Revisiting the "Great Trade Collapse" with the Endogenous Input-Choice Model*

Mika Saito† Ichiro Tokutsu‡

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Abstract

We revisit the role of vertical specialization and supply constraints during the "Great Trade Collapse" with new data and a new model that allow us to resolve some of the conceptual and data limitations faced by previous studies. We find that (i) demand factors can explain a smaller (than previously understood) fraction of the sharp increase in trade elasticity as measured by the ratio of real growth in world trade over that in world GDP, (ii) vertical specialization was a stabilizing rather than an amplifying factor and (iii) an increase in the export price premium over domestic price was about 4 percent on average.

JEL classification number: F14, F17, R15
keywords: Trade collapse, Vertical specialization, Trade finance, Input-output model

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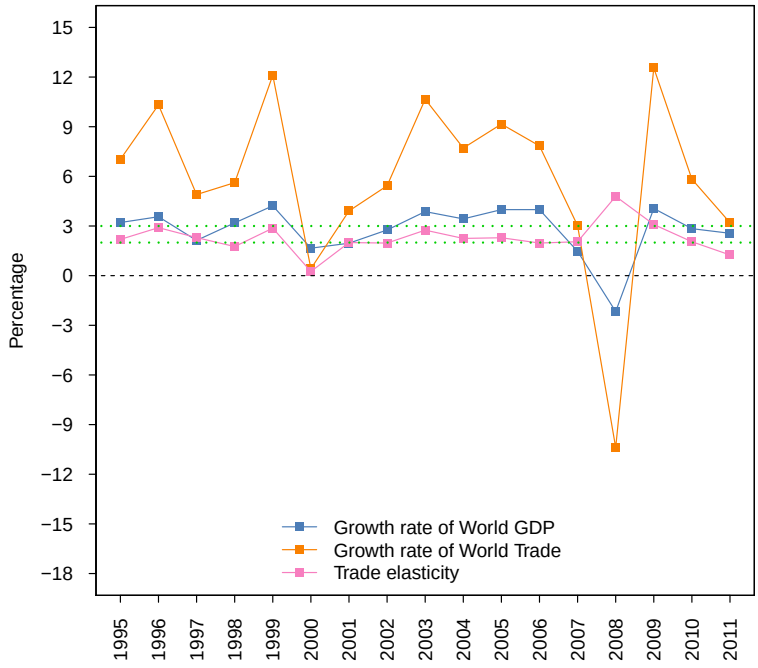
†African Department, International Monetary Fund, 700 19th Street, N.W., Washington, D.C. 20431, U.S.A.

‡Corresponding author, Graduate School of Business Administration, Kobe University, 2-1 Rokko, Nada, KOBE 657-8501, Japan; phone and facsimile to +81 78 803 6926; email to tokutsu@port.kobe-u.ac.jp.

1 Introduction

The Lehman shock in September of 2008 in the United States spread worldwide in an instant and gave rise to the so-called the Global Financial Crisis. As is shown in Figure 1, the crisis inverted the steady growth of world economy thus far suddenly into a negative growth. The growth rate of the world GDP, which was 4 percent on average for the previous 5 years, took a more than 2 percent decrease from 2008 to 2009. Moreover, a noteworthy fact is that this decrease was accompanied by a sharp decline in world trade.



Source: *International Financial Statistics*, International Monetary Fund

Figure 1: Growth rate of gross trade, GDP and trade elasticity: 1995-2011

The World Economic Outlook Database of the International Monetary Fund shows that the rate of the decrease in world trade from 2008 to 2009 was -10.39 percent. This was almost 5 times the rate of the -2.17 percent decline in the world GDP over the corresponding period. The ratio of the real growth rate of world trade over that of world GDP, often called *trade elasticity*, jumped up to 4.79. Trade elasticity typically varied within the range of 2 to 3 (green

line) for over previous years as shown by Houthakker and Magee (1969) and Irwing (2002).[1] It should be noted that the increase in the trade elasticity was temporary and returned to about 2 by 2010. This large but temporary decline of world trade relative to that of world GDP is often called the "Great Trade Collapse," and there has been a number of studies exploring the causes and mechanism of the large trade elasticity.[2]

The approaches to analyze the "Great Trade Collapse" taken so far can be classified broadly into two types. The first type attributes the trade collapse to the vertical specialization of production. This approach argues that in the spillover process of the final demand from one country to other countries, intermediate input trade in multiple stages of production may magnify the decrease in gross trade. This approach is often called vertical specialization (VS) approach. For example, using a traditional input-output analysis, Bems et al. (2011) examined this hypothesis using the GTAP (Global Trade Analysis Project) data. They found that about 75 percent of the observed trade elasticity in the "Great Trade Collapse" could be explained by the vertical linkage and accompanied demand spillovers. Eaton et al. (2011) found that up to 80 percent of the observed trade elasticity can be explained by demand factors. This approach may regard the trade collapse as a permanent phenomenon or the consequence of the changing nature of world trade.[3]

The second approach regards the trade collapse as a temporary phenomenon and attributes the large increase in trade elasticity to the temporary malfunctioning of trade finance. Ahn et al. (2011) is representative of this approach. They focused on the observed difference between the export and domestic prices of a number of goods in many countries, and showed that the differences are brought about by trade finance contraction based on extensive regression analyses.

In this paper, we present an approach that incorporates both approaches in a comprehensive manner and revisit the "Great Trade Collapse." This approach has become feasible because of the recently released *World Input-Output Database* (WIOD), which provides the

[1]Calculated from the International Monetary Fund, *World Economic and Financial Surveys, World Economic Outlook Database*, October 2012 (http://www.imf.org/external/pubs/ft/weo/2012/02/weodata/index.aspx). The decreasing rate of GDP is that of gross domestic product, constant prices and percentage change (market exchange rates).

[2]For example, Boldwin's *The Great Trade Collapse* (2009) collected a large number of papers that addressed this sudden and significant decline of trade in the period of the global financial crisis.

[3] Hummels et al. (1998) discuss the change of world trade structure from the view point of vertical specialization. Yi (2009) also discusses the role of vertical specialization in the "Great Trade Collapse."

time series of international input-output transactions in both current prices and the previous year's prices. The paper is organized as follows. In section 2, we provide the basic accounting scheme of our study and re-examine the vertical specialization approach from an empirical view point. In section 3, we present a model where input choices are made endogenous assuming a neoclassical production function. Previous studies such as Bems et al. (2011), Eaton et al. (2011) and Daudin et al. (2011) assume the constancy of input coefficients, which has been a conceptual limitation in analyzing the "Great Trade Collapse," given the sharp changes in prices and the responsiveness of demand and supply during 2008-09.[4] Endogenizing input choices could not replicate the actual increase in trade elasticity. We discuss supply side factors (e.g., changes of the shift parameters of the production function such as Total Factor Productivity (TFP) and capital utilization and export price premium) that could potentially fill the gap between the model predictions and what actually happened. Finally, we summarize the results.

2 Revisiting the "Great Trade Collapse" with new data

We first revisit the 2008-09 episode with the WIOD, which provide not only nominal changes in foreign versus domestic (and final versus intermediate) transactions from 1995 to 2009, but also the real changes in those variables for each period. This database allows us to analyze the episode in real changes in a more comprehensive and consistent manner. For instance, some of the previous studies assumed that final and intermediate goods trade patterns are proportional to gross trade patterns. Some also combined different sources of data to supplement the input-output data (a snapshot of an economy) with macroeconomic data (real changes). The use of the WIOD allows us to circumvent these data limitations faced by previous studies that analyzed the 2008-09 episode.

2.1 International input-output table

In this section we present the basic accounting scheme to model the trade collapse and revisit the vertical specialization approach to the trade collapse. Table 1 presents the illustrative

[4] Bems et al. (2011) and Eaton et al. (2011) assume the constancy of nominal input coefficients. Daudin et al. (2011) assume fixed coefficient in the real term.

international input-output table for the 3-country and 2-sector case. In the table the superscripts and subscripts of all the variables indicate the country and sector, respectively: x_{ij}^{rs} stands for intermediate input from sector i of country r to sector j of country s. For example, x_{12}^{23} indicates the intermediate good import of sector 2 of country 3 from sector 1 of country 2. As for the final goods, f_i^{rs} for $r \neq s$ also stands for the final goods import of country s from sector i of country r.[5]

Table 1: International input-output table: the 3-country, 2-sector case

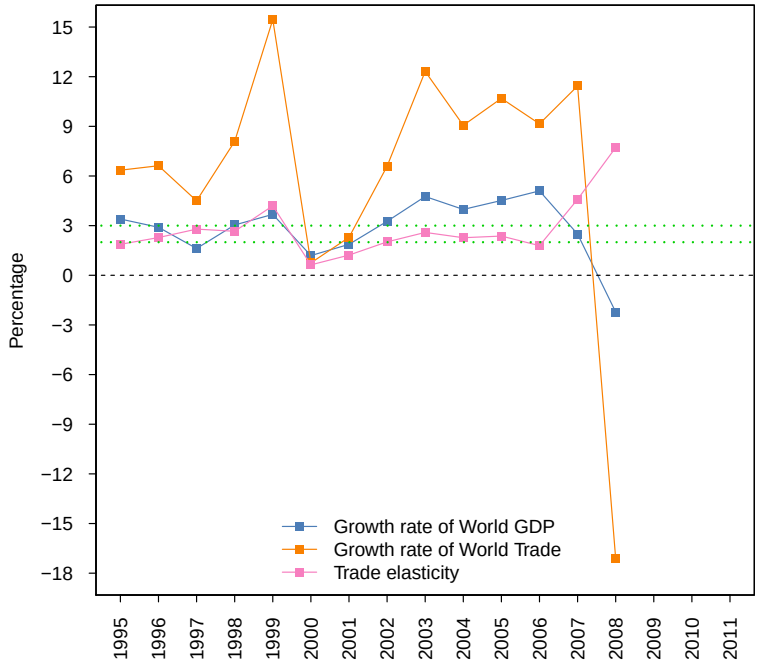
		intermediate demand						final demand			gross output
		country 1		country 2		country 3					
		(1)	(2)	(1)	(2)	(1)	(2)	ctry 1	ctry 2	ctry 3	
ctry. 1	sec. (1)	$p_1^1 x_{11}^{11}$	$p_1^1 x_{12}^{11}$	$p_1^1 x_{11}^{12}$	$p_1^1 x_{12}^{12}$	$p_1^1 x_{11}^{13}$	$p_1^1 x_{12}^{13}$	$p_1^1 f_1^{11}$	$p_1^1 f_1^{12}$	$p_1^1 f_1^{13}$	$p_1^1 x_1^1$
	sec. (2)	$p_2^1 x_{21}^{11}$	$p_2^1 x_{22}^{11}$	$p_2^1 x_{21}^{12}$	$p_2^1 x_{22}^{12}$	$p_2^1 x_{21}^{13}$	$p_2^1 x_{22}^{13}$	$p_2^1 f_2^{11}$	$p_2^1 f_2^{12}$	$p_2^1 f_2^{13}$	$p_2^1 x_2^1$
ctry. 2	sec. (1)	$p_1^2 x_{11}^{21}$	$p_1^2 x_{12}^{21}$	$p_1^2 x_{11}^{22}$	$p_1^2 x_{12}^{22}$	$p_1^2 x_{11}^{23}$	$p_1^2 x_{12}^{23}$	$p_1^2 f_1^{21}$	$p_1^2 f_1^{22}$	$p_1^2 f_1^{23}$	$p_1^2 x_1^2$
	sec. (2)	$p_2^2 x_{21}^{21}$	$p_2^2 x_{22}^{21}$	$p_2^2 x_{21}^{22}$	$p_2^2 x_{22}^{22}$	$p_2^2 x_{21}^{23}$	$p_2^2 x_{22}^{23}$	$p_2^2 f_2^{21}$	$p_2^2 f_2^{22}$	$p_2^2 f_2^{23}$	$p_2^2 x_2^2$
ctry. 3	sec. (1)	$p_1^3 x_{11}^{31}$	$p_1^3 x_{12}^{31}$	$p_1^3 x_{11}^{32}$	$p_1^3 x_{12}^{32}$	$p_1^3 x_{11}^{33}$	$p_1^3 x_{12}^{33}$	$p_1^3 f_1^{31}$	$p_1^3 f_1^{32}$	$p_1^3 f_1^{33}$	$p_1^3 x_1^3$
	sec. (2)	$p_2^3 x_{21}^{31}$	$p_2^3 x_{22}^{31}$	$p_2^3 x_{21}^{32}$	$p_2^3 x_{22}^{32}$	$p_2^3 x_{21}^{33}$	$p_2^3 x_{22}^{33}$	$p_2^3 f_2^{31}$	$p_2^3 f_2^{32}$	$p_2^3 f_2^{33}$	$p_2^3 x_2^3$
labor income		$w^1 l_1^1$	$w^1 l_2^1$	$w^2 l_1^2$	$w^2 l_2^2$	$w^3 l_1^3$	$w^3 l_2^3$				
capital income		$r_1^1 k_1^1$	$r_2^1 k_2^1$	$r_1^2 k_1^2$	$r_2^2 k_2^2$	$r_1^3 k_1^3$	$r_2^3 k_2^3$				
gross output		$p_1^1 x_1^1$	$p_2^1 x_2^1$	$p_1^2 x_1^2$	$p_2^2 x_2^2$	$p_1^3 x_1^3$	$p_2^3 x_2^3$				

x_i^r: output of sector i of country r. p_i^r: product price of sector i of country r.
l_i^r:labor input of sector i of country r. k_i^r: capital input of sector i of country r.
w^r: nominal wage rate of country r. r_i^r: rental price of capital of sector i of country r.
x_{ij}^{rs}: intermediate input of sector j of country s from sector i of country r.
f_i^{rs}: final demand of country s for the product of sector i of country r.

A single price, p_i^r, is applied to the goods produced in sector i of country r, x_i^r, irrespective of the sectors or countries to which the goods are sold. It should be noted that prices are converted to international currency, the U.S. dollar, by the exogenous exchange rates. We make the Armington assumption, that is, we assume that even for the same type of goods, different prices are applied if they are produced in different countries.[6] In this study we utilize the international input-output tables that were recently released from the WIOD project at the University of Groningen. The WIOD provides a consistent and comprehensive international

[5]For a detailed explanation of the variables, see the note below the table.
[6]See Armington(1969).

input-output table for 35 sectors and 40 countries from 1995 to 2009.[7] These tables are also available at the previous year's prices which allows us to compute the real changes in output and trade. The primary purpose of the international input-output table is to describe exhaustively and systematically describe the flow of goods and services between countries and sectors all over the world. However, by aggregating the sectors and countries we can also calculate the aggregated quantities such as world GDP and trade that are internally consistent within the database. Figure 2 plots those aggregated data as a comparison with other macroeconomic database such as the *World Economic Outlook Database*.



Source: *World Input Output Database*, University of Groningen

Figure 2: Growth rate of trade, GDP and trade elasticity: 1995-2008

Figure 2 depicts the transition of aggregated quantities of *World Input Output Database* that correspond to those in Figure 1 from 1995 to 2008. Comparing Figure 2 with Figure 1 shows that the *World Input Output Database* has a tendency to overestimate the rate of

[7] In the empirical part of the paper, 35 sectors are aggregated into 5 sectors and 40 countries are aggregated into 8 countries and regions. See the Data Appendix for details.

change, especially that in world trade volume, but we can conceive about the same pattern of changes in the real world GDP and trade as in Figure 1.[8] The overestimation of the trade change is especially significant in 2008 which results in the corresponding trade elasticity of 7.7 compared to 4.8 in the *World Economic Outlook Database*. For other years, both data sets exhibit a similar shape and the resulting trade elasticities stayed stable between 2 and 3.

2.2 The Leontief model

This section describes the Leontief model which is the basis of many previous studies. Using the variables defined in Table 1, the market equilibrium of each product market for n-country and m-sector case can be presented as

$$x_i^r = \sum_{j=1}^{m}\sum_{s=1}^{n} x_{ij}^{rs} + \sum_{s=1}^{n} f_i^{rs}, \quad r = 1,\ldots,n; i = 1,\ldots,m. \tag{1}$$

Assuming fixed coefficients (i.e., the Leontief model), we can define intermediate demand as follows:

$$x_{ij}^{rs} = a_{ij}^{rs} x_j^s, \quad r,s = 1,\ldots,n; i,j = 1,\ldots,m. \tag{2}$$

By substituting equation (2) into equation (1), we obtain,

$$x_i^r = \sum_{j=1}^{m}\sum_{s=1}^{n} a_{ij}^{rs} x_j^s + \sum_{s=1}^{n} f_i^{rs}, \quad r = 1,\ldots,n; i = 1,\ldots,m. \tag{3}$$

Equation (3) is the simultaneous equations of nm unknowns x_i^r 's with m^2n^2 coefficients a_{ij}^{rs} 's and mn^2 constants f_i^{rs} 's. Thus, the simply observed output levels can also be analytically regarded to be the solution of the simultaneous equations with given input coefficients and final demands. The solution is sometimes called the equilibrium outputs. Once we have obtained the equilibrium outputs, the exports and imports of intermediate goods are obtained

[8] For the rate of change of the world GDP and world trade volume, the sample correlation coefficients between two data in the period from 1995 to 2008 were 0.947 and 0.916, respectively.

again by equation (2). The value added of sector i of country r is also calculated as

$$v_i^r = x_i^r - \sum_{s=1}^{n}\sum_{j=1}^{m} a_{ij}^{rs} x_j^s, \qquad r = 1, \ldots, n; i = 1, \ldots, m. \tag{4}$$

Equation (3) has different solutions according to different values of constant term, say final demands. Dividing the final demand by country, we can obtain the equilibrium outputs that are separately induced by the final demand of the corresponding country. Also the value added that is induced by the final demand of a certain country can be calculated. The value added of country r that is induced by the final demand of country s is called the "value added trade (export)" from country r to country s.[9] The gross trade generally differs from the value added trade. Kei -Mu Yi and his collaborators called this discrepancy "vertical specialization trade" (VS trade). They argued that recent development of VS trade is what affects the large trade elasticity and they analyzed the impact of vertical specialization on trade elasticity based on the traditional input-output (Leontief) model described above. Actually, as will be shown later in this section, VS trade bears an important responsibility in world trade in recent years including during the period of the "Great Trade Collapse."

Indeed, if there is no vertical specialization of production, the rate of change in trade always equals the rate of change in final demand by definition, that is to say, the trade elasticity of the world as a whole is always equal to 1.[10] In this sense, it is intuitive to find large trade elasticities on vertical specialization trade. However, trade elasticities could be 1 even if vertical trade does exist. For example, if the rates of change of the final demand in all the sectors and countries were same, the aggregated trade elasticity would be 1. Accordingly, the VS approach attributes the discrepancy of trade elasticity from 1 to the asymmetry in the rates of change across various sectors. A sharp decline in the demand for durable goods, which rely heavily on imported intermediate inputs, is often highlighted as a key explanation of a sharp increase in trade elasticity (e.g., Bems et al. (2011), Levchenko et al. (2010), and Freund (2009)).[11] Indeed, the WIOD confirms that about 60 percent of the decline in the

[9]This gives a new look to the foreign trade multiplier that was developed in Metzler (1950) . Daudin et al. (2011), Johnson and Noguera (2012) and Koopman et al. (2010) are the recent representative examples of the minute empirical studies on value added trade.

[10]For the world as a whole, the change of trade in final goods exactly equals that of value added trade.

[11] Bems et al. (2011) originally developed the international input-output table from the GTAP 7.1 data and analyzed the large jump in trade elasticity based on the traditional input-output model with fixed coefficients.

world output was due to the demand for durable goods. However, the decline in demand for durables with a fixed coefficient model can replicate only 40 percent of the decline in total trade and 20 percent of the decline in intermediate inputs trade. We show this in turn.

2.3 Replicating existing evidence with the WIOD

To revisit the vertical specialization approach in the common parlance using WIOD, we convert the above simultaneous equations in terms of the rate of change. Substituting the change of final demands Δf_i^{rs} into equation (3), the corresponding change of output Δx_i^r can be obtained as follows:

$$\Delta x_i^r = \sum_{j=1}^{m}\sum_{s=1}^{n} a_{ij}^{rs}\Delta x_j^s + \sum_{s=1}^{n}\Delta f_i^{rs}, \quad r = 1,\ldots,n; i = 1,\ldots,m. \tag{5}$$

Once we have Δx_i^r, the rate of change in the intermediate goods trade can be obtained as

$$\Delta x_{ij}^{rs} = a_{ij}^{rs}\Delta x_j^s. \quad r,s = 1,\ldots,n; i,j = 1,\ldots,m. \tag{6}$$

Dividing the solution Δx_{ij}^{rs} and the exogenous final demands Δf_i^{rs} by the initial level of x_{ij}^{rs} and f_i^{rs}, the rate of change of the intermediate goods trade induced by the final demand change can be estimated. First, the WIOD confirms that the contribution of the decline in the demand for durables was significant and about 60 percent of the decline in the total final demand.

Table 2 presents the percentage change of the final demand by sector for the five years prior to the "Great Trade Collapse" in 2008. Panel (A) of the table indicates the rates of change for the goods produced in the corresponding sectors. As observed from the table, all the change turned to negative in 2008. Among these, the rate of change in durables

Because their input-output table is available only for the single year, the changes of some of the key variables are completed by the external data source other than the input-output table. They employed the -3.7 percent decrease in world GDP and a 15 percent decrease in gross trade, both of these numbers are from the *IMF Global Data Source database* and reconstructed in equation (3) in terms of the rate of change. Accordingly, the actual target trade elasticity to be explained by the model is 4.05(=15÷3.7) which is smaller than those calculated from the *The World Economic Outlook Database* or the *World Input Output Database* from 2008 to 2009. The estimated rate of decrease in world trade was 11 percent, which is equivalent to the trade elasticity of 2.97(=11÷3.7). They concluded that by incorporating the vertical specialization more than 70 percent(= 2.97÷4.05) of the large trade elasticity can be explained.They also noted that the rate of decrease in durables was large and that it contributed to the large trade elasticity in the corresponding period.

Table 2: Growth rate of the final demand by sector

	2004	2005	2006	2007	2008
(A) Rates of change					
(1) Primary products	2.98	6.73	5.70	6.64	-4.40
(2) Non durables	3.09	4.11	4.77	1.75	-3.88
(3) Durables	6.35	7.44	8.28	2.55	-13.2
(4) Finance	7.14	7.36	9.09	1.74	-1.04
(5) Service and others	3.68	3.93	4.45	2.49	-0.29
Total	3.98	4.52	5.10	2.49	-2.22
(B) Shares in final demand					
(1) Primary products	0.03	0.03	0.03	0.03	0.03
(2) Non durables	0.13	0.13	0.13	0.13	0.13
(3) Durables	0.10	0.10	0.10	0.10	0.10
(4) Finance	0.04	0.04	0.04	0.04	0.04
(5) Service and others	0.71	0.70	0.70	0.70	0.69
Total	1.00	1.00	1.00	1.00	1.00
(C) Contribution to final demand change: (A) × (B)					
(1) Primary products	0.09	0.20	0.17	0.21	-0.14
(2) Non durables	0.39	0.53	0.62	0.23	-0.51
(3) Durables	0.62	0.73	0.82	0.26	-1.31
(4) Finance	0.28	0.30	0.37	0.07	-0.04
(5) Service and others	2.60	2.76	3.12	1.73	-0.20
Total	3.98	4.52	5.10	2.49	-2.22

Unit: Percentage for growth rate and decimal for shares

is drastically inverted from a 2.55 percent increase to a -13.2 percent decrease. Moreover, durables' contribution to the decline in total demand was about 60 percent. Panel (B) of the table indicates the share of each sector in the final demand of the base year. For example, the share of durables in 2008 is 0.10 and the share of service and others is 0.69. Multiplying the share of each sector by the growth rate, we obtain the contribution of each good to the total final demand change. Panel (C) of the table shows the contribution of each sector. As observed from the table, -1.31 percent, which is 60 percent of the rate of change in the total final demand (-2.22 percent) is attributed to the change of durables in 2008.[12]

Second, the traditional input-output (constant input-coefficient) model which is represented by equation (3) replicates the world gross output relatively well. Dividing the final

[12]The contribution of durables was the largest and if this sector maintained the same growth rate in 2008 as in 2007 (2.55 percent), the contribution of this sector would be 0.26 and the corresponding final change would be -1.17. However, it should be noted that if the service sector also maintained the same growth rate as in 2007, the final demand change would be only -0.29 percent. In this sense it can be said that the change of final demand for the service sector also played an important role in reversing the final demand change in 2008.

demands by sector, we can also obtain the change of output, the value added and the intermediate good trade that were induced exclusively by the corresponding sectors. Table 3 presents the rate of change of the real gross output, GDP and the trade that were induced by the change in the final demand for the products of 5 sectors. In Panel (A) of the table, in 2008 the effect of the change of the final demand for the good of the corresponding sectors are -0.13 percent for primary goods, -0.62 percent for non durables, -1.69 percent for durables, -0.04 percent for finance and 0.04 percent for service.

The sum of these rate is the rate of change in the world gross output, which is -2.44 percent. That is to say, 69 percent(= 1.69 ÷ 2.44) of the world output change is attributed to the change of the final demand for durable goods. It should be noted that the predicted rate of change of gross output (-2.44 percent) as calculated based on equation (3) is different from the actual rate of change of the world output (-2.81 percent) that is shown in the last row of Panel (A). That is to say, equation (3) can explain about 87 percent(= 2.44 ÷ 2.81) of the output change for the world as a whole. For the years before 2007, the traditional input output model also explained more than 80 percent of the actual rate of change in the gross output of the world as a whole. As far as the aggregated output is concerned, it can be said that the model performed satisfactory.

The predicted and actual GDP are exactly equal for the world as a whole by definition. Accordingly, in Panel (B) the rate of change of the world GDP (-2.22 percent) accords to the actual rate of the exogenous change in the final demand in Table 2.[13]

Third, despite the success of the model in replicating the world gross output, the model can replicate only a small portion of the decline in intermediate inputs trade. Panel (C) of Table 3 presents the change of intermediate goods trade that was induced by the final demand change of the corresponding sectors. As far as the predicted value is concerned, 75 percent (= 2.91 ÷ 3.89) of the decrease in intermediate good trade is attributed to the decrease in the final demand for durables. However, it should be noted that the table also shows that the model predicts that intermediate inputs trade declines by -3.89 percent which is only about 20 percent of the actual decline observed during this period (-19.0 percent). Given the perfect prediction in the final goods trade by definition and as shown in Panel (D), the model explains only 40 percent (= 6.86 ÷ 17.1) of the actual change of the total trade.[14]

[13] Accordingly, Panel (B) of Table 3 and Panel (C) of Table 2 are exactly same.

[14] In terms of the trade elasticity, the predicted elasticity was 3.09, which is only 40 percent of the actual elasticity

Table 3: The changes induced by final demand by sector

	2004	2005	2006	2007	2008
(A) Gross output					
(1) Primary products	0.07	0.19	0.15	0.18	-0.13
(2) Non durables	0.51	0.69	0.81	0.33	-0.62
(3) Durables	0.90	1.04	1.18	0.51	-1.69
(4) Finance	0.25	0.26	0.33	0.05	-0.04
(5) Service and others	2.53	2.69	3.11	1.75	0.04
Total	4.26	4.87	5.58	2.83	-2.44
(Actual)	(5.37)	(5.70)	(6.25)	(3.28)	(-2.81)
(B) Gross domestic products					
(1) Primary products	0.09	0.20	0.17	0.21	-0.14
(2) Non durables	0.39	0.53	0.62	0.23	-0.51
(3) Durables	0.62	0.73	0.82	0.26	-1.31
(4) Finance	0.28	0.30	0.37	0.07	-0.04
(5) Service and others	2.60	2.76	3.12	1.73	-0.20
Total	3.98	4.52	5.10	2.49	-2.22
(C) Intermediate goods trade					
(1) Primary products	0.06	0.16	0.12	0.15	-0.13
(2) Non durables	0.80	1.06	1.15	0.56	-1.10
(3) Durables	1.63	1.99	2.17	1.10	-2.91
(4) Finance	0.17	0.18	0.23	0.06	-0.03
(5) Service and others	2.39	2.66	3.24	2.05	0.28
Total	5.05	6.04	6.90	3.92	-3.89
(Actual)	(9.85)	(11.5)	(9.32)	(14.3)	(-19.0)
(D) Final goods trade					
(1) Primary products	0.15	0.21	0.13	0.24	-0.11
(2) Non durables	2.45	2.70	2.82	2.43	-2.98
(3) Durables	4.22	5.15	5.00	2.40	-9.40
(4) Finance	0.06	0.17	0.23	0.06	-0.01
(5) Service and others	0.75	0.90	0.65	0.65	-0.62
Total	7.63	9.13	8.84	5.78	-13.1
(E) Total trade					
(1) Primary products	0.09	0.18	0.13	0.18	-0.12
(2) Non durables	1.39	1.62	1.72	1.19	-1.70
(3) Durables	2.55	3.09	3.13	1.53	-5.00
(4) Finance	0.13	0.17	0.23	0.06	-0.02
(5) Service and others	1.81	2.05	2.36	1.57	-0.01
Total	5.97	7.11	7.56	4.55	-6.86
(Actual)	(9.06)	(10.7)	(9.15)	(11.4)	(-17.1)

Unit: Percentage

of 7.7.

2.4 An increase in home bias during 2008-09

As far as domestic transactions are concerned, the change of input coefficients matter little at least in the short-run because inputs coefficients can be regarded as technically fixed relation between output and inputs. The changes of input coefficient matter only in the long-run where a technical progress matters. However, once we take the international transaction into account, the input coefficients should change even in the short-run. Actually, the input coefficients changed drastically from 2008 to 2009. Figure 3 shows graphically the change of the input coefficient for 5 sectors and 8 regions. In Figure 3, black and gray cells indicate the positive change of the corresponding input coefficient and red and beige cells indicate the negative change. The color depth indicates the magnitude of change both for the positive and negative case. As observed from the figure, positive change are dominant for the domestic transaction and negative change is dominant for international transactions.[15] It should be noted that a large part of the domestic transaction also indicates a negative change for the United States.

Indeed, we observe that during 2008-09 more than 75 percent of the changes in input demand are associated with changes in input choices rather than changes in output demand. This is in sharp contrast to previous periods where changes in input choices is only about 30 percent of those in input demand on average. Taking the change of the input coefficients into consideration,[16] the change of the intermediate input from period t to $t+1$ can be decomposed into the contribution of the output change and the coefficient change as[17]

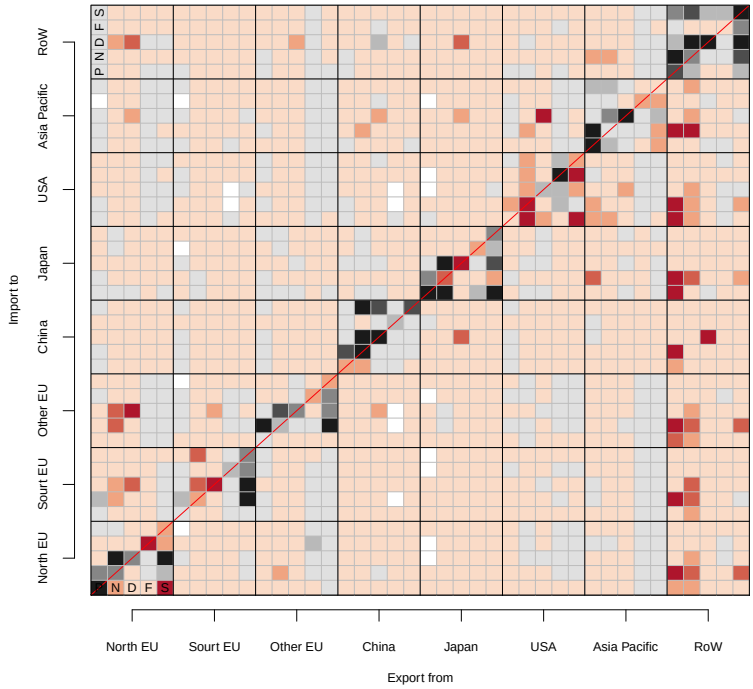
$$\Delta x_{ij}^{rs} = \overline{a}_{ij}^{rs}\Delta x_j^s + \overline{x}_j^s \Delta a_{ij}^{rs}, \quad r,s = 1,\ldots,n; i,j = 1,\ldots,m. \tag{7}$$

The first term on the right-hand side of equation (7) is the contribution of the output with the input coefficients being fixed and the second term on the right-hand side is the contribution of the input coefficients with the level of output being fixed. We call the first term the "output effect" and the second term the "coefficient effect."

[15] For EU countries, Asia Pacific countries and the rest of the world, diagonal blocks include the intrare-gional transaction and the domestic transaction, but for China, Japan and USA, the diagonal blocks are exactly correspond to domestic transaction.

[16] The changes are the difference between the table in the previous year price of period $t+1$ and the table in the current price of period t. That is to say, it is the real change and does not include the change of price.

[17] The bars over the symbol mean the average of period t and $t+1$.



Source: *World Input Output Database*

Figure 3: Change of input coefficient: 2008-09

Table 4: Factor decomposition of intermediate goods trade

		2004	2005	2006	2007	2008
(A) Growth rate:						
(1) GDP		3.98	4.52	5.10	2.49	-2.22
(2) Trade		9.06	10.7	9.15	11.4	-17.1
(B) Trade elasticity		2.27	2.37	1.79	4.59	7.72
(C) Factor decomposition:						
(1) Output effect:	$\overline{a}_{ij}^{rs}\Delta x_j^s$	398	543	678	448	-547
		(62.8)	(63.6)	(84.8)	(31.1)	(23.3)
(2) Coefficient effect:	$\overline{x}_j^s\Delta a_{ij}^{rs}$	236	311	121	993	-1,800
		(37.2)	(36.4)	(15.2)	(68.9)	(76.7)
Total:	Δx_{ij}^{rs}	634	854	800	1,440	-2,347

Unit: Percentage for growth rate, in previous year US billion dollars for other entries.

Table 4 presents the results of the factor decomposition for the five years prior to the trade collapse. The first and second rows indicate the growth rate of the world GDP and

trade, and the third row indicates the trade elasticity. The results of the factor decomposition by (7) is shown in the forth and fifth rows. As observed from the table, the output effect is dominant for the period of stable trade elasticities in 2004 to 2006 but the coefficient effects is dominant for the periods of large trade elasticities. In 2008, the coefficient effect is 3 times that of the output effect. We can easily conjecture that the "Great Trade Collapse" in 2008 is mostly induced by the change of input choice rather than the synchronized decrease of trade that accompanied the worldwide shrinkage of production or demand.

2.5 Vertical specialization as a stabilizing factor during 2008-09

Switching trade partners during 2008-09 was in fact relatively rare in the durable goods sector compared to other sectors. This confirms the anecdotal evidence that supply-chain relationships are relatively inelastic. The change of intermediate goods trade can also be decomposed by sector. As observed from the Table 5, the coefficient effect is significantly smaller for durables than for other sectors. If the large trade elasticity is attributed to the coefficient effect and the output effect reflects the synchronized effect to the world wide shrinkage of production, the vertically specialized production of durables rather has an stabilizing effect on the extra ordinal fluctuation like the large jump in the "Great Trade Collapse."

Table 5: Factor decomposition of intermediate goods trade by sector: 2008 - 2009

		(1) Primary Products	(2) Non durables	(3) Durables	(4) Finance	(5) Service & others	(6) Total
Output effect:	$\overline{a}_{ij}^{rs}\Delta x_j^s$	-17 (17.1)	-259 (21.0)	-270 (48.3)	-2 (27.9)	1 (-0.3)	-547 (23.3)
Coefficient effect:	$\overline{x}_j^s\Delta a_{ij}^{rs}$	-83 (83.0)	-971 (79.0)	-289 (51.7)	-5 (72.1)	-451 (100.3)	-1800 (76.7)
Total:	Δx_{ij}^{rs}	-100	-1,230	-560	-7	-450	-2347

unit: Percentage for growth rates, billions of US dollars in constant price of the base year.

To check the robustness, we also decompose the changes in gross trade, ΔEX, into vertical

specialization ΔVS and the changes in value added trade ΔVAX as follows:[18]

$$\frac{\Delta EX_t}{EX_t} = \frac{\Delta VS_t}{VS_t} \cdot \frac{VS_t}{EX_t} + \frac{\Delta VAX_t}{VAX_t} \cdot \frac{VAX_t}{EX_t}. \tag{8}$$

The first and second terms on the right-hand side of (8) are the contribution of the vertical specialization trade and value added trade, respectively. Table 6 presents the result of decomposition by (8) again for the 5 years prior to the trade collapse. It can be observed from the table that the contributions of vertical specialization are still smaller than those of value-added trade, but the contribution of vertical specialization did increase significantly during 2007 and 2008.

Putting the two findings in Table 5 and 6 together, we conclude that the large increase in trade elasticity in 2008 was induced mainly by the shift of transactions from overseas to domestic, and the recent development of vertical specialization was in fact a softening rather than an amplifying factor of the "Great Trade Collapse."

Table 6: Growth rate of gross trade, VA trade, VS trade

	2004	2005	2006	2007	2008
(A) Growth rate of:					
(1) Gross trade	9.06	10.69	9.15	11.44	-17.13
(2) VA trade	8.21	9.55	8.40	8.90	-13.02
(3) VS trade	11.53	13.89	11.19	18.14	-27.15
(B) Share of:					
(4) VA trade	0.74	0.74	0.73	0.73	0.71
(5) VS trade	0.26	0.26	0.27	0.27	0.29
(C) Contribution of:					
(6) VA trade; (2) × (4)	6.11	7.04	6.12	6.45	-9.24
	(0.67)	(0.66)	(0.67)	(0.56)	(0.54)
(7) VS trade; (3) × (5)	2.95	3.65	3.03	4.99	-7.89
	(0.33)	(0.34)	(0.33)	(0.44)	(0.46)

Unit: Percentage for growth rate and decimal for shares.

3 Revisiting the "Great Trade Collapse" with a new model

The previous section highlighted the evidence of sharp changes in cross-border input-output choices during the 2008-09 episode. Moving away from the Leontief model or adopting a

[18]The symbols are the same as in Bems et al. (2011)

model that allows for cross-border input-output choices to change when prices change is crucial in describing this episode. Therefore, this section revisits the Great Trade Collapse with the WIOD and with a new model, the endogenous input-choice model.

3.1 The endogenous input-choice model

In this section, we present a model that endogenizes the input choices based on the neoclassical model with a specific functional form that describes the production technology. The basic idea is first to start by finding the changes in prices that would be needed to restore an equilibrium after an exogenous shocks to an economy. We then find how much the output supply and corresponding intermediate input demand (both from home and abroad) would change in response to such price changes. Let us begin by describing how we obtain the changes in prices that are induced by an exogenous shocks to an economy.

We assume the homogeneous firm that maximizes the short-run profit for a given level of capital input.[19] As for the production function, a homogeneity of degree one is assumed. Accordingly, the supply and demand for the intermediate inputs and labor can be expressed as functions of prices.[20] The excess supply functions of n countries and m sectors are expressed as functions of relative prices

$$e_i^r(\mathbf{p};\mathbf{g}) = x_i^r(\mathbf{p}) - \sum_{s=1}^{m}\sum_{j=1}^{n} x_{ij}^{rs}(\mathbf{p}) - \sum_{r=1}^{n} f_i^{rs}, \quad r = 1,\ldots,n; i = 1,\ldots,m, \tag{9}$$

where $\mathbf{p}$ is the column vector of the relative prices of p_i^r of dimension mn and $\mathbf{g}$ is also the column vector of the exogenous variables of dimension h that possibly shift each excess supply function, where h is the number of exogenous variables. For example, the total factor productivity (TFP), capital input, and exogenous final demands are typical shift parameters of excess supply functions. As for the labor market, firms are assumed to be able to adjust the labor input based on the real wage rate for a given level of nominal wage rates, but market clearing is not assumed.[21] That is to say, the nominal wage rates are also the exogenous

[19] One of the main reasons for adopting a short-run profit maximization in our model is to capture the responsiveness of the output supply (production level decision) to price changes. If firms were allowed to adjust capital inputs instantaneously, we would simply have a vertical long-run supply curve that does not depend on prices.

[20] For detailed explanation of the model, see Tokutsu (1994) , Tokutsu (2002) and Saito and Tokutsu (2006) .

[21] We could specify an excess supply function for the labor market in each country and let the nominal wage

variables.

We first need to obtain the amount that prices would have to change to restore an equilibrium when there is an exogenous shock to an economy. To do so, we differentiate the excess supply function (9) with respect to the vector of exogenous variables $\mathbf{g}$ and set the excess supply to zero as follows:

$$\mathbf{\Phi}_p \mathbf{\Gamma}_g + \mathbf{\Phi}_g = \mathbf{0}, \tag{10}$$

where

$$\mathbf{\Phi}_p = \left[\frac{\partial \mathbf{e}}{\partial \mathbf{p}}\right] \ (mn \times mn), \ \mathbf{\Gamma}_g \ = \left[\frac{\partial \mathbf{p}}{\partial \mathbf{g}}\right] \ (mn \times h) \text{ and } \mathbf{\Phi}_g = \left[\frac{\partial \mathbf{e}}{\partial \mathbf{g}}\right] \ (mn \times h).$$

Matrix $\mathbf{\Phi}_p$ indicates the change of the excess supply e_i^r that is induced by an infinitesimal change of price p_j^s. For example, the first column of $\mathbf{\Phi}_p$ is the change of excess supply of all mn markets that is induced by an infinitesimal change of the price of the output of sector 1 of country 1. The matrices $\mathbf{\Gamma}_g$ and $\mathbf{\Phi}_g$ are the change of the relative prices p_i^r and excess supply e_i^r respectively that are induced by an infinitesimal change of the exogenous variable $g_k (k = 1, \ldots, h)$.[22]

Solving equation (10) with respect to $\mathbf{\Gamma}_g$, we obtain

$$\mathbf{\Gamma}_g = -\mathbf{\Phi}_p^{-1} \mathbf{\Phi}_g. \tag{11}$$

This matrix shows how much prices need to change to restore an equilibrium when there is an exogenous shock. In what follows, to avoid the unnecessary complexity of expressions, we exclusively consider an exogenous change in final demand.[23] An increase of final demand shifts the excess supply of the corresponding market downwards by the same amount and does not shift the excess supplies of other markets. That is to say, in this case $\mathbf{\Phi}_g$ is a negative

rates adjust to clear labor markets as in Saito and Tokutsu (2006) . We do not do so in this paper because (i) labor market clearing is not a suitable assumption to describe this period and (ii) modeling labor markets would add one more layer of complexity without adding useful insights to the puzzle we are trying to solve in this section.

[22] In empirical analysis, an infinitesimal change is paraphrased by a unit increase.

[23] In the empirical part of this sector, we also discuss the effect of the changes in supply factors in the same manner.

unit matrix of size mn and

$$\mathbf{\Gamma}_g = \mathbf{\Phi}_p^{-1}. \tag{12}$$

Each column of $\mathbf{\Phi}_p^{-1}$ indicates the change of the prices of all mn products that are induced by a unit increase of the final demand for the product of the corresponding sector.

Once we know the change of prices that is induced by a unit increase in the final demand, we can estimate how much the output supply and the corresponding intermediate input demand would have to change. These changes are obtained by multiplying $\mathbf{\Phi}_p^{-1}$ by the Jacobian matrices of the supply function of the output

$$\mathbf{\Theta}_p = \left[\frac{\partial \mathbf{x}}{\partial \mathbf{p}}\right] \ (mn \times mn) \tag{13}$$

and demand function for intermediate inputs

$$\mathbf{\Theta}_p^d = \left[\frac{\partial \mathbf{x}^d}{\partial \mathbf{p}}\right] \ (mn \times mn), \tag{14}$$

respectively, as follows:

$$\mathbf{\Psi}_g = \mathbf{\Theta}_p \mathbf{\Phi}_p^{-1}, \text{ and} \tag{15}$$

$$\mathbf{\Omega}_g = \mathbf{\Theta}_p^d \mathbf{\Phi}_p^{-1}. \tag{16}$$

Equations (15) and (16) allow us to analyze the effect of the changes in the final demand on the output supply and intermediate input trade.

Technological parameters and the size of the exogenous shock (i.e. changes in final demand) are obtained from the WIOD.[24] First, by assuming that the Cobb-Douglas functional form describes production technology with a homogeneity of 1, all parameters can be obtained from the input-output tables. More specifically, under the assumption of profit maximization the exponential parameters are equivalent to the value input coefficients. Second, the real changes in final demand are also obtained from the WIOD. As was stated before, the WIOD reports the input-output tables in both current and previous year prices and there-

[24] See the Appendix for more details.

fore we can obtain the actual real change of final demand for each sector and country. For example, multiplying the $mn \times n$ matrix of the actual real change of final demands Δf_i^{rs} 's from 2008 to 2009, to the equations (12), (15) and (16), we can predict the corresponding changes in prices and the corresponding changes in the supply of output and those in input demand that are induced by the change of the final demand of each country.

The endogenous input-choice model does reasonably well in predicting the aggregate supply and aggregate intermediate inputs demand (i.e. explains about 85 and 75 percent of actual changes, respectively), but does poorly in replicating the supply and demand at the individual region or country level and the exact composition of domestic versus foreign supply (or demand). Let us present the results in turn.

3.2 Changes in final demand and supply factors

Table 7 presents the change of output and GDP as well as the actual change of final demand that induces the real changes in the endogenous variables. Column (1) indicates the actual rate of change in final demand, columns (2) and (3) are the actual and predicted changes in gross output, columns (5) and (6) are the actual and predicted changes in GDP, and columns (8) and (9) are the actual and predicted changes of prices. As for the price change, the predicted price changes are in terms of prices relative to the wage rate, and we subtract the rate of change in the nominal wage rate from the change of prices.

First, the model predicts the aggregate supply of gross output well but replicates the supply at the individual region or country level less successfully. For the world as a whole the model predicts the rate of change of gross output at -2.38 percent, which is about 85 percent of the actual decrease of -2.81 percent. However, for each regional or country the prediction errors are not nontrivial. For China, the predicted rate of change is 3.78 percent, which is only 37 percent of the actual change of 10.8 percent. This is also true for the USA and Japan, where the model explains only 57 and 65 percent of actual change of the gross outputs, respectively. However, for three EU regions it is to be noted that 73 to 78 percent of the actual rates of change are explained by the model.

As for the world GDP, the actual and predicted rates of change are exactly the same at -2.22 percent by construction.[25] However, for the individual regions or countries the changes

[25]The world value added (or GDP) must equal the world final demand.

Table 7: Changes of gross output supply, value added and prices induced by final demand change: 2008-09

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Final demand	Gross output			GDP			Price		
	actual	actual	predicted		actual	predicted		actual	predicted	
			final demand shock	final demand + supply shock		final demand shock	final demand + supply shock		final demand shock	final demand + supply shock
North EU	-3.13	-5.63	-4.15	-5.30	-3.23	-3.46	-3.81	-0.068	-0.023	-0.051
South EU	-4.89	-6.59	-4.82	-6.52	-3.60	-3.99	-4.81	-0.053	-0.027	-0.059
Other EU	-6.76	-6.43	-5.07	-6.13	-3.43	-4.47	-5.48	-0.139	-0.031	-0.059
China	10.8	10.1	3.78	9.33	6.91	3.14	7.70	-0.018	0.023	0.180
Japan	-3.12	-7.87	-5.09	-7.31	-4.01	-3.84	-4.81	0.044	-0.030	-0.087
USA	-2.72	-4.32	-2.48	-3.59	-0.98	-2.36	-2.40	-0.031	-0.016	-0.053
Asia Pacific	0.83	0.44	0.91	0.75	2.40	1.08	1.77	-0.088	-0.001	-0.009
Row	-3.82	-3.61	-3.43	-3.67	-7.48	-2.90	-2.67	-0.037	-0.024	-0.021
World Total	-2.22	-2.81	-2.38	-2.60	-2.22	-2.22	-2.22	-0.046	-0.015	-0.018

Unit: Percentage except for price (2008=1.000)

in GDP can differ from the changes in final demand even in the actual values. For example, the actual rate of change in the final demand of China is 10.8 percent , but the actual rate of change of GDP is only 6.91 percent. In contrast, the rate of decrease of the final demand of Japan is -3.12 percent and the actual rate of change in GDP is -4.01 percent. That is to say, the increase of the final demand in China induces an increase of the foreign value added or GDP, but a decrease in Japanese final demand does not decrease foreign value added. As for the predicted values, the model predicts China's GDP growth at 3.14 percent which is about 45 percent of the actual change, and Japan's growth is predicted at -3.84 percent and its rate of change is predicted at -4.01 percent, which is more than 95 percent of the actual rate.

It should be noted here that price change in this study is a composite change that consists of domestic price and exchange rate. Large divisions between the model predictions and the actual price movements, especially for China, may be partially reflecting factors affecting price movements other than the changes in excess demand or supply.

Second, the model does reasonably well in predicting the aggregate intermediate inputs

demand but does poorly in replicating the composition of domestic versus foreign intermediate demand. In fact the model systematically underestimates the decline in foreign demand and overestimates the decline in domestic demand. Table 8 presents the breakdown of the predicted change of the intermediate demand to domestically and overseas in terms of percentage. As for the intermediate goods demand, the model explains 75 percent (= 2.54÷3.37) of the actual rate of decrease. However, for the domestic demand the estimated rate of change is -2.31 percent in spite of the fact that the actual rate of change is positive, 0.50 percent. On the contrary, for the intermediate goods trade, the model explains only 18 percent (= 3.50 ÷ 19.0).

Table 8: Change of domestic and foreign intermediate demand : 2008-09

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Intermediate demand			Domestic demand			Foreign demand		
	actual	predicted		actual	predicted		actual	predicted	
		final demand shock	final demand + supply shock		final demand shock	final demand + supply shock		final demand shock	final demand + supply shock
(A) Percentage change									
North EU	-7.28	-4.38	-6.64	-4.36	-4.54	-7.38	-14.5	-4.00	-4.81
South EU	-8.67	-5.05	-8.54	-6.48	-5.25	-9.42	-20.9	-3.94	-3.66
Other EU	-7.32	-4.63	-6.72	-5.66	-5.04	-7.50	-12.2	-3.45	-4.41
China	11.50	1.86	10.29	15.91	3.57	15.20	-16.1	-8.84	-20.4
Japan	-10.87	-5.36	-9.77	-9.03	-6.09	-12.09	-24.7	0.10	7.71
USA	-6.72	-2.61	-5.10	-6.27	-2.56	-5.65	-10.7	-3.01	-0.17
Asia Pacific	-0.85	0.05	-0.25	3.27	1.03	0.45	-14.5	-3.17	-2.55
Row	-3.50	-3.15	-3.63	7.17	-3.62	-4.18	-29.8	-1.99	-2.28
World total	-3.37	-2.54	-2.97	0.50	-2.31	-2.64	-19.0	-3.50	-4.30
(B) Change in billions of 2008 U.S. dollars									
North EU	-631	-380	-575	-269	-280	-456	-362	-100	-120
South EU	-376	-219	-370	-238	-193	-346	-138	-26	-24
Other EU	-351	-222	-322	-203	-180	-268	-149	-42	-54
China	1,054	171	943	1,256	282	1,201	-203	-112	-258
Japan	-531	-262	-477	-389	-263	-521	-142	1	44
USA	-801	-311	-607	-672	-274	-605	-129	-36	-2
Asia Pacific	-59	4	-17	174	55	24	-233	-51	-41
Row	-404	-364	-419	589	-297	-343	-993	-66	-76
World total	-2,099	-1,583	-1,845	248	-1,151	-1,315	-2,347	-432	-530

In terms of U.S. dollars the intermediate goods demand decreased by -2,099 billion dollars in 2008 for the world as a whole. The predicted decrease is -1,583 billions dollars which amounts to 75 percent($= 1,583 \div 2,099$) of the actual decrease. As for the foreign intermediate demand, the model explain only 18 percent ($= 432 \div 2,347$) of the actual decrease. The model predicts a decrease by -1,151 billion dollars for the domestic intermediate demand but the actual data shows an increase of 248 billion dollars. That is to say, the model underestimates the decline in foreign demand and overestimate the decline in domestic demand, which indicates that the model does not capture the actual patterns of transaction simply by endogenizing the input choices as functions of price.

For the individual regions or countries, the prediction by the model is not satisfactory even for gross output. For EU countries the model explains more than 70 percent of the actual rate of change in gross output, but for other countries the model prediction explains, for example, only 37 percent of the change for China and 57 percent of the change for the United States. That is to say, the response to the relative price change is not sufficient to explain the change of supply and demand from 2008 to 2009 for individual countries.

It is evident that exogenous demand shocks alone cannot replicate what happened during the 2008-09 crisis and that a model must be able to incorporate supply side shocks that lead to a fall in the supply of goods. The previous studies mentioned above all took the supply of goods as a given (determined by the demand at the long run equilibrium level), reflecting the effect of temporary supply shocks was not feasible. To overcome this constraint, in our endogenous input-choice model, we assume that capital input is fixed in the short run so that it can capture temporary deviations from the long-run equilibrium level of production. That is, our model has upward-slope supply curves rather than horizontal ones as in previous studies. This feature, which allows us to analyze the supply and demand shocks in a comprehensive manner, is a critical difference from previous studies.

Taking into account of the changes in exogenous supply-side factors such as TFP or the level of capital input, which has not discussed thus far, can improve the model predictions but the failure to replicate the composition of foreign versus domestic supply (or demand) remains. The change in gross output that was induce by exogenous supply factors is estimated by the gap between the predicted and actual change of gross output in a simple

comparative static based exclusively on the final demand change.[26] The columns that are labeled "final demand + supply shock" in Tables 7 and 8 indicate the predicted value by incorporating the change in the exogenous supply factors. As can be observed from the tables, the model predictions improve on gross output change and prices. For the world as a whole, the predicted rate of change in gross output is -2.60 percent (which amount to 93 percent of the actual rate of change) and 2.97 percent for total intermediate demand (which amount to 88 percent of the actual rate of change). In the following discussions we will rely on the estimates both by final demand and by supply shock.

Table 9: "Unexplained" changes in demand for intermediate inputs: 2008-09

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Intermediate demand			Domestic demand			Foreign demand		
	actual	predicted	unexplained	actual	predicted	unexplained	actual	predicted	unexplained
North EU	-631	-575	56	-269	-456	-186	-362	-120	242
South EU	-376	-370	6	-238	-346	-108	-138	-24	114
Other EU	-351	-322	29	-203	-268	-66	-149	-54	95
China	1,054	943	-111	1,256	1,201	-56	-203	-258	-55
Japan	-531	-477	54	-389	-521	-132	-142	44	186
USA	-801	-607	193	-672	-605	66	-129	-2	127
Asia Pacific	-59	-17	42	174	24	-150	-233	-41	192
Row	-404	-419	-15	589	-343	-932	-993	-76	917
World Total	-2,099	-1,845	254	248	-1,315	-1,563	-2,347	-530	1,817

Unit: Billions of 2008 U.S. dollars

Table 9 presents the "actual," "predicted" and "unexplained" (=predicted - actual) demand in billions of U.S. dollars. Although the prediction performance of the model is reasonable for the total intermediate demand, those for domestic and foreign demand are still poor. That is to say, the overestimation of the decline in domestic demand and the underestimation of the decline in foreign demand remains. For example, for the world as a whole, the model overestimates the decline in the domestic intermediate demand by -1,563 billion U.S. dollars and underestimate the decrease of foreign intermediate demand by 1,817 billion dollars. The magnitude of underestimation and overestimation are comparable and seem to offset each other. This is also true for individual regions and countries. For example, the

[26]The estimated gap in 2008 between the predicted and actual change of gross output is provided in the Appendix by sector and country.

186 billion dollar overestimation of the decline in domestic intermediate demand in North EU is almost comparable to the 242 billion dollar underestimation of the decline in foreign intermediate demand. These results imply that it is difficult to explain the sharp increase in trade elasticity by only allowing the input choices to respond to the relative price changes that are induced by the exogenous changes in final demand and TFP.

3.3 Changes in export price premium

Let us recap what we have done so far. We have taken an exogenous shock in the final demand and the supply factors in 2008 - 09 as given, and for each market we calculated (i) the excess demand (or supply) created by these shocks, (ii) the changes in prices needed to restore an equilibrium, and (iii) the new equilibrium price and quantity for each market given these changes in prices. The new equilibrium obtained from this approach does a reasonable job in replicating what has happened in the aggregate (or the world as a whole) but did a poor job in replicating the domestic versus foreign composition of the change. More specifically it was unable to replicate the "home bias" in transactions that was observed during the crisis (i.e., a sharp drop in cross-border transactions relative to domestic transactions). In the rest of this section we compute the export price premium that must have increased during the crisis to result in the home bias that we observe in the data.

The overestimated fall in domestic demand and underestimated fall in foreign demand by the model suggests that these markets were clearly segmented and that there were upward (leftward) shifts in the export supply curves relative to the domestic supply curves during the crisis. This is the same idea found by Ahn et al. 's regression result that the prices of exports rose relative to domestic prices during the crisis. Ahn et al. (2011) focus on the "observed" difference between export and domestic prices and attribute the change in prices to the sharp and temporary decrease in export. On the contrary, in our general equilibrium framework, the prices for exports and domestic markets thus far have been treated the same, but we observe differences in domestic and export transactions. The overestimation of export can be explained by the temporary upward shift of the supply function by the "unobserved" price premium due to the rise of the risk of international transactions. Therefore, we calculate the size of these shifts (which we call "export risk premium" hereafter) that are "revealed" in the size of the unexplained fall in domestic and foreign demand. The export risk premium (i.e.

the increases in export prices relative to domestic prices) can be calculated for every country and sector in the database but we present only the aggregated results below for the sake of space.

Table 10: Export price premium: 2008-09

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	domestic market				export market				
	slope of supply[1]		gap[2]	shift	slope of supply[1]		gap[2]	shift	export price premium
	(a)	(b)		= (3) × (2)	(a)	(b)		= (7) × (6)	= (8) − (4)
North EU	0.035	0.036	-186	-0.007	0.136	0.136	242	0.033	0.040
South EU	0.063	0.065	-108	-0.007	0.407	0.398	114	0.045	0.052
Other EU	0.059	0.060	-66	-0.004	0.213	0.209	95	0.020	0.024
China	0.060	0.061	-56	-0.003	0.373	0.553	-55	-0.031	-0.027
Japan	0.073	0.076	-132	-0.010	0.551	0.467	186	0.087	0.097
USA	0.024	0.024	66	0.002	0.213	0.202	127	0.026	0.024
Asia Pacific	0.051	0.050	-150	-0.008	0.191	0.194	192	0.037	0.045
Row	0.021	0.022	-932	-0.020	0.061	0.061	917	0.056	0.076
Average	0.048	0.049	-195	-0.007	0.268	0.275	227	0.034	0.041

[1] Slopes are in 10^3, and are calculated at the initial equilibrium (a) and the new equilibrium (b) that incorporates final demand and supply shocks.
[2] Gaps are unexplained fall in domestic and foreign demand, reported in columns (6) and (9) of Table 9, respectively. Positive (and negative) signs indicate underestimation (and overestimation) of a decline in demand.

Here are the main steps we follow to calculate the export price premium over domestic prices. Let us focus on the foreign demand for simplicity. Recall that the model predicts a fall in foreign demand but there is an additional fall left to be explained (shown as "unexplained" in column (9) of Table 9 and "gap" in column (7) of Table 10). For instance, the post-shock quantity of the external demand for goods in North EU (that incorporates the shock in the final demand and supply factors) was 242 billion U.S. dollars "higher" than the actual level observed in 2009. We treat this positive quantity as the additional fall in quantity that must have been caused by a decrease in supply (i.e., upward or leftward shift in the supply curve) in the exports market. The size of the shift in terms of the change in "quantity" is 242 billion U.S. dollars and the equivalent shift expressed in term of the change in "prices" can be estimated by the change in quantity times the slope of the supply curve (which we discuss below in more detail). In the example of North EU, the additional fall in exports

that need to be explained (i.e. 242 billion U.S. dollars) is estimated to be equivalent to an increase in the export prices on average by 3.3 percent, see column (8). The same exercise is repeated for the domestic (or intra North EU) market, see columns (1)-(4). Continuing with the North EU example, the negative value of -186 U.S. dollars is interpreted as the excess fall in quantity that the model predicted which must have been adjusted by an increase in supply (i.e. downward or rightward shift in the supply curve) in the domestic market. This shift is estimated to be equivalent to a fall in the domestic price premium of 0.7 percent. We call the size of the upward shift in the supply of the export market over the domestic market as the "export price premium," which is shown in column (9); in the case of North EU, the export price premium (i.e. the premium on the export market minus that in the domestic market) is 4.0 percent.[27]

Now the question is "How do we obtain the slope of the supply curve?" From the diagonal entries of the Jacobian matrix of the supply functions of the endogenous input-output choice model that was described in the earlier section, we know the partial derivative of the quantity of good A supplied (to both domestic and foreign markets) with respect to a unit change in the price of good A. The inverse of the partial derivative (split into the domestic and foreign markets according to the quantity supplies in the initial equilibrium) gives us the change in the price of good A for a unit change in the quantity of good A, all other prices being constant. The estimate of the slope of the supply curve (aggregated over all sectors and for some countries over all countries within each region) at the initial equilibrium is reported in column (5) in Table 10. The slope at the new equilibrium (which incorporates the exogenous shocks in final demand and supply factors) is reported in column (6) in Table 10. In calculating the export price premium, the latter is used.

As observed from the table, the supply curve showed the expected direction of the shift for most countries. For domestic market, we observe rightward shifts in the supply curves which capture the home bias in the supply, except for the United States where there was an additional decline in the supply of goods for the domestic market. The shifts range from 0.3 percent for China to 2.0 percent for the rest of the world. On the contrary, the supply curves for foreign market shift leftward, indicating an aversion to export, except for China.

[27] The export price premium can be calculated for all 40 countries and 35 sectors in the WIOD. Such an exercise will allows us to compare the findings of Ahn et al. (2011), which focused on certain products. For the sake of space we presented the aggregated results in Table 10.

The width of the shifts are generally larger than those for the domestic supply function. The export price premium over domestic prices ranges from 2.4 percent for Other EU countries to 9.7 percent for Japan and is estimated at about 4.1 percent on average.

4 Concluding remarks

It is an established argument that more than 70 percent of the large trade elasticity in the "Great Trade Collapse" can be explained by vertical specialization trade. However, based on the recently released comprehensive dataset, the traditional fixed coefficient (Leontief) model, explains only 40 percent of the actual trade elasticity, but the estimated trade elasticity is around 3 irrespective of the underlying data. It should be noted that these models predict final goods exports perfectly by construction; that is, it explains 100 percent of the actual trade elasticity for final goods. In other words, these models explain very small fraction of the actual trade elasticity for intermediate input trade (about 20 percent).

Based on the factor decomposition, we find that the actual change of intermediate demand is mostly attributed to changes of the input coefficients rather than the synchronized change to the output decrease during the "Great Trade Collapse." A sharp decline in demand for durables and heavy reliance of the durable sectors on global supply chains are often highlighted in explaining the "Great Trade Collapse." However, changes in input coefficients occurred at the smallest amount in the durable sector. This evidence leads us to a different model that endogenizes input choice.

The endogenous input choice model presented in this paper performs reasonable well in predicting the total supply and total demand patters. It can explain up to 90 percent of the actual rate of change in intermediate demand. However, the model performs poorly in replicating the domestic versus foreign demand composition of intermediate input trade. It systematically underestimated the decline in imported intermediate inputs demand and overestimated the decline in domestic demand. We estimated the remaining gap between the model predictions and the actual observation in term of the export price premium based on the right upward sloped supply curve within the framework of input-output analysis. The export price premium varies across sectors and countries and is estimated to be about 4 percent on average.

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Appendix: Sources and processing of data

A1. Sector aggregation

Table A1: Sector concordance

No.	*World Input-Output Database* 35-sector	No.	Saito-Tokutsu 5-sector
(1)	Agriculture, Hunting, Forestry and Fishing	(1)	Primary products
(2)	Mining and Quarrying		
(3)	Food, Beverages and Tobacco	(2)	Non durables
(4)	Textiles and Textile Products		
(5)	Leather, Leather and Footwear		
(6)	Wood and Products of Wood and Cork		
(7)	Pulp, Paper, Paper , Printing and Publishing		
(8)	Coke, Refined Petroleum and Nuclear Fuel		
(9)	Chemicals and Chemical Products		
(10)	Rubber and Plastics		
(11)	Other Non Metallic Mineral		
(12)	Basic Metals and Fabricated Metal		
(17)	Electricity, Gas and Water Supply		
(13)	Machinery, Nec	(3)	Durables
(14)	Electrical and Optical Equipment		
(15)	Transport Equipment		
(16)	Manufacturing, Nec; Recycling		
(28)	Financial Intermediation	(4)	Financial intermediation
(18)	Construction	(5)	Service and others
(19)	Sale, Maintenance and Repair of Motor Vehicles, etc.		
(20)	Wholesale Trade and Commission Trade, etc.		
(21)	Retail Trade, etc		
(22)	Hotels and Restaurants		
(23)	Inland Transport		
(24)	Water Transport		
(25)	Air Transport		
(26)	Other Supporting and Auxiliary Transport Activities, etc.		
(27)	Post and Telecommunications		
(29)	Real Estate Activities		
(30)	Renting of M&Eq and other Business Activities		
(31)	Public Admin and Defence; Compulsory Social Security		
(32)	Education		
(33)	Health and Social Work		
(34)	Other Community, Social and Personal service		
(35)	Private Households with Employed Persons		

A2. Country aggregation

Table A2: Country-region concordance

No.	Abbreviation	*World Input-Output Database* 41-country	No.	Saito-Tokutsu 8-region
(2)	AUT	Austria	(1)	North EU [9]
(3)	BEL	Belgium		
(10)	DEU	Germany		
(14)	FIN	Finland		
(15)	FRA	France		
(21)	IRL	Ireland		
(26)	LUX	Luxembourg		
(30)	NLD	Netherlands		
(36)	SVN	Slovenia		
(8)	CYP	Cyprus	(2)	South EU [6]
(12)	ESP	Spain		
(17)	GRC	Greece		
(22)	ITA	Italy		
(29)	MLT	Malta		
(32)	PRT	Portugal		
(4)	BGR	Bulgaria	(3)	Other EU (Non Euro Area) [12]
(9)	CZE	Czech Republic		
(11)	DNK	Denmark		
(13)	EST	Estonia*		
(16)	GBR	United Kingdom		
(18)	HUN	Hungary		
(25)	LTU	Lithuania		
(27)	LVA	Latvia		
(31)	POL	Poland		
(33)	ROU	Romania		
(35)	SVK	Slovak Republic*		
(37)	SWE	Sweden		
(7)	CHN	China	(4)	China [1]
(23)	JPN	Japan	(5)	Japan [1]
(40)	USA	The United States of America	(6)	USA [1]
(1)	AUS	Australia	(7)	Asia Pacific [7]
(6)	CAN	Canada		
(19)	IDN	Indonesia		
(20)	IND	India		
(24)	KOR	Korea, Republic of		
(28)	MEX	Mexico		
(39)	TWN	Taiwan Prov.of China		
(5)	BRA	Brazil	(8)	Rest of the world[4]
(34)	RUS	Russian Federation		
(38)	TUR	Turkey		
(41)	ROW	Rest of the world		

Estonia and Slovak Republic are currently in the Euro area, but in 2008 they did not adopt the euro and they are included in Other EU.

A3. Value added section

We assume the homogeneous production function of the Cobb-Douglas type. Under the assumption of profit maximization, the parameters of the Cobb-Douglas production function are equivalent to the cost shares of the corresponding input. The cost shares of the intermediate inputs are estimated directly by corresponding input coefficients of the input-output table in value term. As for the labor and capital input, the shares are estimated from the Socio-Economic Accounts of the *World Input Output Database* . The labor share is the ratio of labor compensation to gross value added at current basic prices and capital share is the ratio of capital compensation to gross value added at the current basic prices.

In case of negative capital compensation, for example in 2008, the capital compensation of (1) the primary product of Austria, Greece, Ireland, Korea, Luxemburg, Poland, Portugal, Romania and Slovenia and (4) the financial intermediation of Malta are negative. For these sectors, we applied the average capital share of the 40 countries of the corresponding sector, say 0.781 for the primary product and 0.451 for the financial intermediation. For the rest of the world, also the 40 country average capital and labor shares of the corresponding sectors are applied.

Capital compensation and labor compensation in U.S. dollars are calculated by multiplying the above capital and labor shares to the value added at the basic prices in the input-output tables. We define the sectoral value added as the difference between the gross output and the intermediate input. The capital and labor shares for the estimation of the Cobb-Douglas production function are adjusted by including "taxes less subsidies on products," "cif/fob adjustments on exports" and "international transport margins" into the capital compensation, and "Direct purchases abroad by residents" and "purchases on the domestic territory by non-residents" into labor compensation.

A4. Estimates of exogenous supply shock

Table A3: Gap between the actual and estimated gross output by the final demand shock in 2009

		(1) primary product	(2) non durables	(3) durables	(4) finance	(5) service
(1)	Australia	8	-21	-7	-5	-25
(2)	Austria	0	-8	-6	2	-2
(3)	Belgium	1	-3	-3	-0	-1
(4)	Bulgaria	0	-0	-0	1	3
(5)	Brazil	33	37	11	5	11
(6)	Canada	3	1	6	-4	-28
(7)	China	117	424	172	42	129
(8)	Cyprus	0	0	0	0	0
(9)	Czech Republic	1	-10	-6	0	-5
(10)	Germany	2	-113	-101	0	-6
(11)	Denmark	1	-7	-1	-0	-4
(12)	Spain	2	-20	-18	0	49
(13)	Estonia	0	-1	-1	-0	-1
(14)	Finland	1	-9	-8	1	-1
(15)	France	24	34	5	-17	-49
(16)	United Kingdom	-10	-35	-2	-4	7
(17)	Greece	-1	-1	-0	2	-6
(18)	Hungary	1	-6	-7	1	1
(19)	Indonesia	9	16	0	1	17
(20)	India	-15	-15	3	4	5
(21)	Ireland	1	10	4	0	1
(22)	Italy	-1	-120	-38	-2	-10
(23)	Japan	8	-91	-151	-14	-20
(24)	Korea, Republic of	9	4	28	5	9
(25)	Lithuania	1	-2	-0	0	-3
(26)	Luxembourg	0	-1	-0	-6	2
(27)	Latvia	0	-0	-0	0	-1
(28)	Mexico	1	10	-14	2	-3
(29)	Malta	0	-0	-0	0	0
(30)	Netherlands	1	-3	-5	2	3
(31)	Poland	3	-8	-4	-4	4
(32)	Portugal	1	-0	-0	1	6
(33)	Romania	0	2	1	-0	-1
(34)	Russian Federation	19	4	-18	1	6
(35)	Slovak Republic	0	-6	-2	-0	1
(36)	Slovenia	0	-2	-1	0	-1
(37)	Sweden	1	-12	-10	1	-3
(38)	Turkey	11	6	-2	4	0
(39)	Taiwan Prov.of China	3	-61	-11	-2	3
(40)	United States	-48	-264	-57	146	-267
(41)	Rest of the World	-364	-121	-6	27	297

Unit：Billions of 2008 U.S. dollars