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Steven Brakman, Charles van Marrewijk

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Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email office@cesifo.de
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Resilience, Supply Chains and the Great Recession

Abstract

We analyse the link between supply chains and the extent to which the Great Recession has affected national economies. Our analysis is in two steps, namely first for value added measures of supply chains and then for the Grubel-Lloyd index using gross-export data. Regarding value added measures we find, in general, no effect. Only if we separate out Europe do we find that the trough in Europe occurs about 0.17 years later and the recovery (for the countries that have recovered) about 1.55 years later. Moreover, the duration of the decline in Europe is about 4 months longer and of the recovery about 17 months longer. We explain this link and Europe's special role using a detailed Grubel-Lloyd index applied to gross-exports as an alternative supply chain measure, which significantly affects the impact of the Great Recession regarding the timing and duration of the recovery (later and longer).

JEL-Codes: E320, R110, R120.

Keywords: resilience, Great Recession, supply chains.

Steven Brakman
University of Groningen
Groningen / The Netherlands
s.brakman@rug.nl

Charles van Marrewijk
Xi'an Jiaotong – Liverpool University
Suzhou / PR China
Charles.Vanmarrewijk@xjtlu.edu.cn

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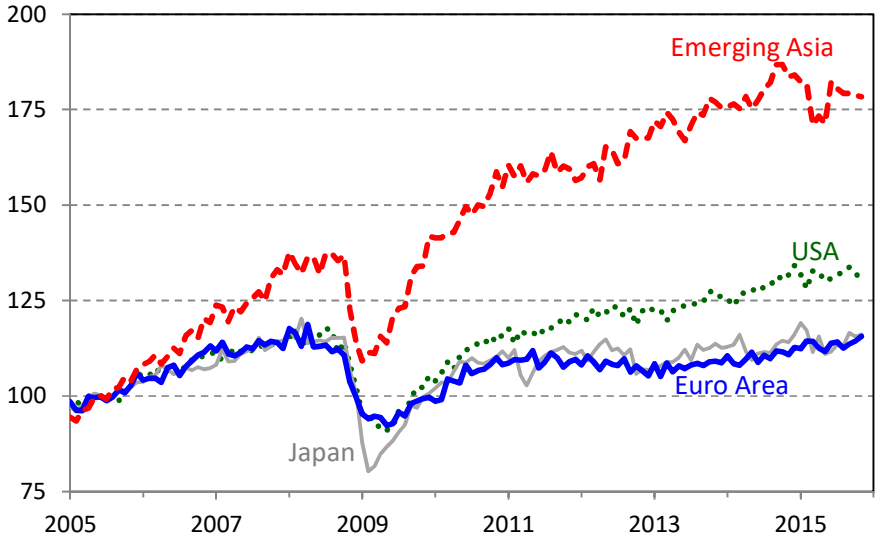
1 Introduction

Shocks affect regions differently. Some regions are hit particularly hard by a shock, and others are not. For natural disasters this is hardly surprising, as these are often region specific, but why macro-economic, or economy wide shocks affect regions differently is the topic of a growing body of literature; see for examples and recent surveys: (i) the 2010 special issue of the Cambridge Journal of Regions, Economy, and Society on *The Resilient Region*, (ii) the 2014 special issue of Raumforschung und Raumordnung on *Regional Economic Resilience: Policy Experiences and Issues in Europe*, and (iii) the 2016 special issue of Regional Studies on *Resilience Revisited*.

The Great Recession, which started in 2008, is an example of an economy wide shock which illustrates that not all regions respond in the same way, see Figure 1. The size of this shock has not been seen since the 1930s, see Irwin (2012). We analyse the role played by international trade linkages through supply chains (or global value chains) in the decline and recovery process following the Great Recession using various measures related to value-added trade flows (forward, backward, and total linkages) and the Grubel-Lloyd index of intra industry trade. In general, we find no effect for the value-added measures of supply chains, but strong effects for the Grubel-Lloyd index: a more intense involvement in intra-industry trade flows implies the duration of the trade decline and (particularly) recovery takes longer, such that the timing of the recovery is later. This also helps us to partially explain Europe's recovery problem, see Salvatore (2017).

Figure 1 Volume of trade, selected regions and countries; index (2005 = 100)



Source: based on monthly data from CPB Netherlands Bureau for Economic Policy Analysis (CPB); trade volume for a country or region is average of export and import index.

The first step in the resilience line of research is by now well-established, namely to show that regions differ in their shock sensitivity, see Fingleton, et al. (2012), Brakman,

Garretsen, and van Marrewijk (2015), and Martin et al. (2016). Although the concept of resilience has intuitive appeal, especially for policy makers, it is not without problems, see Martin and Sunley (2015) for a discussion of the main issues and Bailey and Turlok (2016) for an evaluation of its merits.

Existing resilience studies have an inward looking methodology; countries are most often studied in isolation with scant attention for linkages between countries or regions and the global economy. This is remarkable as the recent attention for supply chains hints at a relationship between resilience and international linkages. The World Trade Organization (2009, p.2), for example, notes: "...the magnitude of recent declines relates to the increasing presence of global supply chains in total trade. … – goods cross many frontiers during the production process and components in the final product are counted every time they cross a frontier. … this effect, whose magnitude can only be guessed at in the absence of systematic information...." Altomonte et al. (2012) observe that along a global supply chain shocks as well as recoveries can be magnified due to 'inventory' effects (the so-called bullwhip effect).[2] Brakman, Garretsen, and van Marrewijk (2015) suggest a link between regional specialization patterns (due to comparative advantage) and resilience, see Brakman and van Marrewijk (2017) and Ceglowski (2017) on measuring comparative advantages and Egger, Francois, and Nelson (2017) on connections associated with goods-trade networks. If specialization patterns are driven by international competition then a link between trade and resilience should be visible.

At the country level, the current discussion on the impact of supply chains on the Great Recession is inconclusive, ranging from Altomonte et al. (2012) on the one hand to Wagner and Gelübcke (2014) and Behrens et al. (2013) on the other hand. In these studies, Altomonte et al. (2012) note for France that along a global supply chain shocks as well as recoveries can be magnified due to a bullwhip effect, Wagner and Gelübke (2014) conclude for Germany that the hypothesis that foreign multinationals are more volatile following a negative shock is not supported by their empirical research, while Behrens et al. (2013) conclude that value chains play a minor role in Belgium. It is, however, not the inconclusiveness of the debate that is interesting: it is the heterogeneity of country experiences that suggests a study of more countries is informative, which is another contribution of this paper.

Sections 2 and 3 describe the data and the methodology. In section 4 we provide some highlights of the Great Recession and focus on the timing of various stages of the 'trade-cycle'. In section 5 we discuss measures of supply chains. We link these measures to the Great Recession in section 6 and conclude in section 7.

[2] Altomonte et al. (2012) focus on the ownership structure of French firms and find that the magnifying effects of supply chains is larger for within firm trade than for arms's length trade.

2 Data

We use four main data sources. First, our primary data source for the analysis in section 4 on the timing and extent of the Great Recession is based on real monthly data (based on gross trade flows) from the World Trade Monitor (WTM) kindly provided to us by CPB Netherlands Bureau for Economic Policy Analysis (CPB). The objective of the WTM is to provide a monitor for developments in global international trade as well as industrial production, but we restrict attention to trade flows only. The CPB processes over 3300 source series for its trade data on the basis of which it compiles generic monthly series for each included country that is standardized regarding frequency (monthly), denomination (US dollar), indexation, and seasonal & working day adjustment. In addition, the CPB compiles a consistent series of values, prices, and volumes, see CPB (2013) for technical details. We focus attention on monthly trade volume data measured in millions of constant 2005 US dollar for 80 individual countries.

Figure 1 already shows a big difference in trade recovery (resilience) for global regions. The CPB identifies eight major regions (four advanced regions and four emerging regions). At the aggregate level, the timing of the trough (the minimum) occurs early in Emerging Asia and at about the same time in other regions. The timing of the recovery, that is the return to the pre-crisis trade volume, varies enormously. It is quick in Emerging Asia and slow in the Euro Area. The main paper analyzes countries and not aggregate regions, as illustrated by the slow recovery in Japan and the intermediate recovery in the USA in Figure 1.

To analyse the possible connections between supply chains and the Great Recession in section 6, we use three main secondary data sources, namely the (i) World Development Indicators (WDI) online, (ii) the OECD-WTO Trade in Value Added (TiVA) database, and (iii) the Brülhart (2008) intra-industry trade data.

(i) The WDI is our source of information on population (in million) and income per capita (GDP PPP in constant 2011 international dollars). The income data is supplemented with information from the CIA World Factbook for missing data, see van Marrewijk (2017) for details.

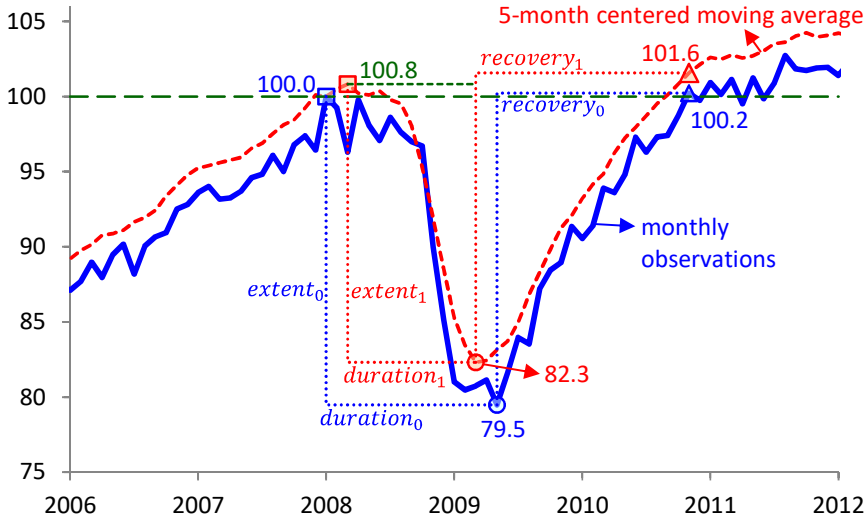
(ii) The TiVA database is our source of information for value-added based indicators of supply chain involvement in section 5, such as backward linkages (the share of foreign value added in gross exports) and forward linkages (the share of domestic value added directed to intermediate goods in gross exports).

(iii) We use the Brülhart data, compiled in preparation for the World Bank (2009) World Development Report, as our source for a country's involvement in intra-industry trade flows. Note that Brülharts results are based on detailed gross trade flows, where we use his 5-digit trade-weighted Grubel-Lloyd index as an alternative indicator for supply chain involvement in section 5. Whenever we refer to the Grubel-Lloyd index, please keep in mind that it is based on gross trade flows.

3 Methodology

We apply a simple definition of resilience; the time it takes to recover from a shock, that is, to return to the original (trend) level. We do not look at possible changes in sector structure or innovations that could be important for recovery. Our methodology is most easily explained by example. Figure 2 depicts the volume of 'trade' flows, which is calculated as the average of exports and imports. At the world level the difference between exports and imports is less than 0.3 percent in January 2008 (which is the index month in Figure 2, see below). For individual countries this difference can, of course, be much larger as countries can have a substantial trade surplus or deficit at a point in time.

Figure 2 The Great Recession; volume of world trade, index (January 2008 = 100)



Source: compiled from CPB WTM gross trade volume; trade is average of export and import volume; square is peak; circle is trough; triangle is recovery.

The solid line in Figure 2 depicts the monthly volume of world trade, which varies substantially from one month to the next. The Great Recession adversely affected the volume of world trade in particular from July 2008 to March 2009, while recovery is clear in the second half of 2009. To investigate the extent of the recession, the duration of the decline, and the speed at which the recession affected the volume of trade, we have to determine the pre-recession 'peak' as well as the 'trough', the low point of the recession. To investigate the duration of the recovery from the recession and the speed at which this occurs, we have to determine the post-recession 'recovery'.

- We define the *peak* as the maximum volume of trade in the period 2007 and 2008. Using monthly data at the world level the peak occurs in January 2008, which we therefore take as the basis for our volume index.
- We define the *trough* as the minimum volume of trade in the period 2008 – 2010. Using monthly data at the world level the trough occurs in May 2009, with an index of 79.5. This implies that the *extent* of the decline (the fall since the peak) is 20.5

percent, the *duration* of the *decline* (from peak to trough) is 16 months, and the average *speed* of the *decline* is 1.28 percent per month ($= 20.5/16$ percent).

- We define *recovery* as the first post-trough moment the volume of trade exceeds the peak level. Using monthly data at the world level recovery occurs in November 2010. This implies that the *duration* of the *recovery* (from trough to recovery) is 18 months, the *speed* of the *recovery* is 1.14 percent per month ($= 20.5/18$ percent), and the *total duration* (from peak to recovery) is 34 months (16 plus 18).

It is clear from Figure 2 that determining peak, trough, and recovery on the basis of monthly data depends to a fair extent on the 'natural' monthly fluctuations, even at the world level. After the peak in January 2008, for example, the volume of world trade declines in February and March of 2008, but then bounces back to almost the January level (at 99.8 percent) in April 2008, which could therefore be taken as an 'almost peak'. Similarly, after the recovery in November 2010 the volume of trade declines below the peak level in December 2010 (at 99.7 percent) before bouncing back above that level in January 2011.

Table 1 Overview of countries included in the analysis

Algeria	Estonia	Latvia	Singapore
Argentina	Finland	Lithuania	Slovak Rep
Australia	France	Macedonia	Slovenia
Austria	Germany	Malaysia	South Africa
Belarus	Guatemala	Malta	South Korea
Belgium	Hong Kong	Mexico	Spain
Brazil	Hungary	Morocco	Sweden
Bulgaria	Iceland	Netherlands	Switzerland
Canada	India	New Zealand	Taiwan
Chile	Indonesia	Norway	Tanzania
China	Iran	Paraguay	Thailand
Colombia	Ireland	Peru	Turkey
Costa Rica	Israel	Philippines	Ukraine
Croatia	Italy	Poland	Un. Arab Emirates
Cyprus	Japan	Portugal	United Kingdom
Czech Rep	Kazakhstan	Romania	United States
Denmark	Kenya	Russia	Vietnam
Dominican Rep	Kuwait	Saudi Arabia	Zambia

To reduce the impact of monthly fluctuations we calculated 5-month centered moving average trade flows, which are also depicted in Figure 2. Using the methodology outlined above for this new series, the peak of world trade occurs two months later in March 2008 (at an index of 100.8), the trough occurs two months earlier in March 2012 (at an index of 82.3), and recovery occurs in the same month (November 2010). The timing of peak,

trough, and recovery based on the centered 5-month moving average series is quite clear; note that the extent of the decline is somewhat smaller ($= 100 * (100.8 - 82.3)/ 100.8 = 18.4$ instead of 20.5 percent), the duration of the decline is somewhat shorter (12 instead of 16 months), the speed of the decline is somewhat higher ($= 18.4/12 = 1.53$ instead of 1.28 percent per month), the duration of the recovery is somewhat longer (20 instead of 18 months), the speed of the recovery is somewhat smaller ($= 18.4/20 = 0.92$ instead of 1.14 percent per month), and the total duration is somewhat shorter (32 instead of 34 months). Also note that all measures are related to the peak at 100.8 (and not the index value 100).

Our analysis is based at the volume of trade flows at the country level using the centered 5-month moving average methodology (from now on: unless specifically stated otherwise). We were provided with data for 80 individual countries. The idea is to have a country graph similar to Figure 2, such that we can attribute timing, decline, and recovery to the Great Recession and not to other fluctuations or influences. After determining peak, trough, and recovery as outlined above we visually inspected all country graphs and decided to exclude eight countries from the analysis as the evolution of the volume of their trade flows was not sufficiently linked to the natural experiment of Figure 2; the fluctuations are not sufficiently linked to the Great Recession.[3] The excluded countries are: Bolivia, Ecuador, Greece, Iraq, Luxembourg, Oman, Qatar, and Uruguay; see Table 1 for an overview of the 72 included countries (together accounting for 5.4 billion people, or 3/4th of the world population) and the Appendix for details on the excluded countries.

4 The Great Recession: The Country Experience

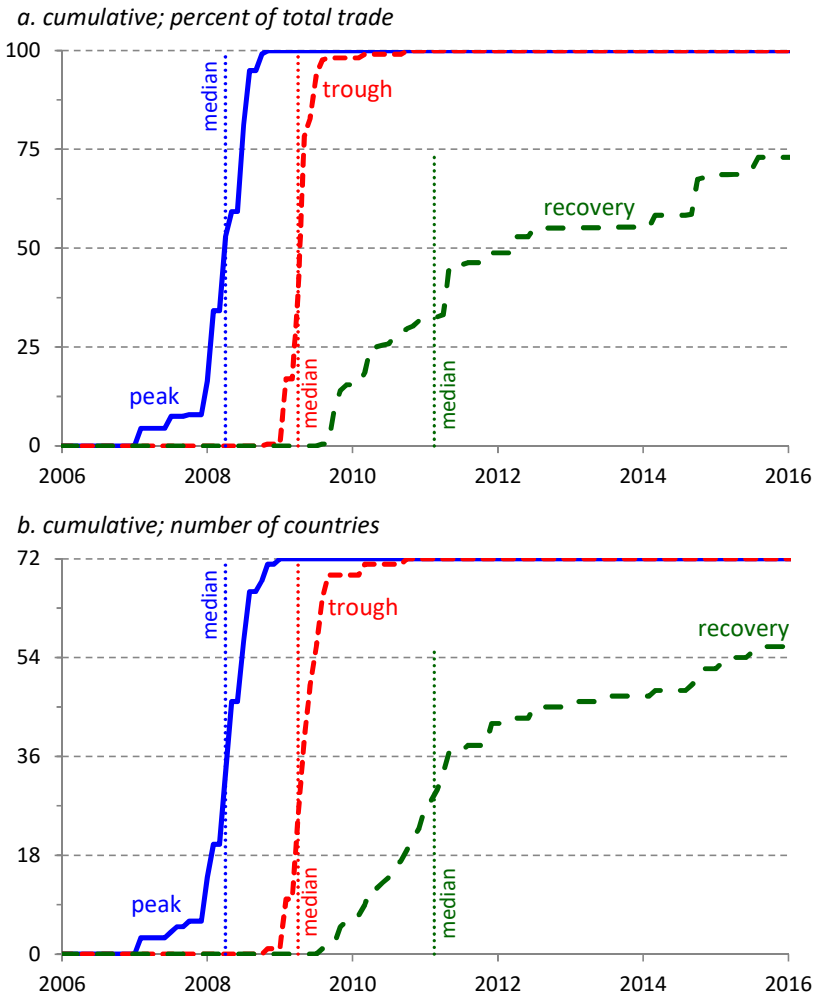
Based on the CPB-WTM real gross trade data (see section 2), the pre-crisis peak in *world* trade occurs in March 2008, the crisis-trough occurs 12 months later in March 2009, and it takes another 20 months until November 2010 for trade to recover to the pre-crisis peak level. This timing varies, of course, for the 72 individual countries we analyse.

- The median country peak occurs in April 2008, ranging from the first peak in January 2007 for Ireland and Italy to the last peak two years later in January 2009 for Paraguay.[4]
- The median country trough occurs in April 2009 (one year after the peak), ranging from the first trough in November 2008 for Vietnam to the last trough one year and 10 months later in September 2010 for the United Arab Emirates.
- As of February 2016 no less than 16 countries (22 percent of all countries, representing 27 percent of the trade flows) still had *not* recovered their trade flows to

[3] Bolivia, for example, had a stagnating trade flow in 2008-10, but not a decline. Qatar had a continuously rising trade flow throughout the period 2007-9. Greece is a special case for many reasons, and so on.
[4] The peaks for all three countries occur at the borders of our search period (2007 and 2008); checking the data shows that the actual peak occurs indeed in January 2007 for both Ireland and Italy, but one month later (January 2009 instead of December 2008) for Paraguay.

the pre-crisis peak level. Of the 56 countries that *did* recover the median recovery occurred in February – March 2011, ranging from the first recovery in August 2009 for Vietnam to the most recent recovery six years later in August 2015 for Belgium.

Figure 3 Timing of peak, trough, and recovery; cumulative distribution)



Source: authors's calculations using section 3 methodology for centered 5-month moving average trade; the median values refer to countries in both panels.

These observations are illustrated using cumulative distributions in Figure 3 in two panels, where panel *a* uses the country's weight in total trade flows and panel *b* uses the country as unit of observation. The figure illustrates that the timing of the trough is quite steep around April 2009 and that the time to recovery varies substantially between countries. In fact, 16 countries have not yet recovered; namely three countries in Asia (Iran, Japan, and United Arab Emirates) and 13 countries in Europe (Austria, Croatia, Cyprus, Denmark, Finland, France, Italy, Norway, Portugal, Spain, Sweden, Ukraine, and UK).

Table 2 provides basic statistics on the Great Recession at the country level. We already discussed the median, minimum, and maximum values for the timing of peak, trough, and

recovery. The average timing is close to the median value for peak and trough, but substantially higher for recovery, namely around September 2011 instead of February-March, indicating a skewed distribution. The standard deviation of the timing of the trough is only 0.26 years, somewhat smaller than for the peak (0.37 years) and substantially smaller than for recovery (1.66 years). This indicates again large variation between countries in terms of recovery.

Table 2 Summary of Great Recession statistics, country level

	average	median	minimum	maximum	st. dev.	# obs
Peak	2008.22	2008.25	2007.00	2009.00	0.37	72
Trough	2009.32	2009.25	2008.83	2010.67	0.26	72
Recovery	2011.64	2011.12	2009.58	2015.58	1.66	56
Size (%)	21.64	21.05	5.34	45.45	6.36	72
Duration (months)						
Decline	13.2	12	6	37	5.45	72
Recovery	28.3	21	6	76	19.57	56
Total	40.9	35	13	97	22.11	56
Speed (% per month)						
Decline	1.84	1.80	0.41	5.68	0.81	72
Recovery	1.07	1.02	0.23	2.50	0.60	56

Source: authors's calculations; timing: *x*.00 = January, each extra month adds 1/12; size = extent of the decline from peak to trough in percent.

The average size of the decline is 21.6 percent, ranging from 5.3 percent for Algeria to 45.4 percent for Ukraine. The median duration of the decline is 12 months, ranging from 6 months for six different countries to 37 months for Ireland. The median duration of the recovery (for the countries that have recovered) is 21 months, ranging from 6 months for Indonesia to 76 months for Belgium and Malaysia. The median total duration (decline plus recovery for the countries that have recovered) is 35 months, ranging from 13 months for Paraguay (14 months for China and South Korea) to 97 months for Ireland. In all cases the average duration is higher than the median.

The median speed of the decline is 1.80 percent per month, substantially faster than the median speed of recovery which is 1.02 percent per month. The speed of the decline ranges from about 0.4 percent per month for Algeria and Ireland to almost 5.7 percent per month for Ukraine. The speed of recovery ranges from a crawling 0.23 percent per month for Belgium to more than ten times that speed for China and Paraguay. The variation between countries is large. Our hypothesis is that international linkages could explain the differences between countries. A straightforward measure of linkages is to look at global supply chains. Modern trade is characterized by the fragmentation of the production process that links countries to each other (Baldwin, 2016). This linkage implies that a shock on one end of this chain could travel all the way to the other end.

5 Measuring supply chains

Adequately measuring supply chains is notoriously difficult as it involves the simultaneous importing and exporting of goods and components at different stages of the production process in related sectors. Streams are usually co-ordinated at the firm level, often involving multinational enterprises and different countries (allowing for differences in comparative advantages). As a consequence, supply chains connect countries at different levels of economic development, and are possible channels along which shocks propagate over the world.

One way to measure supply chains is to focus on the value added at different stages of the production process. Great advances have been made recently, for example thanks to the work of the World Input Output Data (WIOD) database at the University of Groningen (www.wiod.org) and the work of the Organization of Economic Cooperation and Development (OECD) and the World Trade Organization (WTO) in the Trade in Value Added (TiVA) database. We use the TiVA database as it incorporates a larger range of countries. At the country level, supply chains are measured in the TiVA database in three different ways:

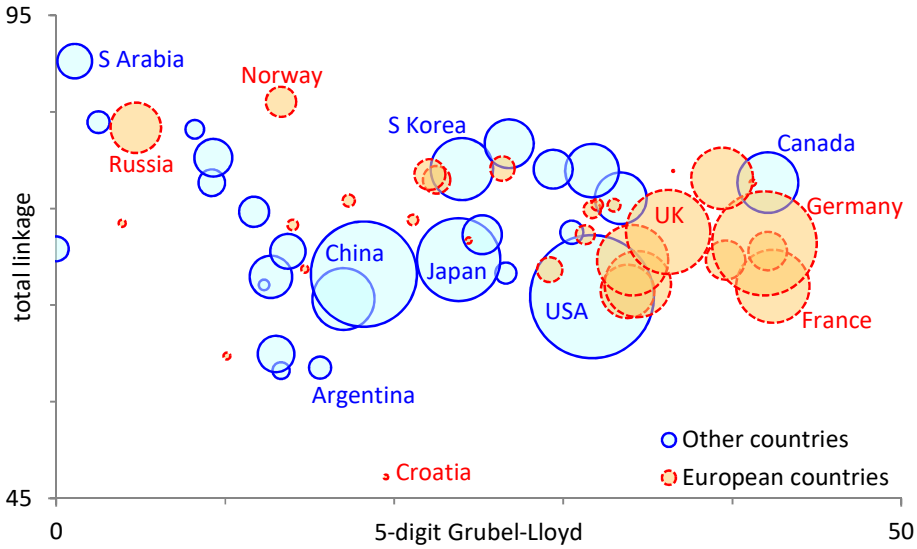
- *Backward* linkages; this measures the share of value added in export flows that is imported from abroad.
- *Forward* linkages; this measures the share of domestic value added content in export flows that is used as an intermediate input of foreign sectors.
- *Total* linkages; this is the sum of backward and forward linkages.

Brakman, Kohl, and van Marrewijk (2015) discuss some advantages and disadvantages of measuring supply chains using the WIOD or TiVA value added data. Some limitations are (i) the informational requirements for constructing the data (which creates a bias by excluding the least developed countries), (ii) the limited number of identified sectors (34 for TiVA and 35 for WIOD), and the limited number of countries. This is related to informational requirements and the level of aggregation in input-output data, and (iii) the measures can be biased because of outlying countries. Take, Saudi Arabia for instance, It's oil exports are used as an intermediate input in many countries. This does not mean that Saudi Arabia is part of supply chains in the sense that oil is part of fragmentation of the production processes that has been made possible by the information technology revolution (Baldwin, 2016). Oil supplied by Saudi Arabia can easily be replaced by oil supply from another source (for example by shale oil produced in the US). In contrast, a faulty taptic engine for the Apple watch in 2015 disrupted the production process severely as no substitutes were available. Other examples are Brunei and Russia that also score high in the value-added index but their involvement in global supply chains mimics that of Saudi Arabia and is rather limited.[5] On the other end of the picture, the USA, China, and Germany only score relatively low on the value-added supply chain index,

[5] Norway and Luxembourg also score high, but this might reflect actual involvement in supply chains.

whereas we know that all three countries play an important role in many global supply chains. Their low score seems related to the size of their trade flows rather than their actual involvement (see van Marrewijk, 2017 ch. 15, for a further discussion).

Figure 4 Supply chain measures; total linkage and 5-digit Grubel-Lloyd



Source: authors's calculations; size of bubble proportional to trade in 2008; 55 countries included.

An alternative measure of supply chains, which does not have these limitations, focuses on the two-way trade nature of supply chains and uses a detailed 5-digit Grubel-Lloyd (G-L) index instead. The advantage of this measure is that (i) information is available for almost all countries, (ii) information is available at a detailed sector level, and (iii) the index measures actual involvement in supply chains rather than more distant involvement. Since supply chains measured by the G-L index involve two-way trade in the same sector, it can be biased if intermediate products come from outside the sector itself. Broadening the definition of sectors deals with this problem. Under the assumption that most intermediate trade – within a supply chain – is predominantly trade within the same sector, we can use it as a method for measuring supply chains; the higher the index the more important are supply chains. It also corrects for the 'too distant' value-added problem of Saudi Arabia discussed above by excluding trade flows with other sectors. We analyse data at the detailed 5-digit level based on the work of Marius Brülhart (2008).

In this paper, we do not compare the merits of either supply chain measure as such, but simply analyse the relationships between the economics of the Great Recession (regarding peak, trough, and recovery) and the available measures of supply chains.

Our analysis of the Great Recession uses data for 72 countries. The TiVA database (which covers 61 countries) provides information on the backward and forward linkages for 55 of our 72 countries. Figure 4 distinguishes between European and Other countries and provides information regarding the extent to which the total linkages supply chain

measure is related to the 5-digit Grubel-Lloyd index: there is virtually *no* relationship between these two measures (the correlation coefficient is even mildly *negative*: -0.065). Countries like Saudi Arabia and Russia score high on total linkages (thanks to their strong forward linkages) but low on the Grubel-Lloyd index; countries like Argentina and Croatia score low on total linkages and low-medium on Grubel-Lloyd index; countries like the UK and Germany score medium on total linkages and high on Grubel-Lloyd index, and so on.

Table 3 Correlation coefficients between different supply chain measures

	backward linkages	forward linkages
Backward linkages	1	
Forward linkages	-0.782	1
5-digit Grubel-Lloyd index	0.392	-0.386

Source: authors's calculations; 55 countries included.

Note: backward- and forward linkages are based on value-added trade flows, while Grubel-Lloyd index is based on gross trade flows (see section 2).

Table 3 explains why the correlation between total linkages and the Grubel-Lloyd index is so low: there is a reasonably strong *positive* correlation between backward linkages and the Grubel-Lloyd index (0.392), which is almost perfectly compensated by a reasonably strong *negative* correlation between forward linkages and the Grubel-Lloyd index (-0.386). The table also shows that there is a strong negative correlation between backward and forward linkages (-0.782): countries with high backward linkages tend to have low forward linkages, and vice versa. The next section thus analyzes backward and forward linkages both jointly and separately.

6 Supply chains and the Great Recession

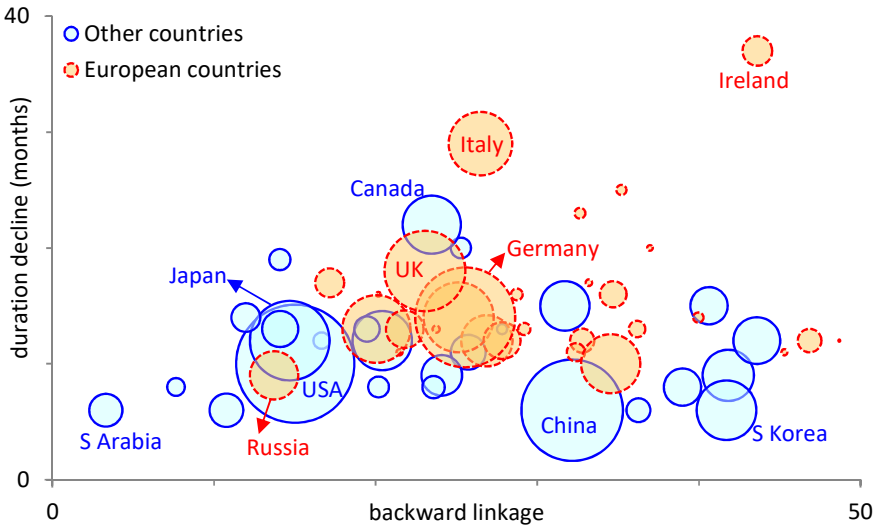
We analyse the links between two different supply chain measures and the impact of the Great Recession in two steps, namely first for the value added measures (backward- and forward linkages) and then for the Grubel-Lloyd index based on gross trade flows.

6.1 Value added measures and the Great Recession

The main relationship between the impact of the Great Recession and the value added measures of supply chains is illustrated for backward linkages and the duration of the decline (measured in months) in Figure 5: there is no relationship. The duration of the decline was short (six months) in Saudi Arabia with virtually no backward linkages as well as in China and South Korea with substantial backward linkages. Similarly, the duration of the decline was high in Ireland (37 months) with high backward linkages, but also high in Italy and Canada (29 and 22 months) with medium backward linkages. A formal regression shows indeed that there is *no* relationship between the size of the backward linkages and the duration of the decline in months (see the discussion around Table 4 below for details). The duration of the decline is chosen for illustration purposes

as it includes all 55 countries, in contrast to the duration of the recovery which includes only 42 countries (see again the discussion below).

Figure 5 Backward linkages and the duration of the decline in months



Source: authors's calculations; size of bubble proportional to trade in 2008; 55 countries included.

Table 4 summarizes the absence of a relationship between value added supply chain measures and the Great Recession in two parts. Table 4*a* analyzes the impact of backward and forward linkages on nine different Great Recession variables, namely the timing (in years) of (i) peak, (ii) trough, and (iii) recovery, (iv) the size of the decline, the duration (in months) of (v) the decline, (vi) the recovery, and (vii) in total (sum of decline and recovery), and finally the speed (in percent per month) of (viii) decline and (ix) recovery. Not one of the estimated 18 coefficients is statistically significant. This result is surprising as supply chain linkages are expected to force countries to move in tandem with respect to recessions, and even to magnify linkages along the supply chain, as explained by Altomonte, et al., (2012).

Table 4b repeats the analysis of Table 4a with a dummy variable for Europe as a control variable. Again, not one of the 18 estimated backward and forward linkages is statistically significant. In contrast, the Europe variable is highly statistically significant in seven of the nine cases; this indicates that in Europe the timing of the trough occurs about 0.17 years later, the timing of the recovery (for the countries that have recovered) about 1.55 years later, that the duration of the decline is about 4 months longer and of the recovery about 17 months longer (in total about 21 months longer), and that the speed of the decline is about 0.5 percent per month slower and of the recovery about 0.6 percent slower. The reason to include a Europe control is straightforward. Of the 55 countries for which we have value added supply chain measures 13 have not yet recovered fully from the Great Recession; of these 13 countries 12 are in Europe (the other country is Japan).

Table 4 Regression overview with backward and forward linkages as exogenous variable

Panel a Without Europe control

Variable	backward	P>|t|	forward	P>|t|		R^2
Timing (year)						
Peak	-0.001	0.846	0.008	0.240		0.082
Trough	0.001	0.828	0.001	0.705		0.003
Recovery	0.069	0.149	0.037	0.388		0.064
Size (%)	0.079	0.477	-0.104	0.288		0.124
Duration (months)						
Decline	0.029	0.804	-0.077	0.463		0.043
Recovery	0.786	0.156	0.396	0.432		0.066
Total	0.810	0.195	0.303	0.593		0.070
Speed (% per month)						
Decline	0.011	0.453	0.007	0.576		0.011
Recovery	-0.016	0.329	-0.016	0.302		0.028

Panel b With Europe control

Variable	backward	P>|t|	forward	P>|t|	Europe	P>|t|	R^2
Timing (year)							
Peak	0.000	0.982	0.007	0.288	-0.167	0.113	0.127
Trough	-0.001	0.871	0.002	0.524	0.169***	0.005	0.146
Recovery	0.037	0.419	0.030	0.460	1.550**	0.013	0.206
Size (%)	0.068	0.544	-0.099	0.318	1.094	0.481	0.133
Duration (months)							
Decline	-0.010	0.928	-0.056	0.573	4.031**	0.013	0.154
Recovery	0.438	0.415	0.314	0.509	16.931**	0.020	0.191
Total	0.386	0.519	0.203	0.701	20.648**	0.011	0.216
Speed (% per month)							
Decline	0.015	0.255	0.004	0.708	-0.485**	0.010	0.131
Recovery	-0.003	0.823	-0.013	0.358	-0.612***	0.004	0.221

Source: authors's calculations; shaded cells are significant at 10% or better; number of observations is 55 for Peak, Trough, Decline & Size rows and 42 for Recovery & Total rows.

Note: backward- and forward linkages are based on value-added trade flows.

Possible objections to our analysis in Table 4 are that we ignore the total supply chain linkage and that we include both backward and forward linkages in the regression, while the correlation between these two supply chain measures is high (-0.782, see Table 3). To alleviate these concerns, Table 5a provides separate estimates of the impact of backward linkages, forward linkages, and total linkages on each of the nine Great Recession variables, while including a Europe control variable in Table 5b to deal with the special role of Europe in supply chain networks (think f.i. of Germany). With the exception of

the size of the decline in percent, not one of the 27 estimated supply chain measure coefficients is statistically significant. The exception regarding the size of the decline implies that a one percentage point higher backward linkage results in a 0.15 percent higher trade decline, or equivalently (in view of the high correlation between backward and forward linkages) that a one percentage point *lower* forward linkage results in a 0.14 percent higher decline. In contrast, the Europe variable is (highly) statistically significant in all cases, except for the size of the decline and for the timing of the peak for forward linkages. This brings us to the next sub-section.

Table 5 Regression overview with backward-, forward-, and total-linkages separately

Panel a Backward-, forward, and total-linkages estimates

Variable	backward	P>|t|	R^2	forward	P>|t|	R^2	total	P>|t|	R^2
Timing (year)									
Peak	-0.006	0.227	0.107	0.007	0.106	0.127	0.005	0.406	0.094
Trough	-0.003	0.316	0.139	0.003	0.238	0.146	0.002	0.649	0.126
Recovery	0.009	0.724	0.195	0.003	0.905	0.192	0.031	0.436	0.205
Size (%)	0.154**	0.038	0.116	-0.144**	0.026	0.127	-0.061	0.549	0.046
Duration (months)									
Decline	0.039	0.599	0.148	-0.049	0.442	0.154	-0.046	0.640	0.147
Recovery	0.144	0.627	0.182	-0.009	0.972	0.177	0.333	0.478	0.188
Total	0.195	0.553	0.213	-0.081	0.781	0.207	0.231	0.658	0.210
Speed (% per month)									
Decline	0.011	0.185	0.129	-0.006	0.447	0.109	0.007	0.553	0.105
Recovery	0.008	0.327	0.204	-0.010	0.183	0.220	-0.011	0.412	0.198

Panel b Associated Europe dummy variable estimates

	backward var estimate		forward var estimate		total var estimate	
Variable	Europe	P>|t|	Europe	P>|t|	Europe	P>|t|
Timing (year)						
Peak	-0.176*	0.095	-0.166	0.107	-0.212**	0.037
Trough	0.166***	0.005	0.168***	0.005	0.149***	0.009
Recovery	1.581**	0.010	1.680***	0.005	1.611***	0.005
Size (%)	1.220	0.431	1.221	0.424	2.187	0.156
Duration (months)						
Decline	4.103**	0.010	4.012**	0.011	4.331***	0.005
Recovery	17.263**	0.017	18.473***	0.009	18.011***	0.008
Total	20.863***	0.009	22.004***	0.005	22.227***	0.003
Speed (% per month)						
Decline	-0.491***	0.009	-0.457**	0.015	-0.414**	0.021
Recovery	-0.625***	0.003	-0.624***	0.002	-0.533***	0.007

See Table 4 for details; regressions in panel a are with Europe control, which is provided in panel b.

Note: backward-, forward-, and total linkages are based on value-added trade flows.

6.2 The Grubel-Lloyd index and the Great Recession

The analysis in sub-section 6.1 indicates that value added based supply chain measures have no impact on the Great Recession, but also that Europe plays a special role. The Grubel-Lloyd index, our alternative supply chain measure, highlights the special role of Europe relative to other countries of the world and relative to the value added supply chain measures better than the measure based on value added data (see section 5).

Table 6 Europe versus Other country differences in supply chain characteristics

	GL5	GL5*	backward	forward	total
a Other countries					
Minimum	0.0	0.0	3.3	33.3	58.2
Maximum	42.1	42.1	43.6	87.0	90.3
Average	13.8	18.6	24.0	49.0	73.0
Weighted-average#	23.0	24.0	24.5	46.7	71.2
Observations	39	26	26	26	26
b European countries					
Minimum	3.9	3.9	13.7	27.0	47.2
Maximum	42.4	42.4	48.7	69.7	86.1
Average	25.3	27.3	30.5	42.1	72.6
Weighted-average#	34.6	35.1	25.7	46.2	71.9
Observations	33	29	29	29	29
c European average minus Other country average (as percent of other country average)					
Average	84	47	27	-14	-1
Weighted-average#	51	46	5	-1	1

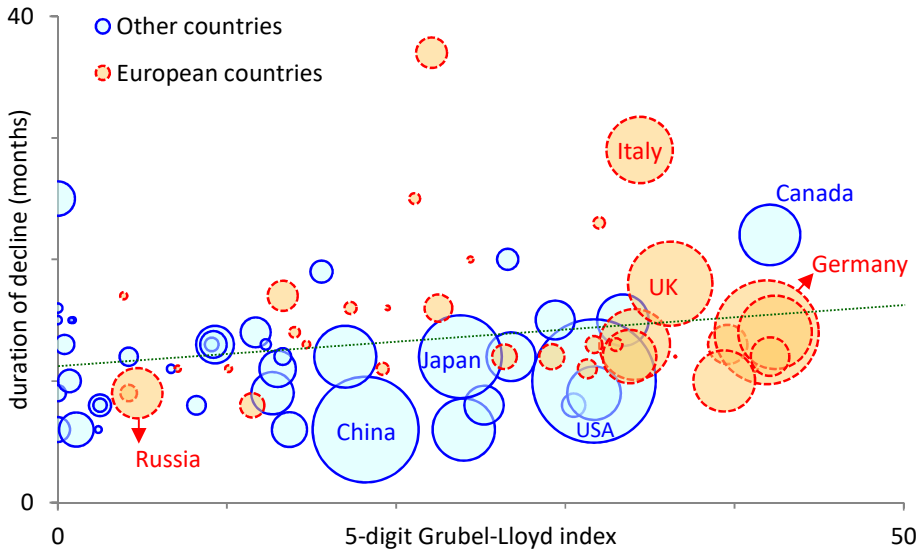
Source: authors's calculations; * includes countries for which backward, forward, and total linkages are also available; # based on size of trade flows in 2008; GL5 is 5-digit GL index.

Note: backward-, forward-, and total linkages are based on value-added trade flows, while the Grubel-Lloyd index is based on gross trade flows.

Table 6 provides an overview of the differences in characteristics of the supply chain measures for European countries (panel a) versus Other countries (panel b) and compares the difference in trade-weighted averages (panel c; the unweighted averages are provided for comparison, but the discussion focuses on the weigthed averages). The GL5 column provides the summary statistics of the Grubel-Lloyd index for all 72 countries in the data set (33 European countries and 39 Other countries). It indicates that the range (minimum, maximum, and their difference) is quite similar for European countries and for Other countries, but that the average is substantially larger for European countries, namely about 12 percentage points (or about 51 percent higher than the Other countries' trade-weighted average). Since we do not have the value added supply chain measures available for all countries, column GL5* repeats the exercise for the 55 countries for which we have backward, forward, and total linkages available (29 European countries

and 26 Other countries). We arrive at the same conclusion: the range is similar for European and Other countries, but the average is substantially higher for European countries, namely about 11 percentage points (or about 46 percent of the Other countries' trade-weighted average).

Figure 6 Grubel-Lloyd index and the duration of the decline in months



Source: authors's calculations; size of bubble proportional to trade in 2008; 72 countries included; dotted line is a simple regression line for all countries.
Note: the Grubel-Lloyd index is based on gross trade flows.

The columns backward, forward, and total repeat the exercise for the value added supply chain measures. There are again modest differences in the ranges of the supply chain measures (which is somewhat smaller for European countries in both backward and forward linkages, but somewhat larger for European countries in total linkages). This time, however, there are only small differences in the averages for European versus Other countries, namely of only about one percentage point for backward linkages, forward linkages, *and* total linkages (which translates to about 5 percent, 1 percent, and 1 percent of the Other countries' trade-weighted averages). The conclusion is therefore simple: the differences between European countries and Other countries regarding the value added supply chain measures are small, but regarding the Grubel-Lloyd index are substantial.

Figure 6 shows the relationship between the Grubel-Lloyd index and the duration of the decline (in months), and is thus the counterpart of Figure 4. The figure depicts a modest positive relationship between the duration of the decline and the Grubel-Lloyd index which is statistically significant (see Table 7). This relationship holds for both groups of countries. Among the Other countries group the duration of the decline is, for example, short in China (6 months) with a medium-low Grubel-Lloyd index and long in Canada (22 months) with a high Grubel-Lloyd index, with Japan and the USA in between. Among the European countries the duration of the decline is short in Russia (9 months)

with a low Grubel-Lloyd index and long in the UK, Italy, and Germany with a high Grubel-Lloyd index, with a range of small countries in between. When we include a Europe control variable the relationship therefore remains statistically significant (see Table 7).

Table 7 Regression overview with 5-digit Grubel-Lloyd index as exogenous variable

	Without Europe control			With Europe control				
Variable	GL5	P>|t|	R^2	GL5	P>|t|	Europe	P>|t|	R^2
Timing (year)								
Peak	-0.011***	0.001	0.150	-0.122	0.191	-0.009**	0.013	0.171
Trough	-0.004*	0.093	0.040	0.096	0.167	-0.005**	0.034	0.066
Recovery	0.045***	0.008	0.124	1.190**	0.011	0.028*	0.094	0.225
Size (%)	0.035	0.541	0.005	4.290**	0.011	-0.038	0.540	0.095
Duration (months)								
Decline	0.083*	0.085	0.042	2.611*	0.069	0.039	0.458	0.087
Recovery	0.573***	0.004	0.146	13.24**	0.015	0.391**	0.049	0.237
Total	0.649***	0.004	0.147	0.453*	0.053	15.89**	0.010	0.249
Speed (% per month)								
Decline	-0.010	0.184	0.025	0.079	0.719	-0.011	0.181	0.027
Recovery	-0.009	0.144	0.039	-0.355*	0.050	-0.004	0.514	0.107

Source: authors's calculations; shaded cells are significant at 10% or better; number of observations is 72 for Peak, Trough, Decline & Size rows and 56 for Recovery & Total rows.

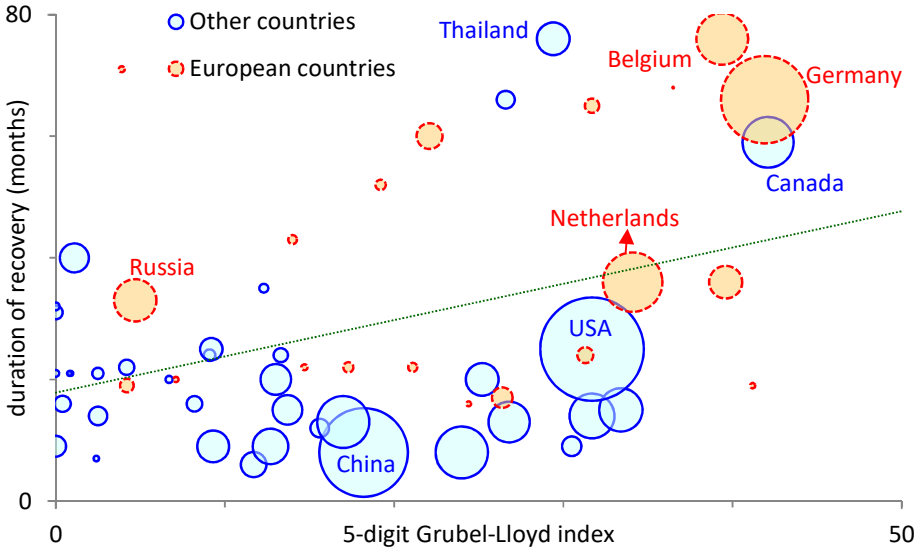
Note: backward-, forward-, and total linkages are based on value-added trade flows, while the Grubel-Lloyd index is based on gross trade flows.

Table 7 provides an overview of the impact of supply chains measured using the Grubel-Lloyd index on nine variables of the Great Recession. The left part of the table groups all countries together and shows that a high Grubel-Lloyd index significantly affects the timing of peak (earlier), trough (earlier to a smaller extent), and recovery (later), as well as the duration of decline (longer), recovery (much longer), and in total (much longer). The size of the decline and the speed of decline and recovery are not significantly affected.

If we take the 11.1 percentage points higher Grubel-Lloyd index for European countries versus Other countries (see Table 6) for the significant variables of the left part of Table 7 as an indication, this implies that as a result of the more intensive involvement of European countries in supply chains the timing of the trade peak occurred in Europe about 44 days earlier, the trough about 14 days earlier, and the recovery about 181 days later.[6] As a consequence, the duration of the decline in Europe was about 28 days longer, the duration of the recovery (for the countries that have recovered) about 191 days longer, and the total duration about 216 days longer.

[6] Regarding timing of the peak, for example: -0.011 times 11.1 is -0.12 years or -44 days, and so on.

Figure 7 Grubel-Lloyd index and the duration of the decline in months



Source: authors's calculations; size of bubble proportional to trade in 2008; 56 countries included; dotted line is a simple regression line for all countries.
Note: the Grubel-Lloyd index is based on gross trade flows.

These effects persist for the three duration variables and the timing of the recovery when we add a Europe control variable. The significance of the timing of peak and trough is then taken over by the Europe variable, while the size of the decline becomes significantly positive and the speed of the recovery significantly negative when a Europe control is added. All in all, we conclude that the Grubel-Lloyd index significantly affects the Great Recession variables, particularly regarding the timing and duration of the recovery (later and longer). Associated with that is, of course, a longer total duration.

Figure 7 illustrates the longer duration of the recovery for the 56 countries that have recovered. Among both groups of countries a high Grubel-Lloyd index implies that it took longer to recover from the Great Recession. Among the Other countries this holds, for example, for Canada and Thailand. Among the European countries it holds, for example, for Belgium and Germany. So what about the countries that have not yet recovered in January 2016 which are excluded from Figure 7? Part of the reason for their late recovery is related to their involvement in supply chains as measured by the Grubel-Lloyd index. The simple average Grubel-Lloyd index of the countries that have recovered from the Great Recession is 17.2 percent, which is substantially lower than the 24.0 percent average for the countries that have not yet recovered. This discrepancy persists (but becomes somewhat smaller) if we take trade-weighted averages, namely an average of 27.0 percent for the recovered countries compared to an average of 31.0 percent for the countries that have not yet recovered.

7 Conclusion

We analyse the link between the existence of supply chains and the extent to which the Great Recession has affected the global economy. We use the Great Recession as an example of a big shock to economies. Our hypothesis assumes countries that are more involved in international supply chains are more susceptible to (global) shocks, but also recover faster. Supply chains could thus explain the resilience of those nations and regions that are heavily involved in global supply chains. The existing literature on resilience has a strong national focus and tends to disregard international linkages of regions. We analyze the international linkages and stress the heterogeneity in outcomes between countries.

We study the impact of the Great Recession in two steps, first for the value added measures and then for the Grubel-Lloyd index based on gross trade flows. Both types of measures highlight different aspects of supply chains; value added measuresstress that part of the production is done elsewhere in the world, whereas the Grubel-Lloyd index emphasizes international intra-industry linkages. The advantage of the latter method is that much more detailed information is available for many sectors and all countries. With respect to the value added measures we, in general, find no effect, which is in line with the studies of Wagner and Gelübcke (2014) and Behrens et al. (2013). Only if we separate out Europe do we find that the timing of the trough in Europe occurs about 0.17 years later and of the recovery (for the countries that have recovered) about 1.55 years later. The duration of the decline in Europe is about 4 months longer and of the recovery about 17 months longer.

We can partially explain the special nature of European resilience using the Grubel-Lloyd index as a measure of supply chains, which is thus in contrast to Wagner and Gelübcke (2014) and Behrens et al. (2013). The G-L index has the advantage that countries that are not involved in the fragmentation of production processes, such as Saudi Arabia, are not biasing the indices. The extent to which European countries are more intensively involved in supply chains as measured by the Grubel-Lloyd index implies that the trade peak occured about 44 days earlier in Europe than in the Other countries, the trough about 14 days earlier, and the recovery about 181 days later. As a consequence, the duration of the decline in Europe was about 28 days longer, the duration of the recovery (for the countries that have recovered) about 191 days longer, and the total duration about 216 days longer.

In contrast to the value added measures, we thus find for the Grubel-Lloyd measure of supply chains that participation significantly affects the Great Recession variables, particularly regarding the timing and duration of the recovery (later and longer). In contrast to Altomonte et al.(2012) we do not find a faster drop and faster recovery in association with the intensity of supply chains. To some extent this might be explained by the different aggregation levels used; we use macro-data and Altomonte et al. (2012) use

micro-data. Our results point towards a slow(er) adjustment of production to new expected levels of demand, which could indicate a stronger influence of risk aversion at the macro level or changes in trade conditions, for example, more stringent export credit prerequisits. This, however, is a topic for future research.

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Appendix

Countries excluded from the analysis because their trade flows do not follow the Great Recession peak – trough – recovery picture depicted in Figure 1.