	-2%	2%	1/3	3	5	28	Global Growth U.S. interest rate CA REER Real GDP growth Terms of trade	- + -
de Haan et al (2008)	1960-2004	29 OECD	-2% plus larger than at t-1	2%	1/3	3	5	41	CA Output gap REER appreciation Government Balance Exch. regime Financial Openness	- + - -

Notes: * They also define persistent deficits, which satisfy: (1) CA/GDP ¡ 2% for 5 consecutive years, (2) no reversal, and (3) CA/GDP ¡ 2/3 of its initial level in each of the 5 years; ** They classify episodes into 3 groups based on the characteristics of the adjustment and find different determinants depending on the type of adjustment. The first is characterized by a slowdown of real GDP and little exchange rate movements, the second by large depreciations without significant changes in the GDP growth, and the third by slower growth and exchange rate depreciation; *** Multiplied by 1 for net oil importers and zero for net oil exporters.

Table 4.5: Episodes of current account surplus reductions

EP1		EP2		EP3	
Emerging Countries					
Bahrain	1981	Bahrain	1983	Argentina	1991
Brazil	2007	Bulgaria	1981	Argentina	2004
Bulgaria	1998	Bulgaria	1998	Bahrain	1984
Colombia	1993	Chile	2008	Bahrain	1989
Cote d'Ivoire	1987	Cote d'Ivoire	1987	Botswana	1988
Croatia	1993	Croatia	1995	Botswana	2000
Czech Republic	1994	Indonesia	1981	Brazil	1993
Egypt	2007	Indonesia	2003	Brazil	2006
Estonia	1994	Jordan	1981	Bulgaria	1985
Hungary	1993	Jordan	1990	Bulgaria	1998
India	2005	Lithuania	1993	China	1983
Indonesia	1981	Macedonia	1992	China	1992
Jordan	1981	Mexico	1988	China	1998
Jordan	1990	Morocco	2007	Colombia	1993
Jordan	2005	Nigeria	1981	Colombia	2001
Lithuania	1993	Oman	1981	Cote d'Ivoire	1987
Macedonia	1992	Qatar	1981	Cote d'Ivoire	1996
Mauritius	2005	Qatar	1986	Cote d'Ivoire	2003
Mexico	1988	Qatar	1990	Croatia	1995
Morocco	2005	Romania	1990	Cyprus	1999
Nigeria	1981	Russia	2007	Czech Republic	1994
Oman	1981	Slovenia	1993	Egypt	1996
Pakistan	2005	South Africa	1981	Egypt	2006
Poland	1996	South Africa	1994	Estonia	1994
Qatar	1983	Taiwan	1988	Hungary	1993
Qatar	1987	Taiwan	1992	India	2004
Romania	1990	UAE	1981	Indonesia	1981
Slovenia	1993	UAE	1991	Indonesia	2003
South Africa	1981			Jordan	1981
South Africa	2003			Jordan	1990
Taiwan	1988			Jordan	2005

Table 4.5: Episodes of current account surplus reductions (cont.)

EP1		EP2		EP3	
Thailand	2002			Kenya	1994
UAE	1983			Kenya	2005
UAE	1991			Lithuania	1993
				Macedonia	1992
				Malaysia	1990
				Mauritius	1988
				Mauritius	2005
				Mexico	1988
				Morocco	1989
				Morocco	2003
				Nigeria	1981
				Nigeria	1991
				Nigeria	2001
				Oman	1982
				Oman	1991
				Oman	2006
				Pakistan	2005
				Peru	1986
				Philippines	1989
				Philippines	1999
				Poland	1996
				Qatar	1990
				Qatar	2006
				Romania	1990
				Russia	2006
				Slovakia	1996
				Slovenia	1995
				Slovenia	2003
				South Africa	1981
				South Africa	1994
				South Africa	2003
				Taiwan	1993
				Thailand	1987
				Thailand	2002

Table 4.5: Episodes of current account surplus reductions (cont.)

EP1		EP2		EP3	
				Tunisia	1989
				Turkey	2002
				UAE	1991
				Vietnam	2002
Advanced Countries					
Austria	1992	Belgium	2000	Austria	1992
Belgium	2000	Belgium	2007	Belgium	2005
Belgium	2005	Finland	2005	Canada	1983
Canada	2007	Germany	1990	Canada	2001
France	2002	Hong Kong SAR	1990	Denmark	2006
Germany	1990	Hong Kong SAR	1994	Finland	1985
Hong Kong SAR	1991	Ireland	1998	Finland	2005
Italy	1999	Japan	2008	France	2005
Netherlands	1986	Korea	1990	Germany	1991
Netherlands	1998	Netherlands	1986	Hong Kong SAR	1994
Switzerland	2007	Netherlands	1998	Ireland	1998
UK	1983	Singapore	2008	Israel	1991
USA	1981	Switzerland	2007	Italy	1987
				Italy	1999
				Japan	1987
				Korea	1990
				Korea	2005
				Netherlands	1986
				Netherlands	1998
				Norway	1986
				Portugal	1994
				Spain	1987
				Sweden	1987
				UK	1982
				USA	1982
				USA	1992

Table 4.6: Description of episodes in emerging countries

Identified by	Country	Year	Initial	Δ CA ratio			# Years		
			CA ratio	1	2	3	1	2	3
EP3	Argentina	1991	3.30			-7.57			4
EP3	Argentina	2004	6.32			-4.96			5
EP1	Bahrain	1981	16.78	-14.36			4		
EP2	Bahrain	1983	21.53		-23.77			3	
EP3	Bahrain	1984	10.07			-16.55			4
EP3	Bahrain	1989	5.00			-22.40			4
EP3	Botswana	1988	25.64			-20.87			5
EP3	Botswana	2000	10.54			-7.06			5
EP3	Brazil	1993	1.44			-5.76			7
EP3	Brazil	2006	1.59			-3.52			5
EP1	Brazil	2007	1.25	-3.18			4		
EP2	Bulgaria	1981	3.66		-3.54			3	
EP3	Bulgaria	1985	1.67			-26.36			9
EP1 EP2 EP3	Bulgaria	1998	4.12	-9.75	-9.7	-29.58	4	3	11
EP2	Chile	2008	4.39		-4.83			3	
EP3	China	1983	1.99			-4.42			4
EP3	China	1992	3.24			-3.02			4
EP3	China	1998	3.88			-2.57			4
EP1 EP3	Colombia	1993	1.36	-5.61		-6.16	4		5
EP3	Colombia	2001	0.81			-3.94			10
EP1 EP2 EP3	Cote d'Ivoire	1987	8.93	-25.56	-26.27	-25.56	4	3	4
EP3	Cote d'Ivoire	1996	0.20			-3.00			5
EP3	Cote d'Ivoire	2003	6.69			-7.37			5
EP1	Croatia	1993	2.62	-6.84			4		
EP2 EP3	Croatia	1995	4.07		-14.77	-11.34		3	8
EP3	Cyprus	1999	2.70			-21.02			10
EP1 EP3	Czech Rep.	1994	1.24	-7.58		-7.58	4		4
EP3	Egypt	1996	0.64			-2.56			4
EP3	Egypt	2006	3.24			-6.08			5
EP1	Egypt	2007	1.63	-4.47			4		
EP1 EP3	Estonia	1994	1.22	-12.36		-12.36	4		4
EP1 EP3	Hungary	1993	0.95	-4.85		-9.32	4		8
EP3	India	2004	1.53			-4.04			7

Table 4.6: Description of episodes in emerging countries (cont.)

Identified by	Country	Year	Initial	Δ CA ratio			# Years		
			CA ratio	1	2	3	1	2	3
EP1	India	2005	0.12	-2.32			4		
EP1 EP2 EP3	Indonesia	1981	3.04	-5.31	-9.8	-7.68	4	3	6
EP2 EP3	Indonesia	2003	4.00		-3.9	-3.95		3	6
EP1 EP2 EP3	Jordan	1981	9.58	-15.03	-17.49	-15.03	4	3	4
EP1 EP2 EP3	Jordan	1990	3.65	-15.29	-18.06	-15.29	4	3	4
EP1 EP3	Jordan	2005	0.78	-12.06		-12.06	4		4
EP3	Kenya	1994	2.10			-6.09			5
EP3	Kenya	2005	0.15			-8.25			5
EP1 EP2 EP3	Lithuania	1993	5.33	-10.25	-15.91	-16.95	4	3	6
EP1 EP2 EP3	Macedonia	1992	6.29	-12.62	-15.3	-14.96	4	3	7
EP3	Malaysia	1990	0.66			-10.25			6
EP3	Mauritius	1988	7.09			-12.13			8
EP1 EP3	Mauritius	2005	0.83	-9.54		-11.41	4		6
EP1 EP2 EP3	Mexico	1988	2.86	-7.51	-5.69	-9.58	4	3	5
EP3	Morocco	1989	0.42			-3.64			7
EP3	Morocco	2003	3.65			-8.39			8
EP1	Morocco	2005	1.69	-7.12			4		
EP2	Morocco	2007	2.15		-7.62			3	
EP1 EP2 EP3	Nigeria	1981	8.85	-13.25	-22.91	-27.59	4	3	6
EP3	Nigeria	1991	7.62			-15.74			4
EP3	Nigeria	2001	12.57			-6.73			4
EP1 EP2	Oman	1981	17.60	-14.19	-11.64		4	3	
EP3	Oman	1982	17.84			-30.32			5
EP3	Oman	1991	9.41			-31.94			8
EP3	Oman	2006	16.75			-17.21			4
EP1 EP3	Pakistan	2005	1.85	-10.19		-10.19	4		4
EP3	Peru	1986	0.29			-8.01			10
EP3	Philippines	1989	0.84			-6.36			5
EP3	Philippines	1999	2.27			-2.63			4
EP1 EP3	Poland	1996	0.61	-8.06		-8.06	4		4
EP2	Qatar	1981	106.84		-49.57			3	
EP1	Qatar	1983	74.12	-40.62			4		
EP2	Qatar	1986	62.31		-29.49			3	
EP1	Qatar	1987	33.50	-42.43			4		

Table 4.6: Description of episodes in emerging countries (cont.)

Identified by	Country	Year	Initial	Δ CA ratio			# Years		
			CA ratio	1	2	3	1	2	3
EP2 EP3	Qatar	1990	44.68		-58.73	-75.71		3	6
EP3	Qatar	2006	33.21			-22.41			4
EP1 EP2 EP3	Romania	1990	4.68	-9.38	-12.44	-11.78	4	3	9
EP3	Russia	2006	11.05			-7.43			4
EP2	Russia	2007	9.54		-5.92			3	
EP3	Slovakia	1996	1.95			-10.24			6
EP1 EP2	Slovenia	1993	5.79	-5.51	-7.27		4	3	
EP3	Slovenia	1995	4.26			-8.21			5
EP3	Slovenia	2003	1.07			-6.60			6
EP1 EP2 EP3	South Africa	1981	4.08	-6.58	-4.56	-6.58	4	3	4
EP2 EP3	South Africa	1994	2.13		-3.28	-3.89		3	5
EP1 EP3	South Africa	2003	0.83	-7.14		-8.24	4		6
EP1 EP2	Taiwan	1988	17.38	-10.61	-10.75		4	3	
EP2	Taiwan	1992	6.77		-4.19			3	
EP3	Taiwan	1993	3.91			-2.67			6
EP3	Thailand	1987	0.57			-8.91			4
EP1 EP3	Thailand	2002	4.43	-8.76		-8.76	4		4
EP3	Tunisia	1989	0.96			-9.74			5
EP3	Turkey	2002	1.92			-7.95			5
EP2	UAE	1981	34.06		-15.35			3	
EP1	UAE	1983	22.82	-11.85			4		
EP1 EP2 EP3	UAE	1991	22.07	-22	-13.78	-22.00	4	3	4
EP3	Vietnam	2002	2.10			-14.02			7

Table 4.7: Description of episodes in advanced countries

Identified by	Country	Year	Initial	Δ CA ratio			# Years		
			CA ratio	1	2	3	1	2	3
EP1 EP3	Austria	1992	0.04	-2.89		-2.89	4		4
EP1 EP2	Belgium	2000	7.90	-3.77	-3.26		4	3	
EP1 EP3	Belgium	2005	3.51	-6.06		-6.06	4		4
EP2	Belgium	2007	2.65		-3.61			3	
EP3	Canada	1983	0.61			-4.53			7
EP3	Canada	2001	2.72			-5.32			9
EP1	Canada	2007	1.40	-3.24			4		
EP3	Denmark	2006	4.35			-3.25			4
EP3	Finland	1985	0.07			-5.40			7
EP2 EP3	Finland	2005	6.55		-2.4	-6.01		3	5
EP1	France	2002	1.83	-2.26			4		
EP3	France	2005	0.61			-2.87			4
EP1 EP2	Germany	1990	4.56	-5.51	-5.66		4	3	
EP3	Germany	1991	2.93			-4.35			4
EP2	Hong Kong	1990	9.16		-6.15			3	
EP1	Hong Kong	1991	6.20	-7.02			4		
EP2 EP3	Hong Kong	1994	4.76		-7.28	-9.15		3	4
EP2 EP3	Ireland	1998	2.90		-3.26	-8.23		3	10
EP3	Israel	1991	0.31			-5.30			5
EP3	Italy	1987	0.45			-3.13			6
EP1 EP3	Italy	1999	1.62	-2.4		-5.03	4		10
EP3	Japan	1987	4.26			-2.82			4
EP2	Japan	2008	4.82		-2.78			3	
EP2 EP3	Korea	1990	2.22		-3.42	-6.20		3	7
EP3	Korea	2005	3.90			-4.59			4
EP1 EP2 EP3	Netherlands	1986	7.15	-3.21	-4.23	-5.09	4	3	7
EP1 EP2 EP3	Netherlands	1998	6.48	-4.04	-4.6	-4.04	4	3	4
EP3	Norway	1986	4.73			-4.82			4
EP3	Portugal	1994	0.26			-10.50			7
EP2	Singapore	2008	23.49		-10.95			3	
EP3	Spain	1987	1.50			-5.08			5
EP3	Sweden	1987	0.03			-2.79			6
EP1 EP2	Switzerland	2007	14.40	-7.28	-8.25		4	3	

Table 4.7: Description of episodes in advanced countries (cont.)

Identified by	Country	Year	Initial	Δ CA ratio			# Years		
			CA ratio	1	2	3	1	2	3
EP3	UK	1982	1.89			-6.75			8
EP1	UK	1983	0.80	-1.72			4		
EP1	USA	1981	0.08	-2.48			4		
EP3	USA	1982	0.16			-3.55			6
EP3	USA	1992	0.05			-6.05			15

Table 4.8: Cross-checking of episodes

	EP1	**EP2**	**EP3**	**Fraction**
EP1	**47**	28	39	**71.3%**
EP2	28	**41**	30	**70.7%**
EP3	39	30	**95**	**36.3%**

Table 4.9: Data description and sources

Variables	Description of variables	Sources
CA/GDP	Current account in percent of GDP	*World Economic Outlook Database* (2009)
Real Growth	Growth in real GDP per capita	*World Development Indicators* (2010)
Openness	Trade openness =(Imports+Exports)/GDP	*World Development Indicators* (2010)
Trade Balance	Trade balance to GDP	*World Development Indicators* (2010)
REER Appreciation	Growth in the real effective exchange rate index [2000=100]; an increase means appreciation	*World Development Indicators* (2010) and International Financial Statistics Database2009
Government Deficit	Government deficit to GDP	*World Economic Outlook Database* (2009)
World Growth	World GDP growth	*World Development Indicators* (2010)
Oil Exporter	Dummy variable that equals 1 if the share of oil exports on total exports is higher than 20%	*World Development Indicators* (2010)
Real Oil Price	Nominal oil price adjusted by U.S. CPI	*World Economic Outlook Database* (2009)
Emerging/Advanced	FTSE Global Equity Index Series Country Classification	FTSE (2009)

Table 4.10: Summary Statistics - means and difference in means

		EP1			EP2			EP3		
EMERGING	**Obs.**	**0**	**1**	**Diff.**	**0**	**1**	**Diff.**	**0**	**1**	**Diff.**
$CA/GDP_{t-1,t-3}$	1183	-1.20	11.31	12.51***	-1.15	12.03	13.17***	-1.19	3.32	4.51***
Real $growth_{t-1,t-3}$	1160	2.40	0.63	-1.77**	2.39	0.90	-1.49	2.43	1.17	-1.26***
$Openness_{t-1}$	1174	76.25	84.99	8.74	76.32	84.62	8.3	76.43	77.23	0.8
Δ Trade $Bal_{t-1,t-3}$	999	0.12	-1.81	-1.92***	0.10	-1.30	-1.4**	0.13	-0.81	-0.95***
REER $app._{t-1,t}$	550	0.11	7.96	7.85**	0.29	1.63	1.34	0.15	2.96	2.81
Fiscal $Balance_t$	138	-2.98	1.50	4.48**	-2.92	-1.27	1.65	-2.97	-1.03	1.94
World $growth_t$	1380	2.63	2.66	0.02	2.63	2.62	-0.01	2.62	2.88	0.27
Real oil $price_t$	1380	35.68	38.08	2.4	35.57	43.98	8.42**	36.00	30.73	-5.27**
Oil exporter	977	0.17	0.19	0.02	0.16	0.33	0.17*	0.16	0.22	0.05
ADVANCED										
$CA/GDP_{t-1,t-3}$	710	0.69	4.82	4.13***	0.64	7.42	6.78***	0.71	2.33	1.63
Real $growth_{t-1,t-3}$	780	2.41	2.17	-0.25	2.38	4.00	1.62***	2.40	2.69	0.29
$Openness_{t-1}$	731	84.90	97.37	12.47	83.87	160.42	76.56***	85.44	76.55	-8.89
Δ Trade $Bal_{t-1,t-3}$	710	0.24	-0.24	-0.47	0.24	-0.49	-0.73**	0.25	-0.42	-0.67***
REER $app._{t-1,t}$	695	0.34	1.23	0.89	0.34	1.62	1.29	0.35	0.36	0
Fiscal $Balance_t$	777	-1.86	-1.10	0.76	-1.90	1.03	2.93**	-1.86	-1.48	0.38
World $growth_t$	780	2.63	2.84	0.21	2.62	3.61	1*	2.62	3.06	0.45
Real oil $price_t$	780	35.72	36.63	0.91	35.74	35.44	-0.3	35.84	32.80	-3.04
Oil exporter	707	0.04	0.00	-0.04	0.04	0.00	-0.04	0.04	0.00	-0.04

Notes: Two-tailed t-test p-value *< 0.1, **< 0.05, ***< 0.01.

Table 4.11: Determinants of current account reductions in emerging countries

Substantial Reductions

	EP1			**EP2**		
	(1)	(2)	(3)	(4)	(5)	(6)
CA/GDP$_{t-1,t-3}$	**0.485**	3.013	**0.431**	**0.304**	**0.898**	**0.304**
	[0.16]***	[2.07]	[0.24]*	[0.06]***	[0.45]**	[0.16]*
Real growth$_{t-1,t-3}$	-0.127	0.753	**-0.280**	**-0.174**	**-0.654**	**-0.457**
	[0.10]	[0.82]	[0.13]**	[0.05]***	[0.23]***	[0.22]**
Openness$_{t-1}$	**-0.0402**	0.166	**-0.0644**	**-0.0228**	-0.0593	**-0.0217**
	[0.01]***	[0.11]	[0.03]**	[0.01]**	[0.14]	[0.01]**
Δ Trade Bal$_{t-1,t-3}$	**-0.516**	**-0.998**	**-0.505**	**-0.464**	**-1.258**	-0.341
	[0.16]***	[0.48]**	[0.28]*	[0.18]***	[0.56]**	[0.30]
REER app.$_{t-1,t}$	**0.116**	**0.450**	**0.133**	**0.0644**	0.0690	0.0337
	[0.04]***	[0.19]**	[0.06]**	[0.03]**	[0.09]	[0.03]
World growth$_{t-1}$	0.289	0.918		0.535	0.191	
	[0.52]	[2.65]		[0.68]	[0.83]	
Real oil price$_{t-1}$	-0.0584	-0.110		0.0654	**0.163**	
	[0.05]	[0.10]		[0.04]	[0.07]**	
ROP$_{t-1}$*oil exporter	-0.153			-0.0437		
	[0.14]			[0.03]		
Constant	-1.410	-27.10	-0.893	-6.841	-13.10	0.933
	[1.95]	[11.15]**	[1.49]	[3.24]**	[13.69]	[1.94]
Observations	448	182	113	448	130	84
Fixed effects	No	Country	Year	No	Country	Year
Log-likelihood	-22.68	-9.473	-14.96	-21.67	-11.57	-13.46
McFadden pseudo-R^2	0.435	0.711	0.482	0.319	0.524	0.377
Nr.Clusters	22	8	22	22	6	22

Notes: Robust standard errors in brackets, clustered by country. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ The current account ratio, domestic growth, and the change in trade balance are defined as averages over the 3 years preceding the event. REER appreciation is the lagged annual percentage change in the real effective exchange rate index.

Determinants of current account reductions in emerging countries (cont.)

Substantial and Moderate Reductions

	EP3		
	(1)	(2)	(3)
CA/GDP$_{t-1,t-3}$	**0.204**	**0.314**	**0.248**
	[0.06]***	[0.06]***	[0.06]***
Real growth$_{t-1,t-3}$	**-0.109**	-0.0791	**-0.127**
	[0.04]***	[0.10]	[0.05]**
Openness$_{t-1}$	**-0.00625**	-0.0209	**-0.00798**
	[0.00]*	[0.02]	[0.00]*
Δ Trade Bal$_{t-1,t-3}$	-0.0647	0.0171	0.0383
	[0.12]	[0.15]	[0.16]
REER app.$_{t-1,t}$	**0.0316**	**0.0429**	**0.0359**
	[0.01]***	[0.02]***	[0.01]***
World growth$_{t-1}$	0.359	0.317	
	[0.26]	[0.29]	
Real oil price$_{t-1}$	**-0.0886**	**-0.103**	
	[0.03]***	[0.04]**	
ROP$_{t-1}$*oil exporter	0.0154		
	[0.01]		
Constant -0.964	2.265	-3.078	
	[1.21]	[3.11]	[1.35]**
Observations	448	369	262
Fixed effects	No	Country	Year
Log-likelihood	-81.81	-74.79	-66.87
McFadden pseudo-R^2	0.176	0.205	0.211
Nr.Clusters	22	17	22

Notes: Robust standard errors in brackets, clustered by country. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ The current account ratio, domestic growth, and the change in trade balance are defined as averages over the 3 years preceding the event. REER appreciation is the lagged annual percentage change in the real effective exchange rate index.

Table 4.12: Determinants of current account reductions in advanced countries

Substantial Reductions

	EP1			**EP2**		
	(1)	(2)	(3)	(4)	(5)	(6)
CA/GDP$_{t-1,t-3}$	**0.263**	**1.490**	**0.334**	**0.336**	**1.576**	**0.442**
	[0.07]***	[0.33]***	[0.09]***	[0.16]**	[0.53]***	[0.26]*
Real growth$_{t-1,t-3}$	-0.0499	0.626	-0.337	0.440	**2.316**	0.707
	[0.26]	[1.01]	[0.22]	[0.51]	[0.73]***	[0.63]
Openness$_{t-1}$	-0.0014	**-0.133**	-0.0011	-0.0064	**-0.153**	-0.0069
	[0.01]	[0.05]**	[0.01]	[0.01]	[0.08]**	[0.02]
Δ Trade Bal$_{t-1,t-3}$	**-0.974**	**-2.488**	**-1.532**	-0.612	**-3.819**	**-1.298**
	[0.26]***	[1.36]*	[0.35]***	[0.53]	[1.63]**	[0.62]**
REER app.$_{t-1,t}$	-0.0129	0.0346	0.0332	-0.0661	0.0372	0.0329
	[0.06]	[0.10]	[0.06]	[0.09]	[0.24]	[0.09]
Fiscal Balance$_{t-1}$	**-0.127**	**0.659**	**-0.189**	-0.140	**0.748**	**-0.371**
	[0.07]*	[0.30]**	[0.10]*	[0.10]	[0.43]*	[0.17]**
World growth$_{t-1}$	-0.413	-1.214		**0.899**	**2.757**	
	[0.39]	[0.91]		[0.27]***	[1.37]**	
Real oil price$_{t-1}$	0.0269	0.0763		0.00686	0.0701	
	[0.03]	[0.07]		[0.02]	[0.10]	
Constant	-4.316	2.530	-3.005	-9.542	-25.88	-6.153
	[1.33]***	[2.92]	[1.25]**	[1.81]***	[9.99]***	[1.70]***
Observations	549	201	196	549	126	110
Fixed effects	No	Country	Country	No	Country	Year
Log-likelihood	-42.06	-20.81	-30.64	-27.65	-11.78	-18.66
McFadden pseudo-R^2	0.158	0.476	0.224	0.262	0.564	0.284
Nr.Clusters	23	8	23	23	5	23

Notes: Robust standard errors in brackets, clustered by country. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ The current account ratio, domestic growth, and the change in trade balance are defined as averages over the 3 years preceding the event. REER appreciation is the lagged annual percentage change in the real effective exchange rate index.

Determinants of current account reductions in advanced countries (cont.)

Substantial and Moderate Reductions

	EP3		
	(1)	(2)	(3)
CA/GDP$_{t-1,t-3}$	**0.148**	**0.208**	**0.181**
	[0.05]***	[0.10]**	[0.06]***
Real growth$_{t-1,t-3}$	0.119	0.0346	0.120
	[0.21]	[0.27]	[0.27]
Openness$_{t-1}$	-0.0043	-0.020	-0.0045
	[0.00]	[0.02]	[0.00]
Δ Trade Bal$_{t-1,t-3}$	**-0.750**	**-0.806**	**-0.778**
	[0.32]**	[0.42]*	[0.34]**
REER app.$_{t-1,t}$	0.0151	0.00570	0.0311
	[0.03]	[0.04]	[0.03]
Fiscal Balance$_{t-1}$	-0.0664	0.0169	-0.0474
	[0.05]	[0.06]	[0.05]
World growth$_{t-1}$	-0.0281	-0.0479	
	[0.26]	[0.30]	
Real oil price$_{t-1}$	0.00602	0.00591	
	[0.02]	[0.02]	
Constant	-3.683	-2.542	-2.907
	[0.99]***	[1.07]**	[1.17]**
Observations	549	408	256
Fixed effects	No	Country	Year
Log-likelihood	-79.19	-72.09	-60.25
McFadden pseudo-R^2	0.0779	0.0968	0.142
Nr.Clusters	23	16	23

Notes: Robust standard errors in brackets, clustered by country. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ The current account ratio, domestic growth, and the change in trade balance are defined as averages over the 3 years preceding the event. REER appreciation is the lagged annual percentage change in the real effective exchange rate index.

Table 4.13: Sign of significant coefficient estimates

	Substantial Reductions						Substantial and moderate reductions		
	EP1			**EP2**			**EP3**		
Emerging	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$CA/GDP_{t-1,t-3}$	+		+	+	+	+	+	+	+
Real $growth_{t-1,t-3}$			−	−	−	−	−		−
$Openness_{t-1}$	−		−	−		−	−		−
Δ Trade $Bal_{t-1,t-3}$	−	−	−	−	−				
REER $app._{t-1,t}$	+	+	+	+			+	+	+
World $growth_{t-1}$			N/A			N/A			N/A
Real oil $price_{t-1}$			N/A		+	N/A	−	−	N/A
ROP_{t-1}*oil exporter		N/A	N/A		N/A	N/A		N/A	N/A
	EP1			**EP2**			**EP3**		
Advanced	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$CA/GDP_{t-1,t-3}$	+	+	+	+	+	+	+	+	+
Real $growth_{t-1,t-3}$					+				
$Openness_{t-1}$		−			−				
Δ Trade $Bal_{t-1,t-3}$	−	−	−		−	−	−	−	−
REER $app._{t-1,t}$									
Fiscal $Balance_{t-1}$	−	+	−		+	−			
World $growth_{t-1}$			N/A	+	+	N/A			N/A
Real oil $price_{t-1}$			N/A			N/A			N/A

Table 4.14: Average marginal effects

	EP1		**EP2**		**EP3**	
Emerging	reg.(2)	reg.(3)	reg.(5)	reg.(6)	reg.(8)	reg.(9)
$CA/GDP_{t-1,t-3}$	0.0486	0.0172	0.0244	0.0146	0.0178	0.0184
Real $growth_{t-1,t-3}$	0.0121	-0.0109	-0.0178	-0.0219	-0.0047	-0.0095
$Openness_{t-1}$	0.0027	-0.0026	-0.0016	-0.0010	-0.0012	-0.0006
Δ Trade $Bal_{t-1,t-3}$	-0.0162	-0.0206	-0.0342	-0.0163	0.0008	0.0028
REER $app._{t-1,t}$	0.0072	0.0053	0.0019	0.0016	0.0024	0.0026
World $growth_{t-1}$	0.0147		0.0052		0.0181	
Real oil $price_{t-1}$	-0.0018		0.0044		-0.0058	
Advanced	reg.(2)	reg.(3)	reg.(5)	reg.(6)	reg.(8)	reg.(9)
$CA/GDP_{t-1,t-3}$	0.0532	0.0109	0.0472	0.0122	0.0098	0.0109
Real $growth_{t-1,t-3}$	0.0086	-0.0205	0.0618	0.0078	0.0036	0.0051
$Openness_{t-1}$	-0.0047	0.0000	-0.0052	-0.0002	-0.0011	-0.0003
Δ Trade $Bal_{t-1,t-3}$	-0.0712	-0.0504	-0.1132	-0.0294	-0.0397	-0.0476
REER $app._{t-1,t}$	0.0048	0.0015	0.0057	0.0001	-0.0014	-0.0008
Fiscal $Balance_{t-1}$	0.0261		0.0273		0.0012	
World $growth_{t-1}$	-0.0306		0.0891		-0.0042	
Real oil $price_{t-1}$	0.0017		0.0017		0.0004	

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Appendices

Appendix to Chapter 2

A Information Sources

A.1 Containerization Dataset

I used the three following publications to build my dataset with port-level information on the initial adoption decision and the share of trade that is containerized. All three are annual publications of the container and shipping industries, available only in book format for most of the period from 1956 to the present.

- *Containerisation International* yearbooks
  - Publisher: Informa UK Ltd., London, UK
  - Years: 1968, 1970–2010
  - Description: Each yearbook consists of a detailed directory of all container ports in the previous year. For each port, it provides full contact details, verbal descriptions of current and planned facilities (berths, terminals facilities, and rail facilities) container service providers, and container handling statistics. However, there is more statistical information in later yearbooks than in earlier ones.

- *Lloyd's Ports of the World*
  - Publisher: Shipping World, London, UK (1946–1981); Lloyd's of London Press, Colchester, Essex, UK (1982–)
  - Years: 1946–1996
  - Description: Each book contains a comprehensive list of all the ports in the world. For each port, there is detailed nautical information, a description of its principal facilities and geographical characteristics, and contact details.

- *Shipping Statistics* yearbooks
  - Publisher: Institute of Shipping Economics and Logistics, Bremen, Germany
  - Years: 1968, 1975, 1977, 1979, 1981, 1984, 1986–2009
  - Description: Each yearbook provides detailed statistical surveys for the entire maritime industry. It contains a section, "Port Surveys," with detailed port statistics for a large number of ports worldwide. These statistics include cargo traffic volume, split by origin/destination (foreign and domestic) and by nature (general cargo, dry and liquid bulk, and oil products).

A.2 Maritime Distances

- *Reeds Marine Distance Tables: 59,000 Distances and 500 Ports Around the World*
  - Publisher: Adlard Coles Nautical, London, UK
  - Year: 2010 (11th ed.)
  - Description: This book is the standard reference publication for maritime shipping operators. It contains lookup tables with the shortest or most economical distance between most ports and terminals worldwide.

B Coding Rules

B.1 Adoption of Containerization

To determine a port's year of adoption of containerization, I read the verbal descriptions of ports' facilities in the *Containerisation International* yearbooks. The year of adoption is the year of the first mention of container facilities being in operation at the port. If there is no verbal description, I substitute the year for which the earliest container statistics are available. Since earlier yearbooks lack detailed information for many ports, I also use port descriptions from the *Lloyd's Ports of the World* books to double-check the date when a port was first able to handle containers. A country's adoption year is the year when its first port adopted containerization.

B.2 Usage of Containerization

To construct a dataset with the share of containerized trade handled at each port, I combined data from the *Containerisation International* yearbooks and the *Shipping Statistics* yearbooks. Not only do these publications complement each other, but they also served as a check on each other. The share of containerized trade is the ratio between the volume of containerized trade and all containerizable trade regardless of whether it was containerized or not (in shipping jargon, general cargo trade). I collected data on general cargo trade volumes from the *Shipping Statistics* yearbooks and data on containerized trade volumes from both the *Containerisation International* yearbooks and the *Shipping Statistics* yearbooks. These data correspond to total loaded and unloaded tonnage, measured in metric tonnes. Where the units of measurement were not metric tonnes (e.g., long tons, short tons, revenue tonnes, or harbour tonnes), I converted the numbers into metric tonnes.

In order to fill in missing values, I also collected data from port websites and requested data directly from port authorities. For ports in Australia, Belgium, Brazil, Brunei, Canada, Chile, Colombia, Germany, Ireland, Mexico, Spain, the United Kingdom, and the United States, I used information available online. For the ports of Oakland and Los Angeles, I used data provided directly by the ports. Section D explains my strategy to aggregate these shares of containerized trade across all ports in each country.

B.3 Maritime Distances

For each country, I identify up to 3 main ports. These are ports that handled the largest volume of trade (containerized and bulk) in any two consecutive years. I then calculate the distances between all countries as the minimum maritime distance between their main ports. I use bilateral ocean distances given in the Reeds tables (see Appendix A). For port-pairs not listed in the Reeds tables, I use the closest international hub as a connection point. I use the following 8 major hubs, which ranked top 5 among the world's largest container ports, by volume of container traffic, in 1975, 1983, or 2000 (source: *Containerisation International* yearbooks): Busan (South Korea), Hong Kong (Hong Kong SAR), Kaohsiung (Taiwan), Kobe (Japan), New York (USA), Oakland (USA),

Rotterdam (Netherlands), and Singapore (Singapore). While, ideally, I should have used the largest ports regardless of cargo type, the fact that many of these ports are also large hubs for bulk trade makes this a fairly good set of international hubs.

C Country Coverage

C.1 Adoption of Containerization

Algeria, American Samoa, Angola, Antigua and Barbuda, Argentina, Aruba, Ascension Is., Australia, Austria, Bahamas, Bahrain, Bangladesh, Barbados, Belgium, Belize, Benin, Bermuda, Brazil, Brunei, Bulgaria, Cambodia, Cameroon, Canada, Chile, China, Colombia, Congo (DR), Congo (Republic), Costa Rica, Croatia, Cuba, Cyprus, Czechoslovakia, Czech Republic Denmark, Djibouti, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Ethiopia, Fiji, Finland, France, French Guiana, French Polynesia, Gabon, Gambia, Georgia, Germany, Ghana, Gibraltar, Greece, Guadeloupe, Guam, Guatemala, Guinea, Haiti, Honduras, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Ivory Coast, Jamaica, Japan, Jordan, Kenya, Kiribati, Kuwait, Latvia, Lebanon, Liberia, Libya, Lithuania, Madagascar, Malaysia, Malta, Martinique, Mauritania, Mauritius, Mexico, Montenegro, Morocco, Mozambique, Myanmar, Netherlands, Netherlands Antilles, New Caledonia, New Zealand, Nicaragua, Nigeria, Norway, Oman, Pakistan, Panama, Papua New Guinea, Peru, Philippines, Poland, Portugal, Qatar, Reunion, Romania, Russia, Samoa, Saudi Arabia, Senegal, Seychelles, Sierra Leone, Singapore, Slovak Republic, Slovenia, Solomon Is., Somalia, South Africa, South Korea, Spain, Sri Lanka, St. Lucia, Sudan, Sweden, Switzerland, Syria, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, United Arab Emirates, United Kingdom, USA, Ukraine, Uruguay, Vanuatu, Venezuela, Vietnam, Yemen, and Yugoslavia.

C.2 Usage of Containerization

Argentina, Australia, Bahrain, Bangladesh, Belgium, Benin, Brazil, Bulgaria, Cambodia, Canada, Cameroon, Chile, China, Colombia, Congo (Republic), Costa Rica, Croatia, Cyprus, Denmark, Djibouti, Ecuador, Egypt, El Salvador, Estonia, Fiji, Finland, France, Gabon, Georgia, Germany, Ghana, Greece, Guadeloupe, Guatemala, Haiti, Honduras, Iceland, India, Indonesia, Ireland, Israel, Italy, Ivory Coast, Jamaica, Japan, Jordan, Kenya, Kuwait, Latvia, Lithuania, Malaysia, Mauritius, Mexico, Morocco, Netherlands, Netherlands Antilles, New Caledonia, New Zealand, Nigeria, Norway, Oman, Pakistan, Panama, Peru, Philippines, Poland, Portugal, Qatar, Reunion, Romania, Russia, Saudi Arabia, Senegal, Singapore, Slovenia, Solomon Is., Somalia, South Africa, South Korea, Spain, Sri Lanka, Sudan, Sweden, Syria, Tanzania, Thailand, Togo, Tunisia, Turkey, United Arab Emirates, United Kingdom, Ukraine, Uruguay, USA, Venezuela, Vietnam, Yemen, and Yugoslavia.

D Missing Data, Imputation and Aggregation

In this section, I explain my strategies for imputing missing values and aggregating port-level data by country.

Containerized trade by port

- For each port, I estimate the following equation using OLS and a bayesian approach based on Markov chain Monte Carlo (MCMC) simulation:

$$\text{containerized trade}_t = \beta_0 + \beta_1\{\text{TEUs}\}_t + \beta_2 t + \epsilon_t$$

- R-squares are reasonably high for most ports, and MCMC predictions are not significantly dissimilar from OLS.
- Only those missing values for which both techniques produce similar predictions, namely where the difference between the OLS and MCMC predictions is smaller than one standard deviation of all available data for each port, are considered valid.
- For these valid predictions, my imputed value is the average of the OLS and MCMC predictions.
- This criteria generates a total of 378 imputed values (75 values remain missing), which is 4.2% of the entire dataset.

Share of general cargo (out of total trade)

- I calculate each country's share of general cargo trade as the weighted average share of general cargo trade across its ports using port total trade as weights. (I include only ports with data on total trade.)
- I then use this weighted share of general cargo trade to estimate the following equation for each country, again using OLS and MCMC:

$$\begin{aligned}\text{share general cargo}_t &= \beta_0 + \beta_1\{\text{GDP industry share}\}_t \\ &\quad + \beta_2\{\text{total trade}\}_t + \beta_3 t + \epsilon_t\end{aligned}$$

- The same criteria for selecting valid predictions as for "containerized trade by port" generates 198 imputed values (81 remain missing), which is 6.2% of the entire dataset.

Share of containerized general cargo trade

- The share of containerized general cargo trade in each country is defined as

$$share/degree = \frac{\text{total containerized trade}}{\text{share of general cargo} \times \text{total trade}}$$

- I only use ports with complete data, so that there is no imbalance between ports included in aggregated containerized trade and ports included in aggregated total trade.
- Since units of measurement are completely different between New Zealand's ports (and even within the same port in different years), I calculate a TEU-weighted average share of containerized trade for this country only.
- In order to ensure that my measure of the share of containerized general cargo trade is representative of the country's real usage of containerization, I delete those values that were calculated using only ports that cumulatively account for less than 20% of the country's total general cargo trade.
- In the end, there are 160 values for the share of containerized general cargo trade (across 37 countries) that were calculated using imputed data. Overall, my dataset contains data on the share of containerized general cargo trade for 102 countries between 1956 and 2008.

E Adoption Years

1956 USA

1964 Australia

1966 Belgium, Netherlands, UK

1967 Ireland, New Zealand, Nigeria, Spain

1968 Canada, France, Germany, Italy, Japan, Norway, Sweden, Switzerland

1969 Denmark, Hungary, Jamaica, Malaysia, Peru, Singapore, Taiwan

1970 Ecuador, Finland, Germany GDR, Hong Kong SAR, Israel, Ivory Coast, Poland, Portugal, Yugoslavia

1971 Brazil, Colombia, Greece, India, Philippines, South Africa, USSR

1972 Bahamas, Bulgaria

1973 Cameroon, Chile, Iceland, Trinidad and Tobago

1975 Barbados, Honduras, Indonesia, Kenya, Mozambique, South Korea, Tanzania, Thailand

1976 Aruba, Benin, Dominican Republic, Guatemala, Haiti, Jordan, Mexico, Panama, Saudi Arabia, UAE

1977 Argentina, Bahrain, Cyprus, Iran, Iraq, Kuwait, Lebanon, Morocco, Nicaragua, Papua New Guinea

1978 American Samoa, Antigua and Barbuda, Egypt, El Salvador, French Polynesia, Ghana, Gibraltar, Guam, Oman, Sierra Leone, St Lucia, Vanuatu, Yemen

1979 Algeria, Angola, China, Congo (Rep), Czechoslovakia, Djibouti, Libya, Malta, Martinique, Mauritius, Netherlands Antilles, Qatar, Sri Lanka, Sudan, Syria

1980 Costa Rica, Dominica, Liberia, Madagascar, Pakistan, Uruguay

1981	Bangladesh, Belize, Brunei, Congo (DR), Fiji, Guadeloupe, New Caledonia, Romania, Samoa, Seychelles, Togo, Tunisia, Turkey, Venezuela
1982	Ascension Is, Austria, Gambia, Mauritania, Montserrat, Myanmar, Tuvalu
1983	Bermuda, Ethiopia, Guinea, US Virgin Is
1985	Senegal
1989	Iraq
1992	Latvia, Reunion
1993	Estonia
1995	Lithuania
1998	Cayman Is
2000	Cuba, Vietnam
2001	French Guiana
2002	Georgia, Kiribati
2003	Cambodia

Notes:

Non-adopters: Gabon, Solomon Is, Somalia.

New countries (there was already a container port in these countries before independence; independence year in parenthesis): Former Yugoslavia: Croatia (1992), Montenegro (2007), Serbia (2007), Slovenia (1992), and the Federal Republic of Yugoslavia (2007); Former Czechoslovakia: Slovak Republic (1993); Former USSR: Ukraine and Russia (1992).

Countries with new territory (countries which gained new territory where a container port already existed): Eritrea (1994, from Ethiopia) and Namibia (1995, from South Africa).

Appendix to Chapter 3

F Definitions and Sources

Area: Total area, in square km (sources: Central Intelligence Agency, 1990, 2011)

Banking Crisis: Episode of systematic banking crisis as defined in Laeven and Valencia (2010) (source: database accompanying the paper Laeven & Valencia, 2010)

Bilateral Trade: Imports and exports, in dollars (source: *Direction of Trade Statistics*, 2012)

Coastline: Length of coastline, in km (sources: Central Intelligence Agency, 1990, 2011)

CPI: Consumer Price Index (source: `www.freelunch.com`)

Distance to network: Weighted-average maritime distance to other countries in the container network. I use the shortest distance between any two country's main ports. The weights are obtained using 5-year average bilateral trade shares, in real dollars. (sources: Reynolds & Caney, 2010, *Direction of Trade Statistics*, 2012, and `www.freelunch.com`)

GDP: Real GDP in PPP dollars (source: Heston, Summers, & Aten, 2011)

Judicial efficiency: Efficiency of the judiciary system; scaled from 1 to 10 (source: La Porta et al., 1998)

Network variables: See Table 3.1 for definitions. (sources: author's containerization dataset, Heston et al., 2011, *Direction of Trade Statistics*, 2012, and `www.freelunch.com`)

Oil exporter: Dummy variable that equals one if a country's fuel exports are larger than 2/3 of merchandise exports (source: *World Development Indicators*, 2011)

Paved roads: Length of paved roads, in km (source: Canning, 1998)

POP: Population (source: Heston et al., 2011)

Rail lines: Length of rail lines, in km (source: Canning, 1998)

Rule of law: Rule of law; scaled from 1 to 10. (source: La Porta et al., 1998)

Share world trade: A country's total imports and exports over world's imports and exports. (sources: *Direction of Trade Statistics*, 2012)

Share leased boxes: Share of the world's "box fleet" on operating lease (sources: National Magazine Co., 1983 and 2009)

Trade Openness: Total imports and exports over GDP (sources: *Direction of Trade Statistics*, 2012 and Heston et al., 2011)

XCONST: Executive Constraints constraints on the decision-making powers of chief executives; scaled from 1 to 7. (source: Polity IV, `www.systemicpeace.org`)

G Additional Results

Table G.1: Additional controls (5-year horizon)

	(1)	(2)	(3)	(4)
Exp. containerized trade, 5 yrs	0.756**	1.110**	0.931**	1.215**
	(0.247)	(0.344)	(0.270)	(0.332)
Real GDPpc PPP, log t-5	0.081	-0.214	-0.014	-0.249
	(0.158)	(0.175)	(0.156)	(0.180)
Share world trade, real t-5	0.279**	0.137	0.190+	0.105
	(0.089)	(0.094)	(0.099)	(0.095)
Area km2, log	0.202*	0.207+	0.239*	0.229*
	(0.096)	(0.116)	(0.115)	(0.107)
Oil exporter	-1.010	-1.449	-0.981	-1.375
	(0.759)	(1.035)	(0.856)	(0.969)
Executive constraints, log t-5	0.071	0.074	0.009	0.025
	(0.064)	(0.073)	(0.077)	(0.073)
Rule of law		0.506**		0.409**
		(0.154)		(0.143)
Efficiency of judiciary			0.485**	0.335*
			(0.178)	(0.156)
Dummy 1956-1965	-1.711	-0.988	-1.410	-0.883
	(1.567)	(1.259)	(1.456)	(1.245)
Dummy 1966-1974	2.293*	2.954**	2.604**	3.194**
	(0.935)	(1.090)	(1.003)	(1.059)
Dummy 1975-1983	2.896**	3.515**	3.220**	3.731**
	(0.761)	(0.879)	(0.803)	(0.871)
Constant	-5.370**	-4.811*	-7.500**	-6.046**
	(1.696)	(2.253)	(2.635)	(2.240)
Observations	875	875	875	875
Log-likelihood	-220.655	-211.138	-214.270	-208.156

Notes for Table G.1: The dependent variable is an indicator variable that takes the value one at the year of adoption and zero otherwise. For each country, I drop all observations corresponding to the years after adoption; that is, once a country adopts containerization, it is dropped from the estimation in the following years. All specifications include a constant and period dummies (not shown). Standard errors, computed by bootstrapping the results 1000 times, are in parentheses. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Table G.2: Additional controls (5-year horizon)

	(1)	(2)	(3)
Exp. containerized trade, 5 yrs	1.310**	1.234*	1.277*
	(0.362)	(0.493)	(0.524)
Real GDPpc PPP, log t-5	-0.078	-0.083	-0.243
	(0.178)	(0.238)	(0.244)
Share world trade, real t-5	0.204*	-0.645	-0.716
	(0.090)	(0.516)	(0.497)
Area km2, log	0.211+	0.089	-0.092
	(0.120)	(0.143)	(0.229)
Oil exporter	-1.085	-0.709	-0.546
	(1.005)	(1.438)	(1.404)
Executive constraints, log t-5	0.040	-0.107	-0.153
	(0.084)	(0.097)	(0.110)
Rule of law	0.423**	0.259	0.228
	(0.159)	(0.217)	(0.235)
Efficiency of judiciary	0.307+	0.212	0.326+
	(0.171)	(0.188)	(0.191)
Trade with USA, t-5	-0.275+	-0.002	-0.024
	(0.144)	(0.263)	(0.248)
Trade with AUS, t-5		6.152+	5.553
		(3.631)	(3.568)
Trade with BEL, t-5		-0.544	-0.053
		(4.731)	(5.051)
Trade with NLD, t-5		6.525	6.465
		(4.643)	(4.659)
Trade with GBR, t-5		1.654*	1.751*
		(0.809)	(0.791)
Island			-0.230
			(0.804)
Km of coastline, log			0.388+
			(0.225)
Observations	864	571	528
Log-likelihood	-194.927	-154.768	-149.431

Notes: See Table G.1.

Table G.3: Additional controls (50-year horizon)

	(1)	(2)	(3)	(4)
Exp. containerized trade, 50 yrs	1.299**	1.700**	1.530**	1.820**
	(0.404)	(0.526)	(0.394)	(0.491)
Real GDPpc PPP, log t-5	0.085	-0.198	-0.012	-0.216
	(0.151)	(0.182)	(0.162)	(0.186)
Share world trade, real t-5	0.247**	0.091	0.145+	0.055
	(0.085)	(0.095)	(0.084)	(0.101)
Area km2, log	0.214*	0.256*	0.284*	0.301**
	(0.090)	(0.120)	(0.111)	(0.110)
Oil exporter	-1.024	-1.302	-0.986	-1.229
	(0.749)	(0.953)	(0.838)	(0.921)
Executive constraints, log t-5	0.031	0.042	-0.036	-0.011
	(0.071)	(0.070)	(0.078)	(0.075)
Rule of law		0.502**		0.385**
		(0.144)		(0.149)
Efficiency of judiciary			0.523**	0.355*
			(0.169)	(0.150)
Dummy 1956-1965	-3.436*	-3.458**	-3.474**	-3.590**
	(1.373)	(1.087)	(1.057)	(1.011)
Dummy 1966-1974	1.219+	1.236+	1.245+	1.304+
	(0.644)	(0.681)	(0.651)	(0.690)
Dummy 1975-1983	2.375**	2.680**	2.584**	2.806**
	(0.624)	(0.667)	(0.611)	(0.658)
Constant	-5.319**	-5.611*	-8.205**	-7.361**
	(1.694)	(2.479)	(2.499)	(2.440)
Observations	997	997	997	997
Log-likelihood	-222.590	-212.353	-214.637	-208.758

Notes: The dependent variable is an indicator variable that takes the value one at the year of adoption and zero otherwise. For each country, I drop all observations corresponding to the years after adoption; that is, once a country adopts containerization, it is dropped from the estimation in the following years. All specifications include a constant and period dummies (not shown). Standard errors, computed by bootstrapping the results 1000 times, are in parentheses. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Table G.4: Additional controls (50-year horizon)

	(1)	(2)	(3)
Exp. containerized trade, 50 yrs	1.664**	1.627*	1.569*
	(0.504)	(0.692)	(0.710)
Real GDPpc PPP, log t-5	-0.035	-0.051	-0.193
	(0.184)	(0.229)	(0.234)
Share world trade, real t-5	0.145	-0.815+	-0.899+
	(0.091)	(0.460)	(0.475)
Area km2, log	0.291**	0.186	-0.009
	(0.111)	(0.153)	(0.209)
Oil exporter	-0.985	-0.887	-0.789
	(0.929)	(1.318)	(1.243)
Executive constraints, log t-5	0.024	-0.105	-0.141
	(0.078)	(0.090)	(0.099)
Rule of law	0.362**	0.221	0.173
	(0.138)	(0.208)	(0.213)
Efficiency of judiciary	0.289+	0.204	0.295
	(0.148)	(0.177)	(0.188)
Trade with USA, t-5	-0.218	0.111	0.105
	(0.139)	(0.227)	(0.215)
Trade with AUS, t-5		6.134*	5.795+
		(3.063)	(3.142)
Trade with BEL, t-5		-0.349	0.150
		(5.254)	(5.393)
Trade with NLD, t-5		7.150	7.102
		(5.046)	(4.966)
Trade with GBR, t-5		1.614*	1.741*
		(0.773)	(0.808)
Island			-0.364
			(0.798)
Km of coastline, log			0.359
			(0.218)
Observations	980	579	536
Log-likelihood	-197.017	-155.630	-151.666

Notes: See Table G.3.

Table G.5: Robustness checks: sub-samples (5-year horizon)

	(1)	(2)	(3)	(4)
Exp. containerized trade, 5 yrs	1.335**	1.129*	1.249**	1.027*
	(0.380)	(0.506)	(0.415)	(0.504)
Real GDPpc PPP, log t-5	-0.086	-0.052	-0.123	0.047
	(0.168)	(0.255)	(0.176)	(0.229)
Share world trade, real t-5	0.188+	-0.847	0.272	-1.164+
	(0.112)	(0.624)	(0.188)	(0.704)
Area km2, log	0.219+	0.088	0.122	0.089
	(0.120)	(0.145)	(0.127)	(0.143)
Oil exporter	-1.521	0.101	-1.251	-0.178
	(1.763)	(2.604)	(1.313)	(1.632)
Executive constraints, log t-5	0.041	-0.099	0.009	-0.131
	(0.084)	(0.092)	(0.079)	(0.095)
Rule of law	0.437**	0.222	0.400*	0.171
	(0.163)	(0.216)	(0.187)	(0.231)
Efficiency of judiciary	0.308+	0.210	0.279+	0.144
	(0.157)	(0.185)	(0.163)	(0.195)
Trade with USA, t-5	-0.119	-0.215	-0.137	-0.076
	(0.377)	(0.553)	(0.302)	(0.340)
Trade with AUS, t-5		8.043+		9.356*
		(4.459)		(4.773)
Trade with BEL, t-5		-0.301		1.068
		(6.423)		(6.169)
Trade with NLD, t-5		8.232		6.238
		(5.373)		(5.979)
Trade with GBR, t-5		1.555*		3.084+
		(0.758)		(1.633)
Observations	839	552	696	551
Log-likelihood	-189.252	-149.735	-182.308	-144.999
Sub-sample	Excl. CAN & MEX	Excl. CAN & MEX	Excl Common-wealth	Excl Common-wealth

Notes: See Table G.1.

Table G.6: Robustness checks: sub-samples (5-year horizon)

	(1)	(2)	(3)	(4)
Exp. containerized trade, 5 yrs	1.264**	1.169*	1.541**	1.587**
	(0.391)	(0.514)	(0.281)	(0.399)
Real GDPpc PPP, log t-5	0.061	0.142	-0.075	-0.095
	(0.190)	(0.243)	(0.187)	(0.244)
Share world trade, real t-5	0.185+	-0.885+	0.199*	-0.750
	(0.096)	(0.510)	(0.089)	(0.539)
Area km2, log	0.074	0.041	0.215+	0.110
	(0.118)	(0.154)	(0.117)	(0.150)
Oil exporter	-1.101	-0.612		
	(1.038)	(1.442)		
Executive constraints, log t-5	0.014	-0.137	0.038	-0.098
	(0.084)	(0.098)	(0.080)	(0.096)
Rule of law	0.387*	0.276	0.515**	0.400*
	(0.161)	(0.205)	(0.138)	(0.191)
Efficiency of judiciary	0.243	0.265	0.286+	0.212
	(0.163)	(0.197)	(0.172)	(0.195)
Trade with USA, t-5	-0.230	0.044	-0.275*	0.073
	(0.175)	(0.252)	(0.137)	(0.288)
Trade with AUS, t-5		15.828*		6.275
		(7.439)		(3.914)
Trade with BEL, t-5		-0.568		-0.089
		(6.170)		(5.222)
Trade with NLD, t-5		5.934		6.594
		(4.921)		(4.888)
Trade with GBR, t-5		1.444+		1.512*
		(0.815)		(0.767)
Observations	847	560	838	551
Log-likelihood	-184.303	-145.285	-181.390	-142.782
Sub-sample	Excl NZL, CHN & JPN	Excl NZL, CHN & JPN	Excl. oil exp.	Excl. oil exp.

Notes: See Table G.1.

Table G.7: Robustness checks: sub-samples (50-year horizon)

	(1)	(2)	(3)	(4)
Exp. containerized trade, 50 yrs	1.759**	1.473+	1.792**	1.498+
	(0.541)	(0.755)	(0.632)	(0.833)
Real GDPpc PPP, log t-5	-0.045	-0.030	-0.123	0.001
	(0.179)	(0.247)	(0.188)	(0.241)
Share world trade, real t-5	0.117	-0.995	0.176	-1.220+
	(0.109)	(0.656)	(0.167)	(0.728)
Area km2, log	0.303**	0.176	0.193	0.144
	(0.113)	(0.157)	(0.132)	(0.151)
Oil exporter	-1.541	-0.610	-1.278	-0.592
	(1.827)	(2.482)	(1.160)	(1.527)
Executive constraints, log t-5	0.021	-0.101	-0.018	-0.130
	(0.082)	(0.091)	(0.086)	(0.098)
Rule of law	0.381*	0.197	0.388*	0.199
	(0.162)	(0.222)	(0.185)	(0.252)
Efficiency of judiciary	0.297+	0.203	0.293+	0.179
	(0.166)	(0.188)	(0.171)	(0.201)
Trade with USA, t-5	0.002	0.043	-0.030	0.055
	(0.375)	(0.555)	(0.249)	(0.261)
Trade with AUS, t-5		7.274+		8.523+
		(3.936)		(4.442)
Trade with BEL, t-5		-0.077		0.754
		(5.873)		(6.161)
Trade with NLD, t-5		8.452		7.636
		(5.467)		(6.025)
Trade with GBR, t-5		1.551*		2.402
		(0.782)		(1.868)
Observations	951	560	706	559
Log-likelihood	-190.841	-151.013	-181.899	-145.591
Sub-sample	Excl. CAN & MEX	Excl. CAN & MEX	Excl Common-wealth	Excl Common-wealth

Notes: See Table G.3.

Table G.8: Robustness checks: sub-samples (50-year horizon)

	(1)	(2)	(3)	(4)
Exp. containerized trade, 50 yrs	1.502**	1.387*	1.966**	2.131**
	(0.561)	(0.688)	(0.411)	(0.570)
Real GDPpc PPP, log t-5	0.083	0.144	-0.009	-0.022
	(0.194)	(0.236)	(0.183)	(0.240)
Share world trade, real t-5	0.137	-1.006+	0.135	-0.960+
	(0.090)	(0.592)	(0.093)	(0.502)
Area km2, log	0.178	0.160	0.314**	0.245+
	(0.119)	(0.174)	(0.105)	(0.138)
Oil exporter	-0.950	-0.746		
	(0.914)	(1.240)		
Executive constraints, log t-5	0.010	-0.121	0.014	-0.107
	(0.081)	(0.094)	(0.079)	(0.097)
Rule of law	0.318*	0.215	0.434**	0.339+
	(0.154)	(0.204)	(0.126)	(0.197)
Efficiency of judiciary	0.225	0.240	0.270+	0.201
	(0.147)	(0.198)	(0.150)	(0.191)
Trade with USA, t-5	-0.184	0.137	-0.223	0.192
	(0.134)	(0.232)	(0.147)	(0.263)
Trade with AUS, t-5		14.833+		6.443*
		(7.769)		(3.099)
Trade with BEL, t-5		-0.373		0.058
		(6.289)		(5.792)
Trade with NLD, t-5		6.523		7.450
		(4.933)		(5.121)
Trade with GBR, t-5		1.421+		1.495+
		(0.806)		(0.774)
Observations	958	567	948	557
Log-likelihood	-187.812	-147.570	-183.378	-143.024
Sub-sample	Excl NZL, CHN & JPN	Excl NZL, CHN & JPN	Excl. oil exp.	Excl. oil exp.

Notes: See Table G.3.

Appendix to Chapter 4

H Derivation of σ_T for Different U.S. sizes

Assuming that the share of tradable goods output to GDP is approximately 0.25 in the U.S. and in the rest of the world, the share of tradables to nontradables is approximately 1/3.

$$\frac{P_H Y_H}{P_H Y_H + P_N Y_N} \approx 0.25 \qquad \Rightarrow \qquad \frac{P_H Y_H}{P_N Y_N} \approx \frac{1}{3}$$

and

$$\frac{P_F^* Y_F}{P_F^* Y_F + P_N^* Y_{N^*}} \approx 0.25 \qquad \Rightarrow \qquad \frac{P_F^* Y_F}{P_N^* Y_{N^*}} = \frac{P_F Y_F}{\varepsilon P_N^* Y_{N^*}} \approx \frac{1}{3}$$

With the relative size of the U.S. is given by

$$\frac{\text{U.S. GDP}}{\text{World GDP}} = \frac{P_H Y_H + P_N Y_N}{P_H Y_H + P_N Y_N + P_F Y_F + \varepsilon P_N^* Y_N^*} \approx \frac{4P_H Y_H}{4P_H Y_H + 4P_F Y_F} = \frac{P_H Y_H}{P_H Y_H + P_F Y_F}$$

the value of $\sigma_T = \frac{Y_H}{Y_F}$ such that the U.S. is ω% of the world solves the following nonlinear equation:

$$\frac{\sigma_T/\tau(\sigma_T)}{1 + \sigma_T/\tau(\sigma_T)} = \omega$$

where $\tau(\sigma_T)$ is given by the equilibrium condition

$$1 = \alpha \frac{1}{[\alpha + (1-\alpha)\tau^{1-\eta}]}(1 + if - ca) + (1-\alpha^*)\frac{1}{[\alpha^* \tau^{1-\eta} + (1-\alpha^*)]}\left(\frac{\tau}{\sigma_T} - if + ca\right)$$

In the benchmark model, the U.S. is approximately 21% of the world and σ_T equals 0.22. The initial value of the terms of trade is 0.8439. When China does not participate in the rebalancing, the relative size of the U.S. is approximately 23%. In this case, $\sigma_T = 0.2579$ and the initial value of τ is 0.8843. In the case where the U.S. and Asia do the rebalancing, the relative size of the U.S. is 50% and both σ_T and τ are equal to 1.5361. If only the U.S. and China participate, the relative size of the U.S. is 75%, $\sigma_T = 6.7068$ and $\tau = 2.2357$.