

## Estimating Trade Elasticities: Demand Composition and the Trade Collapse of 2008–2009<sup>†</sup>

By MATTHIEU BUSSIÈRE, GIOVANNI CALLEGARI, FABIO GHIRONI,  
GIULIA SESTIERI, AND NORIHIKO YAMANO\*

*This paper introduces a new empirical model of international trade flows based on an import intensity-adjusted measure of aggregate demand. We compute the import intensity of demand components by using the OECD Input-Output tables. We argue that the composition of demand plays a key role in trade dynamics because of the relatively larger movements in the most import-intensive categories of expenditure (especially investment, but also exports). We provide evidence in favor of these mechanisms for a panel of 18 OECD countries, paying particular attention to the 2008–2009 Great Trade Collapse. (JEL E23, F14, F17, F44, G01)*

The relation between trade flows and aggregate macroeconomic dynamics is a central and long-standing question in international economics. The issue has received renewed attention, and the debate on the determinants of trade flows has reheated, as scholars debated the adjustment of the global trade imbalances that emerged in the 2000s and struggled to understand the dynamics of world trade in the aftermath of the global financial crisis of 2008–2009. One of the key features of

\*Bussière: Banque de France, 31 rue Croix des Petits Champs 75001, Paris, France (e-mail: matthieu.bussiere@banque-france.fr); Callegari: European Central Bank, Kaiserstrasse 29 60318 Frankfurt am Main, Germany (e-mail: giovanni.callegari@ecb.int); Ghironi: Department of Economics, Boston College, Federal Reserve Bank of Boston, and National Bureau of Economic Research (NBER), 140 Commonwealth Avenue, Chestnut Hill, MA 02467-3859, (e-mail: fabio.ghironi@bc.edu); Sestieri: Banque de France, 31 rue Croix des Petits Champs 75001, Paris, France (e-mail: giulia.sestieri@banque-france.fr); Yamano: Organisation for Economic Co-operation and Development (OECD), 2 Rue André Pascal, 75775 Paris Cedex 16, Paris, France (e-mail: norihiko.yamano@oecd.org). For helpful comments and discussions, we thank two anonymous referees, James Anderson, Philippe Bacchetta, Andrew Bernard, Michele Cavallo, Robert Feenstra, Joseph Gruber, Luca Guerrieri, Elhanan Helpman, Leonardo Iacovone, Jean Imbs, Olivier Jeanne, Robert Kollmann, Benjamin Mandel, Andrew Rose, Kathryn Russ, Linda Tesar, Shang-Jin Wei, and seminar and conference participants at ASSA 2011, the Banque de France, the Board of Governors of the Federal Reserve System, Brandeis University, BRUEGEL, the ECB, the Federal Reserve Bank of Boston, the NBER ITI Spring 2011 meeting, the workshop on “Challenges in Open Economy Macroeconomics after the Financial Crisis” at the Federal Reserve Bank of St. Louis, and the BdF/PSE Conference on “The Financial Crisis: Lessons for International Macroeconomics.” We are grateful to Jonathan Hoddenbagh for carefully reviewing our theoretical work. Remaining errors are our responsibility. Work on this paper was done while Callegari was an economist at the International Monetary Fund, and Ghironi was a visiting scholar at the Federal Reserve Bank of Boston. The support of these institutions is acknowledged with gratitude. Ghironi also thanks the National Science Foundation for support through a grant to the NBER. The views expressed in this paper are those of the authors and do not reflect the views or policies of the Banque de France, the European Central Bank, the Federal Reserve Bank of Boston, the International Monetary Fund, the NBER, or the OECD.

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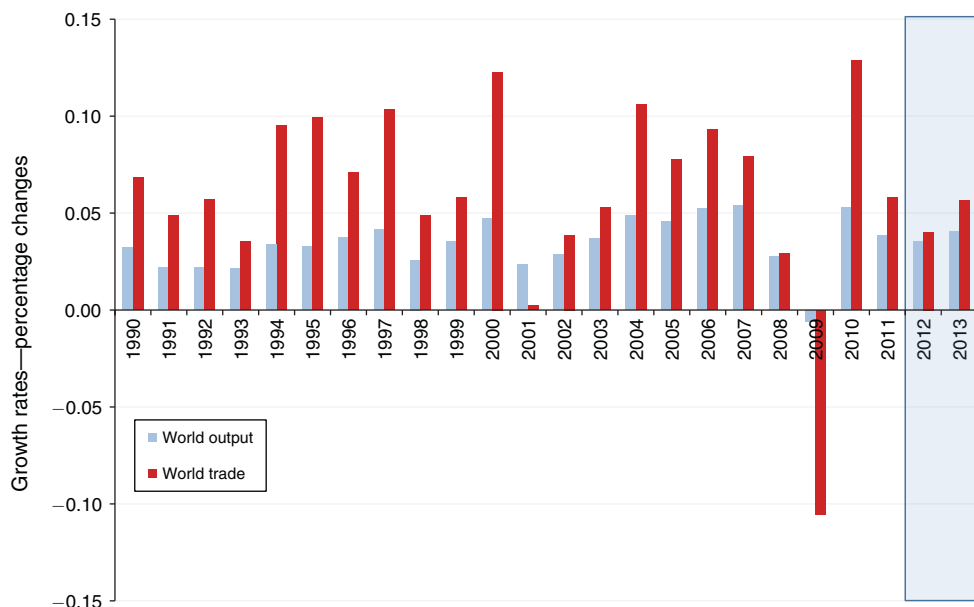


FIGURE 1. RECENT DEVELOPMENTS AND PROJECTIONS IN WORLD TRADE AND OUTPUT (*Volumes*)

Note: The shaded area corresponds to IMF projections.

Source: IMF World Economic Outlook—April 2012

the global recession triggered by this crisis was a sharp contraction in world trade that reached its peak between the end of 2008 and the beginning of 2009. In 2009, global trade fell by more than 10 percent in real terms on a year-on-year basis—an unprecedented development since World War II. A distinct feature of this Great Trade Collapse (GTC; Baldwin 2009) is that the fall in world trade was much more pronounced than the fall in world output (real world GDP dropped by 0.6 percent in 2009). The change in global trade was larger than that of global output by a factor of 17 in 2009, against an average of 1.9 in the 1990–2008 period (Figure 1). The fall in international trade affected a large number of countries in all main economic regions, albeit to a different extent (Figure 2).

In this paper, we reexamine the relation between trade flows and macroeconomic dynamics by developing a new empirical model that takes into account the different import content and cyclical behavior of the different components of aggregate demand. We use the OECD Input-Output tables to show that the most procyclical components of demand (investment and exports) have a particularly rich import content, whereas the other components (private consumption and, especially, government spending) have lower import content. As a result, the fall in imports during recessions typically exceeds that of GDP by a considerable magnitude, due to the sharp reduction in the components of GDP that have the highest import content. The fall in investment is often larger than that of GDP, which triggers a sharp contraction in imports.<sup>1</sup> By contrast, government spending and, to a lesser extent,

<sup>1</sup> In the United States, for instance, the annualized fall in private investment in the last quarter of 2008 and in the first quarter of 2009 was about 25 percent and 32 percent, respectively, whereas GDP—partly supported by

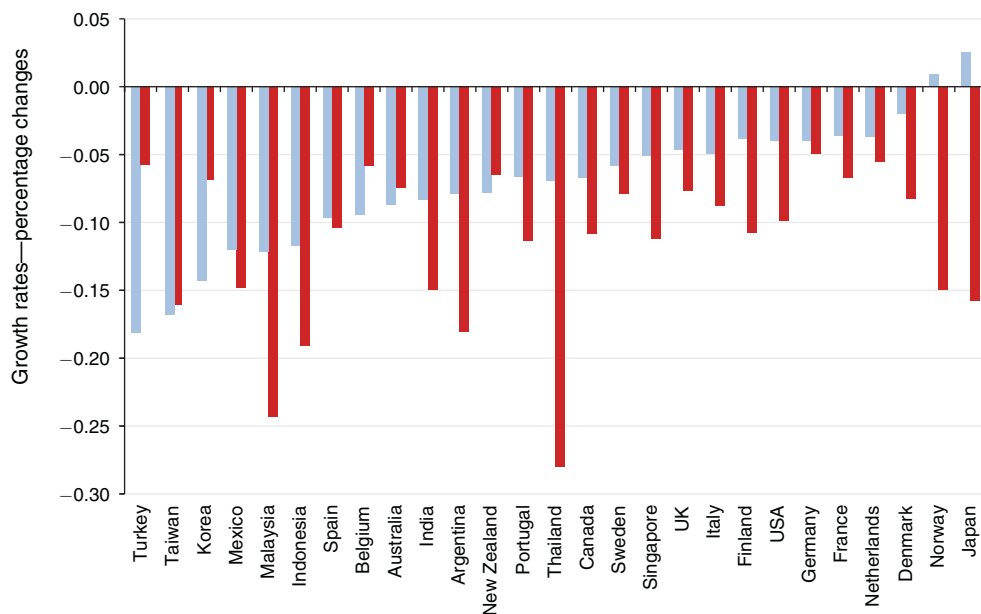


FIGURE 2. REAL IMPORTS IN 2008:IV AND 2009:I (Q-O-Q Growth Rates)

Source: OECD Economic Outlook

private consumption are not affected as much, but this does not dampen the fall in imports due to the relatively lower import content of these categories of expenditure.

Armed with these observations and intuition, we construct a new measure of demand, which we call *IAD* (for Import intensity-Adjusted Demand) as a weighted average of traditional aggregate demand components (investment, private consumption, government spending, and exports) using as weights the import contents of demand computed from the OECD Input-Output tables. We show that *IAD* is highly correlated with GDP, but more volatile on average (especially during recessions). We then take this new measure of demand to the data using a parsimonious, estimable import demand equation for a panel of 18 OECD countries over the period 1985:I–2011:IV. (The choice of countries reflects data availability; the empirical exercise requires sufficiently long time series to be able to capture a sufficient number of business cycles). We find that *IAD* fares well compared to standard, alternative measures of aggregate demand used in the literature in terms of both goodness of fit and stability of parameter estimates.<sup>2</sup>

The *IAD*-based model performs remarkably well in explaining the GTC compared to the alternatives. Our basic specification explains 80 percent of the average fall in imports in the G7 countries in the trough of the GTC against 51 percent when using GDP as an explanatory variable. The regression using *IAD* explains 86 percent of the fall in imports when the additional demand component “changes in inventories”

government spending—contracted by “only” 8.9 percent and 6.7 percent.

<sup>2</sup> We provide a theoretical foundation for *IAD* as the appropriate measure of aggregate demand in empirical trade equations in the Appendix.

is added to the regression. According to the model, there is no major “puzzle” in the magnitude of the fall in world trade observed during the recent financial crisis. Trade fell mostly because demand crashed globally, and did so particularly in its most import-intensive component—investment. Moreover, the strong relationship between exports and imports in each country (in 2005, the average import content of exports was 28 percent for the sample of countries, and 23 percent for the G7), linked to the increased internationalization of production and the strong dependence of the tradable sector on imported inputs, contributed to the simultaneity and unprecedented severity of the trade collapse.

Importantly, our empirical model outperforms the alternatives over the entire sample period, not just during the recent crisis, yielding estimated elasticities of imports to demand that are significantly less volatile across the different phases of the cycle. Our approach and results confirm Marquez’s (1999) argument that using standard measures of aggregate demand, such as GDP or domestic demand, in trade equations may be misleading, and more so in periods in which the more import-intensive components of aggregate demand (i.e., investment and exports) fluctuate much more than the others, such as the 2008–2009 crisis.<sup>3</sup>

The rest of the paper is organized as follows. Section I reviews the related literature, paying particular attention to the different explanations of the GTC. Section II provides stylized facts on the import content of investment, exports, and private and government consumption, and presents the new import intensity-adjusted measure of demand based on the OECD Input-Output tables. Section III turns to the empirical evidence. Section IV concludes.

## I. Related Literature

Our paper relates to the recent literature on the 2008–2009 Great Trade Collapse, for which Baldwin (2009) provided an early assessment and review.<sup>4</sup> Many of the arguments presented in Baldwin’s e-book have been investigated more formally in papers that we review below.<sup>5</sup>

Using disaggregated data on US imports and exports, Levchenko, Lewis, and Tesar (2010) argue that the fall in US imports cannot be explained with a simple import demand model. They find that sectors used as intermediate inputs were characterized by higher decreases in both imports and exports. Our analysis complements and corroborates this result, to the extent that investment is particularly rich in intermediate goods. The same authors further explore and reject the hypothesis that

<sup>3</sup> Marquez (1999) questioned the usefulness of the log-linear model of trade since the elasticities of trade to income varied as trade openness modified the domestic/foreign composition of expenditure. In our model, the elasticity of imports to demand is stable because our adjusted demand measure reflects these composition adjustments by including time-varying import intensities and distribution of expenditure across different categories.

<sup>4</sup> The introductory chapter of Baldwin’s e-book presents a battery of stylized facts on the GTC, pointing out that it was “sudden, severe, and synchronised.” The data include a decomposition of trade flows by country and by product. Potential explanations of the collapse are reviewed, including those related to compositional effects, in particular along the postponeable/nonpostponeable dimension, and trade credit.

<sup>5</sup> The relation between output and imports is of course a long-standing question in international macroeconomics; see for instance Houthakker and Magee (1969), and Hooper, Johnson, and Marquez (2000). The aim here is only to review the recent literature, focusing on the GTC.

US imports of high-quality goods experienced larger falls than low-quality goods (Levchenko, Lewis, and Tesar 2011).

Our work is also closely related to Bems, Johnson, and Yi (2010) and Eaton et al. (2011). Bems, Johnson, and Yi (2010) combine the synthetic global Input-Output table constructed by Johnson and Noguera (2012) with a Leontief production function to study the contribution of changes in the composition of demand and country-specific demand shocks in the global trade contraction. They also show that, in line with our conclusions and in contrast with those of Bénassy-Quéré et al. (2009), the international fragmentation of the production process can amplify the impact of demand shocks. Our work differs from Bems, Johnson, and Yi (2010) in several dimensions. First, the baseline decomposition of domestic GDP is based on expenditure components (private consumption, government consumption, investment, and exports) instead of commodity groupings (durables, nondurables, and services). Second, in our framework, changes in each individual component of spending affect imports according to their import intensity (i.e., the share of spending falling on imported goods), while, in Bems, Johnson, and Yi (2010), the relation between spending components and imports is mostly driven by the share of imports linked to that type of spending in total imports. To better understand this difference, consider the case of changes in investment spending. In our framework, a change in investment spending translates into a change in the aggregate demand measure that matters for import demand according to the share of investment spending that goes (directly or indirectly) to imported goods. By contrast, in Bems, Johnson, and Yi (2010), the relation between spending and import demand is mostly driven by the share of investment goods in total imports. Because of the level of detail of their Input-Output framework, the extension of their analysis to the time series dimension is practically very difficult. Our framework, on the opposite, is suitable for time series analysis and can be replicated easily for all the countries for which expenditure-based Input-Output tables exist.

Eaton et al. (2011) develop a Ricardian model of trade, where the Input-Output tables are used to evaluate value added and derive the component of expenditure falling on intermediate goods. Through the use of counterfactuals, they conclude that the demand composition shock is by far the most important driver of the global trade contraction; trade frictions play a much more limited role. Our work complements their study by integrating compositional shifts in the new demand measure.

Meanwhile, our results are in line with the conclusions of Engel and Wang (2011), who find that a two-country, two-sector model in which durable goods (usually more intensively used in investment, for instance) are traded internationally can replicate both the high variability of imports and exports, as well as their positive correlation.

The composition of domestic demand and its impact on external trade has also been the focus of work in the Dynamic Stochastic General Equilibrium literature. Erceg, Guerrieri, and Gust (2006) use the SIGMA model developed at the Board of Governors of the Federal Reserve System to show that the composition of demand in the United States matters for the response of trade to a variety of shocks (they explore in particular the effect of an investment shock). The main difference with our analysis is that they are primarily concerned with the impact of various shocks on investment in the context of global imbalances and their adjustment. Our study,

by contrast, aims at studying the impact of composition effects and quantifying their importance across countries. In addition, Erceg, Guerrieri, and Gust (2006) focus on the composition of domestic demand only, ignoring the role of the import content of exports.

In parallel, the role of trade credit attracted much attention, given the financial origin of the 2008–2009 crisis. Analyzing the case of Japan, Amiti and Weinstein (2011) show that exporters rely on finance more than firms that sell only domestically in order to reduce the risks that are typical of international transactions (longer payment lags, higher counterparty risks, etc.), thus making the trade sector more sensitive to changes in financing conditions. Ahn, Amiti, and Weinstein (2011) confirm this result by looking at the dynamics of export prices in those sectors where financial frictions are more significant. Feenstra, Li, and Yu (2011) incorporate the conclusions of Amiti and Weinstein (2011) in a model of heterogeneous firms and banks with incomplete information on the firms. They test the implications of the model against the dynamics of China's manufacturing firms over the period 2000–2008, confirming that exporting firms faced more severe financing constraints than domestic ones. Chor and Manova (2012) document that credit conditions had a significant effect on exports to the United States. Our analysis is not inconsistent with this evidence. While abstracting from an explicit analysis of trade credit, our results show that the demand components that are expected to be most sensitive to financing conditions (e.g., investment) experience the largest drop during times of crisis and are the main driver of import dynamics.

Finally, the use of Input-Output tables in international trade analysis has antecedents to our work and that cited above. Hummels, Ishii, and Yi (2001) relied on Input-Output tables to measure and analyze the nature of vertical specialization. Johnson and Noguera (2012) combined Input-Output tables with bilateral trade data to measure how production is shared across countries and types of goods. They show that international trade flows in value added terms are very different from those in gross production terms.<sup>6</sup>

## II. A New Measure of Demand

This section describes the information contained in the OECD Input-Output (henceforth, I-O) database and the methodology to construct the import contents of final demand expenditures. It also introduces our new measure of demand, *IAD*.

### A. The OECD Input-Output Database and the Import Content of Expenditure Components

The I-O tables describe the sale and purchase relations between producers and consumers within an economy. The I-O database is thus used as fundamental

<sup>6</sup> The use of input-output tables for the estimation of trade elasticities and the forecasting of imports actually dates back to Sundararajan and Thakur (1976), who applied it to Korean data. Differently from our paper, they focused only on short-term import dynamics and did not generate a synthetic adjusted demand measure.

statistics to estimate industrial figures in national accounts.<sup>7</sup> The growing importance of globalization has increased demand for the information offered by the Input-Output system. Examples of I-O-based globalization indicators include: the import penetration ratio of intermediate and final goods, the import content of exports (an indicator of vertical specialization), and the unit value added induced by exports. While there is a literature on the import content of exports (e.g., see Hummels, Ishii, and Yi 2001; De Backer and Yamano 2007; and OECD 2011), to our knowledge, this is the first paper to compute and compare the import content by expenditure components across countries.

The most recent version of the OECD I-O database includes tables for all OECD countries and several nonmember countries for the years 1995, 2000, and 2005, and/or the nearest years. Comparisons across countries are made possible through the use of a standard industry list based on ISIC Revision 3. The database covers 88 percent of 2005 world GDP and 64 percent of 2005 world population. The maximum available number of sectors is 48.<sup>8</sup> Imported intermediates and domestically provided inputs are explicitly separated.

Figure 3 provides a stylized illustration of the information in the OECD I-O database. For each country, there are three main matrices: one including total inter-industry flows of transactions of goods and services (domestically provided and imported) and two detailing separately domestically provided and imported flows.<sup>9</sup> Each matrix is then divided in two main parts. The first part (in dark shading in the figure) describes the flows of intermediate inputs used in domestic production. The second part (lightly shaded) contains instead information on final demand expenditure.

The cells in the  $\mathbf{Z}^d$  section of the “domestic” matrix contain the amount of domestically produced inputs from sector  $i$  (row) needed by sector  $j$  (column) for production throughout the year of reference, while the cells in the  $\mathbf{Z}^m$  section of the “import” matrix contain the amount of imported inputs from sector  $i$  (row) needed by sector  $j$  (column). In the calculations below, we will use slightly modified input matrices,  $\mathbf{A}^d$  and  $\mathbf{A}^m$ , where the domestic input coefficients  $a_{i,j}^d$  contain the amount of domestically produced inputs from sector  $i$  needed to produce *one* unit of output in sector  $j$ , and the imported input coefficients  $a_{i,j}^m$  contain the imported inputs from sector  $i$  needed to produce *one* unit of output in sector  $j$ .<sup>10</sup> In the other part of the matrices,  $\mathbf{F}^d$  reports the final demand of domestically produced goods and services (each column refers to a different expenditure component, such as household consumption, government consumption, exports, gross fixed capital formation, change in inventories, etc.), while  $\mathbf{F}^m$  reports the direct imports of goods and services by final expenditure component.

We use both the “domestic” and “import” matrices to construct the import contents of four expenditure components: private consumption, government consumption,

<sup>7</sup> A more detailed explanation of the OECD I-O database and the methodology to compute import contents is in Yamano and Ahmad (2006); De Backer and Yamano (2007); and Guo, Webb, and Yamano (2009).

<sup>8</sup> Two in mining, 22 in manufacturing, 23 in services, and agriculture.

<sup>9</sup> In this section, we use the terms industry and sector interchangeably.

<sup>10</sup> These coefficients can be easily derived by dividing the value of each cell in  $\mathbf{Z}^d$  and  $\mathbf{Z}^m$  by the sum of the respective column (total output of sector  $j$ ).

Total	Intermediate		Final demand				
	Ind 1	Ind 2	PC	GC	GFCF	Exports	Imports
Ind 1							
Ind 2							
VA							
Output							

Domestic	Intermediate		Final demand				
	Ind 1	Ind 2	PC	GC	GFCF	Exports	Imports
Ind 1	$Z^d$		$F^d$				
Ind 2							
Imports							
VA							
Output							

Import	Intermediate		Final demand				
	Ind 1	Ind 2	PC	GC	GFCF	Exports	Imports
Ind 1	$Z^m$		$F^m$				
Ind 2							

FIGURE 3. OECD INPUT-OUTPUT TABLES OF TOTAL, DOMESTIC, AND IMPORT TRANSACTIONS

Notes: PC: Private consumption by households; GC: Government consumption; GFCF: Gross fixed capital formation; VA: value added; Matrix of domestic input coefficients:  $A^d = Z^d/Output$ ; Matrix of imported input coefficients:  $A^m = Z^m/Output$ .

investment (proxied by gross fixed capital formation), and exports.<sup>11</sup> Notice that we aggregate information across sectors and look at the import contents only at a macroeconomic (or country) level. In particular, the matrices allow us to compute, for each expenditure component  $k$ , the value of *indirect* imports, i.e., the amount of imports “induced” by the expenditure on domestically provided goods and services.<sup>12</sup> These include imports of intermediate inputs from foreign suppliers, as well as imports that are already incorporated in capital and intermediate inputs acquired from domestic suppliers. The “import” matrix, instead, allows us to compute the value of *direct* imports for each expenditure component  $k$ .

Let us assume that there are  $S$  sectors and  $K$  final demand components in the economy, and that domestic output from each sector is used both as an intermediate input by the other sectors and to satisfy final demand. The domestic output from sector  $i$  needed to satisfy the final demand from the expenditure component  $k$  is then given by

$$x_{i,k} = \sum_{j=1}^S a_{i,j}^d x_{j,k} + f_{i,k}^d.$$

<sup>11</sup> The highly volatile nature of changes in inventories prevented us from constructing stable and meaningful import contents for such component of total expenditure. Moreover, changes in inventories represent, on average, a very small part of GDP (in the United States, for instance, they accounted for 0.3 percent of GDP, on average, in the last 20 years). We are aware, however, that changes in inventories may play an important role in particular phases of the business cycle, in particular during recession episodes, and that their behavior may explain part of the fall in imports registered during the 2008–2009 crisis (see, for instance, Alessandria, Kaboski, and Midrigan 2010). To explore this hypothesis, in the empirical section, we include changes in inventories as a control variable to our basic specification, and we find that their inclusion improves our results but is not central to them.

<sup>12</sup> Indirect imports are often associated with vertical specialization.



In matrix format this becomes

$$\mathbf{X} = \mathbf{A}^d \mathbf{X} + \mathbf{F}^d,$$

where  $\mathbf{X}$  is the  $S \times K$  matrix of domestic output induced by each spending component  $k$ ;  $\mathbf{A}^d$  is the  $S \times S$  matrix of domestic input coefficients; and  $\mathbf{F}^d$  is the  $S \times K$  matrix of final demands of domestic goods and services. Domestic output can then be expressed as

$$(1) \quad \mathbf{X} = (\mathbf{I} - \mathbf{A}^d)^{-1} \mathbf{F}^d,$$

where  $(\mathbf{I} - \mathbf{A}^d)^{-1}$  is commonly referred to as the Leontief inverse.

The imports of intermediate inputs from sector  $i$  induced by the expenditure on domestically provided goods and services can be calculated for each  $k$  as:

$$m_{i,k}^{ind} = \sum_{j=1}^S a_{i,j}^m x_{j,k}.$$

In matrix format,

$$\mathbf{M}^{ind} = \mathbf{A}^m \mathbf{X},$$

or, using equation (1),

$$\mathbf{M}^{ind} = \mathbf{A}^m (\mathbf{I} - \mathbf{A}^d)^{-1} \mathbf{F}^d,$$

where  $\mathbf{M}^{ind}$  is the  $S \times K$  matrix of indirect imports induced by each spending component  $k$ , and  $\mathbf{A}^m$  is the  $S \times S$  matrix of imported input coefficients.

Direct imports are given instead directly by the following  $S \times K$  matrix:

$$\mathbf{M}^{dir} = \mathbf{F}^m.$$

Total imports can then be expressed as the sum of direct and indirect imports, that is,

$$\mathbf{M} = \mathbf{M}^{ind} + \mathbf{M}^{dir} = \mathbf{A}^m (\mathbf{I} - \mathbf{A}^d)^{-1} \mathbf{F}^d + \mathbf{F}^m.$$

The total import content of each expenditure component  $k$  is hence computed as

$$(2) \quad \omega_k = \frac{\mathbf{u} \mathbf{M}_k^{dir} + \mathbf{u} \mathbf{M}_k^{ind}}{\mathbf{u} \mathbf{F}_k^d + \mathbf{u} \mathbf{F}_k^m} = \frac{\mathbf{u} \mathbf{A}^m (\mathbf{I} - \mathbf{A}^d)^{-1} \mathbf{F}_k^d + \mathbf{u} \mathbf{F}_k^m}{\mathbf{u} \mathbf{F}_k^d + \mathbf{u} \mathbf{F}_k^m},$$

where  $\mathbf{u}$  is a  $1 \times S$  vector with all elements equal to 1, and the subscript  $k$  selects the  $k$ -th column of each matrix, corresponding to the expenditure component of interest.

In addition to the total import content  $\omega_k$ , it is also possible to derive a direct and indirect import content for each expenditure component,

$$\omega_k^{dir} = \frac{\mathbf{uM}_k^{dir}}{\mathbf{uF}_k^d + \mathbf{uF}_k^m},$$

$$\omega_k^{ind} = \frac{\mathbf{uM}_k^{ind}}{\mathbf{uF}_k^d + \mathbf{uF}_k^m},$$

where the indirect import content tells us the share of intermediate imported inputs per unit of final demand, and the direct import content tells us the share of imported final goods and services. Notice that the direct import content of exports is equal to zero as re-exports of goods and services are excluded from the analysis.<sup>13</sup> Table A1 in the online Appendix reports the evolution of import contents (total, direct, and indirect) of the main GDP expenditure components over time for a large set of countries.<sup>14</sup>

### B. Import Intensity-Adjusted Demand

Empirical trade models typically use measures of aggregate demand, such as GDP or domestic demand, ignoring the fact that different components of expenditure have different import contents. Figure 4 shows the import contents of private and government consumption, investment, and exports for our panel of 18 countries based on the 2005 I-O tables, together with the average across all countries and the G7.<sup>15</sup>

As Figure 4 shows, the import content of government consumption is low across all countries (government spending mostly includes nontradables, such as services, and a high share of domestically produced goods, e.g., for the defense industry). Turning to the other two main components of domestic expenditure, investment has a higher import content than private consumption in all countries but the United Kingdom. Finally, exports are also very import-intensive. On average the import content of exports is 28 percent, with peaks of about 40 percent for small open economies, such as Belgium or Portugal, and some emerging countries (see Table A1 in the online Appendix for a comparison across a larger set of countries). The country order of import content shares is mainly determined by two factors: availability of intermediate suppliers (country size) and position in the global production network. Japan and the United States, for instance, have relatively more

<sup>13</sup> We are aware that the amount of processing trade is relatively large for some countries, such as China and other emerging economies, so that our numbers for the import content of exports are biased downward in these cases. In this paper, however, we have chosen not to consider re-exports in line with other OECD publications (see, among others, OECD 2011, 178–79). Moreover, in our empirical analysis we focus mainly on advanced OECD economies for which the amount of re-exports is smaller, so that our results should not be significantly affected.

<sup>14</sup> We report the values for 1995, 2000, and 2005. For some countries, 1985 and 1990 values exist and are available upon request.

<sup>15</sup> The countries we focus on are Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Korea, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, the United Kingdom, and the United States.

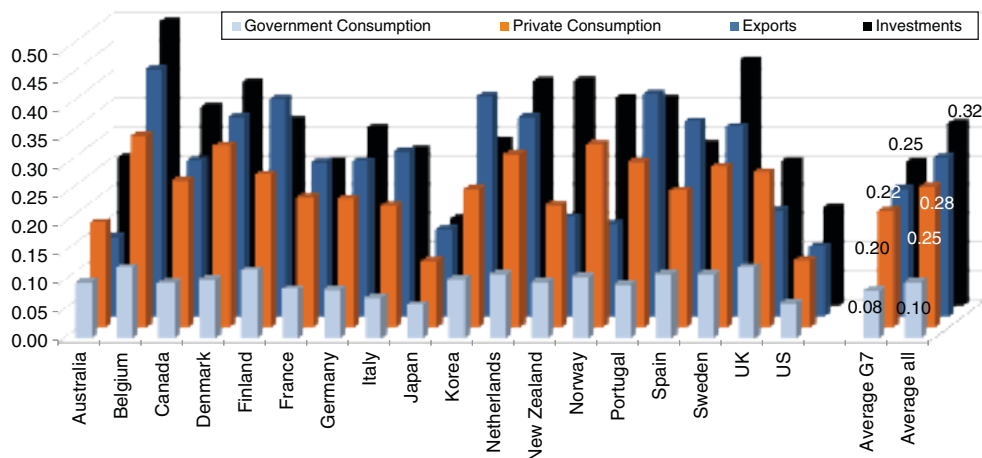


FIGURE 4. IMPORT CONTENTS OF MAIN GDP COMPONENTS

Source: OECD Input-Output tables and authors' calculations

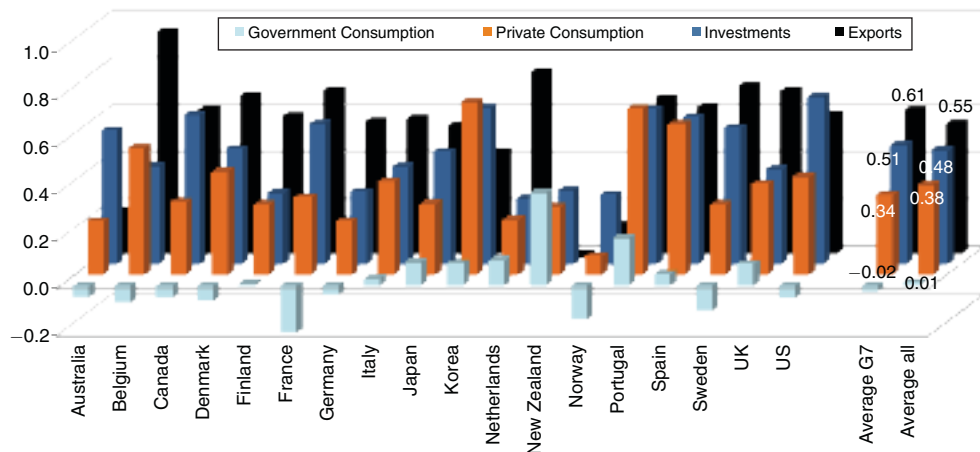


FIGURE 5. SHORT-TERM CORRELATIONS BETWEEN IMPORTS AND MAIN GDP COMPONENTS

Notes: Correlations at quarterly frequency using first differences. Sample period: 1985–2011.

domestic suppliers for their production network than most European countries, which rely on more foreign products for their production. This explains why the import contents of Japanese and US exports are rather low (although, in the case of Japan, rising over time).

Consistent with these findings, imports tend to be strongly correlated, on average, with exports and investment and, to a lesser extent, private consumption, while they appear to be uncorrelated with government consumption, as shown in Figure 5.

In this paper, we focus on imports, and we propose a new measure of demand that reflects the import intensity of the different components of domestic expenditure

and the import content of exports. We call this import intensity-adjusted measure of demand *IAD*, and construct it, country by country, as follows:

$$IAD_t = C_t^{\omega_{C,t}} G_t^{\omega_{G,t}} I_t^{\omega_{I,t}} X_t^{\omega_{X,t}},$$

where *C* stands for private consumption, *G* for government consumption, *I* for investment, and *X* for exports, included to take the import content of export demand into account. In logarithms:

$$\ln IAD_t = \omega_{C,t} \ln C_t + \omega_{G,t} \ln G_t + \omega_{I,t} \ln I_t + \omega_{X,t} \ln X_t.$$

The weights,  $\omega_{k,t}$ ,  $k = C, G, I, X$ , are the total import contents of final demand expenditures and are constructed as explained in Section IIA. They are time varying and normalized in each period such that their sum is equal to one. Since the I-O tables allow us to compute import contents for the different demand components only every five years, we linearly interpolate the available points to construct quarterly weights. For the period after 2005, we assume the same weights as in 2005. For some countries, the I-O tables provide data only since 1995. In these cases, we use the same weights as in 1995 for the period before.

We shall show that *IAD* represents a better measure of demand than domestic demand or GDP to explain import fluctuations since it weighs each GDP component according to its import content. Two facts are also worth noting. First, the relative import contents of the main components of GDP are substantially different from their shares in GDP (on average, private consumption represents 60 percent of GDP in our panel of countries, against 20 percent of government consumption and investment).<sup>16</sup> Second, different components of aggregate demand showed very different behaviors during the crisis. Indeed, investment and exports fell much more than private and government consumption in most countries. The fact that investment falls more sharply than other categories of expenditure during recessions is a robust stylized fact.<sup>17</sup> Thus, the fact that standard GDP computations neglect that investment and exports tend to have larger import content than private consumption and government consumption may explain why the fall in trade during the 2008–2009 crisis was larger than suggested by estimated elasticities based on GDP as measure of demand.

Table 1 reports the descriptive statistics for quarterly changes in *IAD*, GDP, and imports, *M*, for the full set of 18 countries and for the G7 over the entire sample period, while Table 2 differentiates between recessions (defined as two consecutive quarters of negative GDP growth) and expansions. The tables show that *IAD* is highly correlated with GDP—the average correlation coefficient over the entire sample being 0.66 for the full set of countries and 0.77 for the G7—and also strongly correlated with imports—the coefficient being 0.61 and 0.70, respectively, while the correlation between GDP and imports is much lower, especially during expansions.

<sup>16</sup> Exports and imports also represent on average 20 percent of GDP.

<sup>17</sup> It is consistent with the standard property of the business cycle for many countries that investment is more volatile than GDP, while consumption is smoother.

TABLE 1—DESCRIPTIVE STATISTICS—FULL SAMPLE

	<i>IAD</i>	<i>GDP</i>	<i>M</i>
<i>Panel A. All countries</i>			
Mean	0.80	0.61	1.33
SD	1.69	1.02	3.19
$\rho(IAD)$	1.00	—	—
$\rho(GDP)$	0.66	1.00	—
$\rho(M)$	0.61	0.41	1.00
Observations	1,944	1,944	1,944
<i>Panel B. G7 countries</i>			
Mean	0.66	0.50	1.19
SD	1.35	0.78	2.55
$\rho(IAD)$	1.00	—	—
$\rho(GDP)$	0.77	1.00	—
$\rho(M)$	0.70	0.46	1.00
Observations	756	756	756

Notes: The table presents descriptive statistics for the log difference of *GDP*, *IAD*, and imports *M*. The means and standard deviations are reported in percent units.  $\rho(Q)$  is the contemporaneous correlation coefficient between each of the variables in column and the variable  $\Delta \ln Q$ , where  $Q = IAD, GDP, \text{ or } M$ . The dataset covers quarterly data from 1985:1 to 2011:IV.

TABLE 2—DESCRIPTIVE STATISTICS—RECESSIONS AND EXPANSIONS

	Recessions			Expansions		
	<i>IAD</i>	<i>GDP</i>	<i>M</i>	<i>IAD</i>	<i>GDP</i>	<i>M</i>
<i>Panel A. All countries</i>						
Mean	-1.38	-0.86	-1.80	1.06	0.78	1.70
SD	1.96	1.01	4.21	1.44	0.87	2.83
$\rho(IAD)$	1.00	—	—	1.00	—	—
$\rho(GDP)$	0.72	1.00	—	0.54	1.00	—
$\rho(M)$	0.66	0.56	1.00	0.52	0.25	1.00
Observations	207	207	207	1,737	1,737	1,737
<i>Panel B. G7 countries</i>						
Mean	-1.47	-0.81	-1.84	0.94	0.67	1.59
SD	1.90	0.90	3.40	0.96	0.58	2.12
$\rho(IAD)$	1.00	—	—	1.00	—	—
$\rho(GDP)$	0.83	1.00	—	0.58	1.00	—
$\rho(M)$	0.77	0.57	1.00	0.49	0.18	1.00
Observations	87	87	87	669	669	669

Notes: The table presents descriptive statistics for the log difference of *GDP*, *IAD*, and imports *M*. The means and standard deviations are reported in percent units.  $\rho(Q)$  is the contemporaneous correlation coefficient between each of the variables in column and the variable  $\Delta \ln Q$ , where  $Q = IAD, GDP, \text{ or } M$ . The dataset covers quarterly data from 1985:1 to 2011:IV.

Moreover, both first and second moments of *IAD* are closer to those of imports than the moments of *GDP*. In particular, *IAD* is significantly more volatile than *GDP* during recessions—when its average standard deviation is twice that of *GDP*—but also during expansionary phases.

Figure 6 looks explicitly at the behavior of *GDP*, its components, and *IAD* during the two years after the start of a recession (defined as before) for our panel of

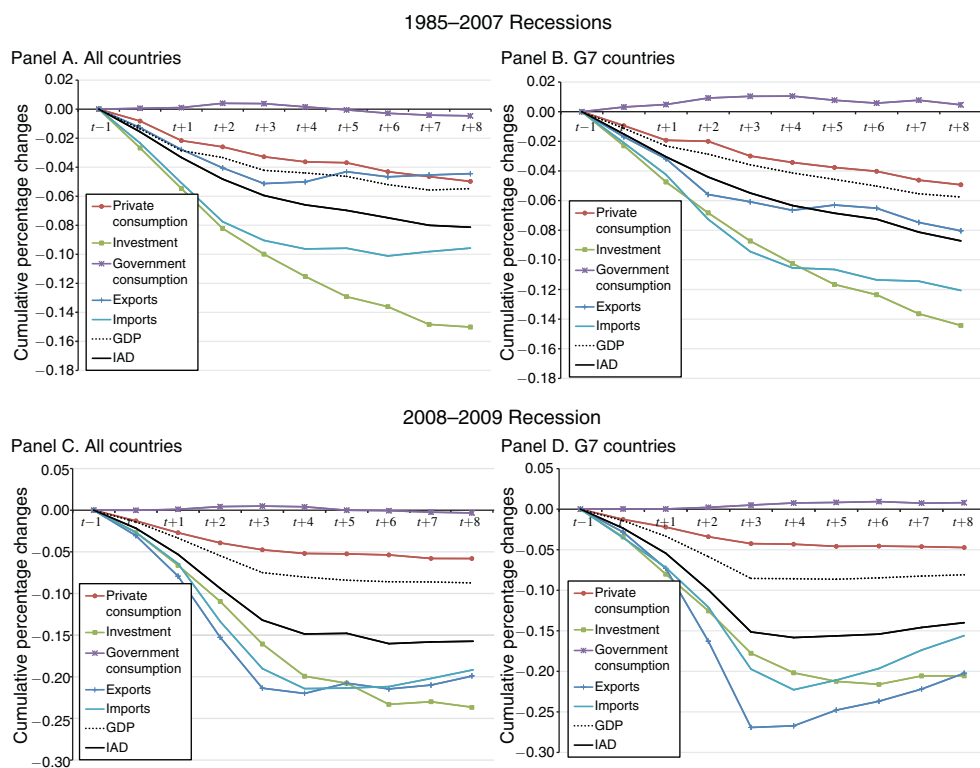


FIGURE 6. AVERAGE BEHAVIOR OF GDP COMPONENTS DURING RECESSIONS (*Real Variables*)

18 OECD countries and the G7.<sup>18</sup> The top panels show the average fall in each variable during all the recessions that occurred between 1985 and 2007, whereas the bottom panels refer to the 2008–2009 recession only. The figures also include the behavior of GDP and the new measure of demand, *IAD*.

As the top panels of Figure 6 show, investment is the demand component that exhibits the largest fall during recessions, dropping by 15 percent, on average, two years after the start of a recession in the sample with all countries. Trade variables also fall substantially in the first year and then gradually recover. Government consumption does not generally fall during recessions (possibly because it is used for countercyclical policy), while private consumption falls less than GDP on average. Our adjusted measure of demand falls by 8 percent, on average, after two years, about 3 percentage points more than GDP; and its dynamics follow quite closely those of imports during recessions. Focusing on the 2008–2009 recession (Figure 6, bottom panels), the first major difference is the scale of the vertical axis, which is almost twice as high. Investment fell by more than 20 percent, on average, and did not exhibit any sign of recovery after two years. The second major difference is the

<sup>18</sup> To generate the charts in Figure 6 we performed panel regressions for each of the variables, where the regressors are an indicator of recession start (equal to one in the first quarter of a recession), the lags of such indicator, and country-specific dummy variables. The methodology is similar to that of IMF (2010). The resulting line for each variable can be interpreted as its unconditional average cumulative fall during recession periods.

size of the average fall of trade, which in the case of imports is more than twice the size observed during previous recessions, and, in the case of exports, is higher by a factor of almost five. This last feature illustrates clearly the global nature of the 2008–2009 recession. Exports on average fell modestly during previous recessions, partly because external demand was sustained by trading partners in a different phase of the cycle. In contrast, during 2008–2009, 17 out of the 18 countries experienced a recession (the only exception being Australia), driving down external demand for each country in the sample. This global effect, together with the propagation/synchronization mechanism implied by increased vertical integration, helps explain why the fall in trade in 2008–2009 was exceptionally large and synchronized. Finally, the analysis of the 2008–2009 recession using the sample of all countries shows that *IAD* exhibits a drop of about 16 percent 2 years after the start of the crisis, reflecting significant export and investment losses, against a realized drop in GDP of “only” 9 percent. The story is broadly similar in terms of behavior of different components of demand and differences in magnitude between past recessions and the 2008–2009 one when looking at the G7 countries.

Having constructed the new import intensity-adjusted demand measure and taken an initial look at its empirical properties, we next briefly discuss its inclusion in trade regressions of the form commonly featured in the literature.

### C. *IAD* in Trade Regressions

The traditional theoretical underpinning of much empirical trade literature is the C.E.S. demand system. Under C.E.S. preferences, (log) import demand is determined by

$$(3) \quad \ln M_t = \ln D_t + \beta_P \ln P_{M,t},$$

where  $D_t$  is aggregate demand (a C.E.S. aggregator of domestic and imported goods) and  $P_{M,t}$  is the relative import price. In the standard framework, the basket  $M_t$  is itself a C.E.S. aggregate of individual imports. Equation (3) restricts the elasticity of imports to aggregate demand to be equal to one, while  $\beta_P$  can take any negative value (estimates based on aggregate macro data typically put its absolute value at or near 1.5—although Corsetti, Dedola, and Leduc (2008) argue in favor of a value between zero and one—while estimates based on more disaggregated data usually find higher absolute values).

The C.E.S. demand equation (3) is the foundation of regressions of the form

$$(4) \quad \Delta \ln M_t = \delta + \beta_D \Delta \ln D_t + \beta_P \Delta \ln P_{M,t} + \varepsilon_t,$$

where  $\Delta$  denotes first difference (on account of nonstationarity),  $\delta$  is a constant, and  $\varepsilon_t$  is the error term.

Equation (4) is also the benchmark regression equation that we will use, but we will replace the standard measures of aggregate demand in the regression with *IAD*. The Appendix provides the derivation of a theoretical (log) import demand equation, which does not restrict the elasticity of imports to aggregate demand to be one,

and in which, under certain assumptions, aggregate demand takes the form of the *IAD* aggregator—in levels, a Cobb–Douglas function, with time-varying weights, of private consumption, government consumption, investment, and exports.<sup>19</sup> *IAD* then becomes our benchmark measure of demand in regressions of the familiar form (4).

### III. Empirical Analysis

The objective of this section is to test empirically the ability of the new import intensity-adjusted measure of demand to explain the dynamics of import flows in regressions of the form (4), against other standard measures of aggregate demand. We then explicitly look at the Great Trade Collapse episode of 2008–2009 to understand whether the fall in world trade during the GTC is still largely unexplained once the import intensity of aggregate demand components is taken into account (which would call for other factors as primary explanations of the GTC). Finally, we assess the performance of our new measure of demand at tracking import flows over different phases of the business cycle, comparing it with the performance of the standard GDP specification and with a specification featuring individual aggregate demand components.

Results build on a dataset of 18 OECD countries, repeated here for the reader's convenience: Australia, Canada, Denmark, Finland, France, Germany, Italy, Japan, Korea, Netherlands, Norway, New Zealand, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States. The data on imports and exports of goods and services, GDP, private and government consumption, and investment, all in volume, as well as the series of import prices and GDP deflators, come from the OECD Economic Outlook database.<sup>20</sup> The time series are at quarterly frequency, and the estimation is performed over the period 1985:I–2011:IV. We construct relative import prices by dividing the series of import prices of goods and services for each country by the respective GDP deflator.

#### A. Panel Estimation Results

We start by estimating a simple, standard equation for imports. We regress the quarterly growth of real imports for each country  $c$ ,  $\Delta \ln M_{c,t}$ , on the quarterly growth of demand,  $\Delta \ln D_{c,t}$ , and the quarterly growth of relative import prices,  $\Delta \ln P_{M,c,t}$ , as well as country dummies  $\delta_c$ :

$$(5) \quad \Delta \ln M_{c,t} = \delta_c + \sum_{l=0}^L \beta_{D,l} \Delta \ln D_{c,t-l} + \sum_{l=0}^L \beta_{P,l} \Delta \ln P_{M,c,t-l} \\ + \sum_{l=1}^L \beta_{M,l} \Delta \ln M_{c,t-l} + \varepsilon_{c,t}.$$

<sup>19</sup> The theoretical foundation for *IAD* relies on a translog GDP function, following Feenstra (2003a, chapter 3); Kee, Nicita, and Olarreaga (2008); and a series of articles by Kohli (1978; 1990a,b; 1993).

<sup>20</sup> We use time series on gross fixed capital formation (GFCF) to proxy for investment in the empirical exercise. This is consistent with the fact that we use the import content of GFCF computed from the OECD I-O tables to construct *IAD*. Although we are aware that investment does not coincide with GFCF, we will use the term investment instead of GFCF in the rest of the paper.



TABLE 3—ESTIMATION RESULTS

	<i>IAD</i> specification		<i>GDP</i> specification		<i>DD</i> specification		
<i>Panel A. All countries</i>							
$\Delta \ln(D)_t$	1.16*** (0.1015)	1.19*** (0.0734)		1.29*** (0.2667)	1.27*** (0.2209)	1.44*** (0.1460)	1.50*** (0.0836)
$\Delta \ln(D)_{t-1}$		0.51*** (0.0549)			0.87*** (0.1325)		0.56*** (0.1255)
$\Delta \ln(P_M)_t$	-0.18*** (0.0615)	-0.19*** (0.04514)		-0.16* (0.0773)	-0.16** (0.0662)	-0.07 (0.0794)	-0.08 (0.0769)
$R^2$	0.40	0.45		0.19	0.26	0.25	0.30
Observations	1,944	1,944		1,944	1,944	1,944	1,944
<i>Panel B. G7 countries</i>							
$\Delta \ln(D)_t$	1.29*** (0.1049)	1.20*** (0.0958)	1.27*** (0.0855)	1.50*** (0.1930)	1.16*** (0.1013)	1.56*** (0.2094)	1.45*** (0.1272)
$\Delta \ln(D)_{t-1}$		0.45*** (0.0987)	0.31** (0.1075)		0.91*** (0.1746)		0.67*** (0.1199)
$\Delta \ln(P_M)_t$	-0.11*** (0.0321)	-0.14*** (0.0289)	-0.14*** (0.0255)	-0.03 (0.0496)	-0.05 (0.0325)	0.07 (0.0413)	0.00 (0.0360)
$\sum_{t=0}^4 \text{Invent.chg.}$			-0.53***				
$R^2$	0.48	0.52	0.60	0.25	0.33	0.26	0.32
Observations	756	756	756	756	756	756	756

*Notes:* The table reports in-sample estimates of panel regressions of the form performed on the full set of 18 countries (panel A) and on the G7 countries (panel B), where *IAD* stands for our new import intensity-adjusted measure of demand. Panel B presents the results of an additional specification where contemporaneous and lagged values of changes in inventories are included in the regression featuring *IAD* as demand variable. To save space we do not report here the point estimates of the constant, and of the lagged values of the dependent variable and of relative import prices  $P_M$ .  $R^2$  is the in-sample coefficient of determination. Robust standard errors are reported in parentheses. The analysis uses quarterly data from 1985:1 to 2011:IV.

\*\*\*Significant at the 1 percent level.

\*\*Significant at the 5 percent level.

\*Significant at the 10 percent level.

In the analysis that follows, we compare three measures of demand: two are standard measures, where either GDP or domestic demand, *DD* (computed as the sum of private and government consumption and investment), are used as proxies for  $D$ , and the third is the new import intensity-adjusted measure of demand, *IAD*. We consider two specifications, one in which import growth depends only on contemporaneous values of the explanatory variables ( $L = 0$ ) and another in which it is a function also of its own lags and lags of the explanatory variables to allow for richer dynamics ( $L = 1$ ). We estimate panel regressions of the type (5) using country-specific fixed effects and robust variance-covariance matrix estimates.

Table 3 presents the in-sample results of the 6 specifications just described for the full set of 18 countries and the G7 (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States) plus an additional specification, for the subset of G7 countries, controlling also for the changes in inventories.<sup>21</sup>

<sup>21</sup> In particular, we estimate equation (5) using *IAD* as demand variable and adding as additional explanatory variables contemporaneous and lagged values of changes in inventories as a percentage of GDP. For this exercise, we used the time series of "change in stocks" and GDP at current prices from the OECD Main Economic Indicator Database. The lack of long spans of data for some countries in our sample makes it impossible to perform the same exercise for the entire panel of 18 countries.

Estimation results show that the regression using *IAD* is noticeably superior to those using GDP or DD in terms of fit, and this applies both to the full set of countries and the subset of G7 countries. Including lags of the dependent and independent variables improves the fit marginally and does not reveal substantial changes in the elasticity point estimates, especially when using *IAD* as demand variable. The ranking of the three measures of *D* also remains unchanged.<sup>22</sup> Finally, the variable changes in inventories are highly significant and negatively related to import growth (the table reports the cumulative effect of the contemporaneous value and four lags of changes in inventories on import growth).<sup>23</sup> To investigate whether import fluctuations are due mainly to changes in the components of *IAD* or changes in the weights of *IAD* components (the import contents), we have run the same regressions as above, but holding the weights in *IAD* fixed over time (we used fixed weights at their 1995–2005 average values). The results, reported in the online Appendix (Table A2) show very little change in the coefficient estimates and in-sample fit of the *IAD* specification. This suggests that the superiority of *IAD* in tracking import fluctuations relies mostly on the ability of our new measure of demand to capture the dynamics of the different demand components.

Figure 7 shows actual and fitted values of real import growth for the United States, where the fitted values are obtained by estimating the panel regression (5) using the alternative demand measures. The superiority of *IAD* in tracking import growth against the alternatives stands out clearly from the figure, especially in periods of large falls in imports, such as the Great Trade Collapse of 2008–09 (Figure A1, in the online Appendix, shows similar results for the other G7 economies).

At this point, a natural question that arises is whether the results differ across countries. To answer this question, we have also run single country equations for the G7 countries, in addition to the panel estimates presented above. The results are displayed in Table 4. They point to more heterogeneity across countries for the model using GDP than the model using *IAD* (the standard deviation of the cumulative coefficients being nearly three times higher for the former, compared to the latter). This suggests that our *IAD* variable picks up a substantial part of the cross-country heterogeneity observed in the model using GDP.

### B. *The Composition of Demand and the Great Trade Collapse*

Figure 8 illustrates exactly how much of the fall in imports observed during the GTC the three demand specifications are able to account for, on average, and for each individual country (panels A and B refer to the panel regression (5) for all 18 countries, whereas panels C and D to the same regression performed on the G7 countries only). The black bar in the “Total” part of each diagram shows the actual

<sup>22</sup> Notice that, in all specifications, we add two dummy variables to capture two episodes of erratic movements in trade in the United Kingdom in 2006:I and 2006:III. Concerning these quarters the UK Office for National Statistics said: “Erratic and large movements in the level of trade associated with VAT Missing Trader Intra Community (MTIC) fraud have made it especially difficult to interpret movements in imports and exports of goods.”

<sup>23</sup> As a corollary, the *IAD* specifications also provide higher (in absolute value) and more statistically significant estimates for the import elasticities to  $P_M$ .

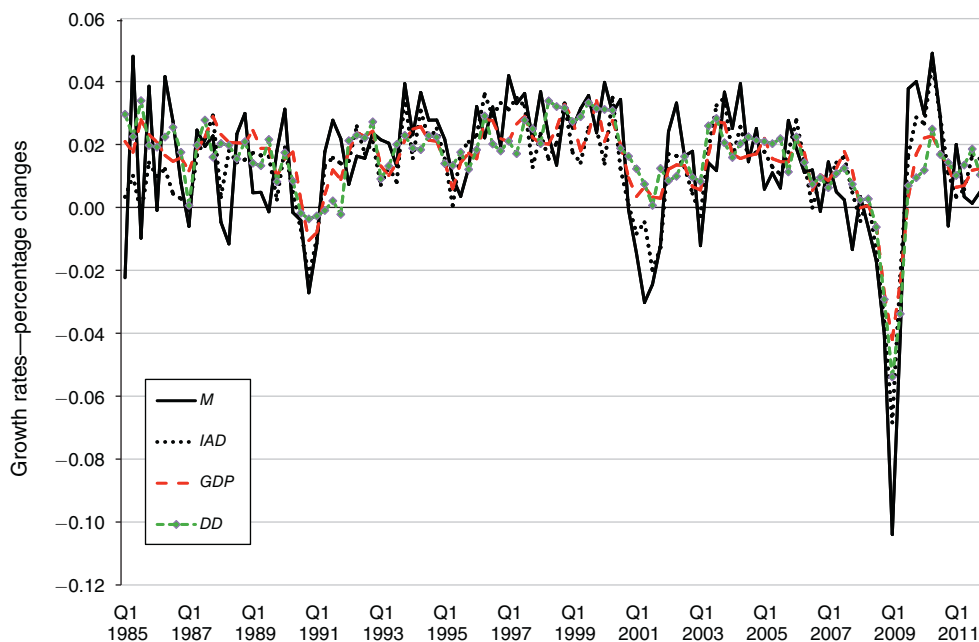


FIGURE 7. ACTUAL VERSUS FITTED VALUES OF US REAL IMPORT GROWTH DURING THE GREAT TRADE COLLAPSE

Notes: The solid line shows actual quarterly import growth, the dotted line shows fitted values from the regression using *IAD* as a measure of demand and the additional component changes in inventories, the dashed line from the *GDP* specification and the dotted line with diamonds from the domestic demand specification, *DD*.

TABLE 4—SINGLE COUNTRY RESULTS

	$\sum \Delta \ln(GDP)_{t-1}$	$\sum \Delta \ln(IAD)_{t-1}$
US	2.77	1.74
UK	1.74	1.57
Japan	1.59	1.43
Germany	1.61	1.40
France	2.82	1.89
Italy	2.87	1.92
Canada	2.09	1.54
Panel G7	2.07	1.65

Notes: The table reports in-sample estimates of regressions of the form (5) performed individually on each G7 country. The table reports the cumulative coefficients ( $l = 0, 1$ ) of the alternative demand measures *GDP* and *IAD* and compares them with the coefficients estimated using the panel regression (cfr. Table 3). All coefficients are significant at the 1 percent level. The analysis uses quarterly data from 1985:I to 2011:IV.

average fall in imports in the 18 countries<sup>24</sup> together with the predicted average fall using *IAD*, *GDP*, and *DD*, respectively. In particular, the weighted average of real imports in our sample of countries fell by 4.8 percent in 2008:IV and 9.2 percent in 2009:I, on a quarterly basis. The model using *IAD* as explanatory demand variable captures 69 percent and 61 percent of the fall in aggregate imports in 2008:IV

<sup>24</sup> To construct the average import growth, we used the average values of countries' import shares between 2000 and 2009.

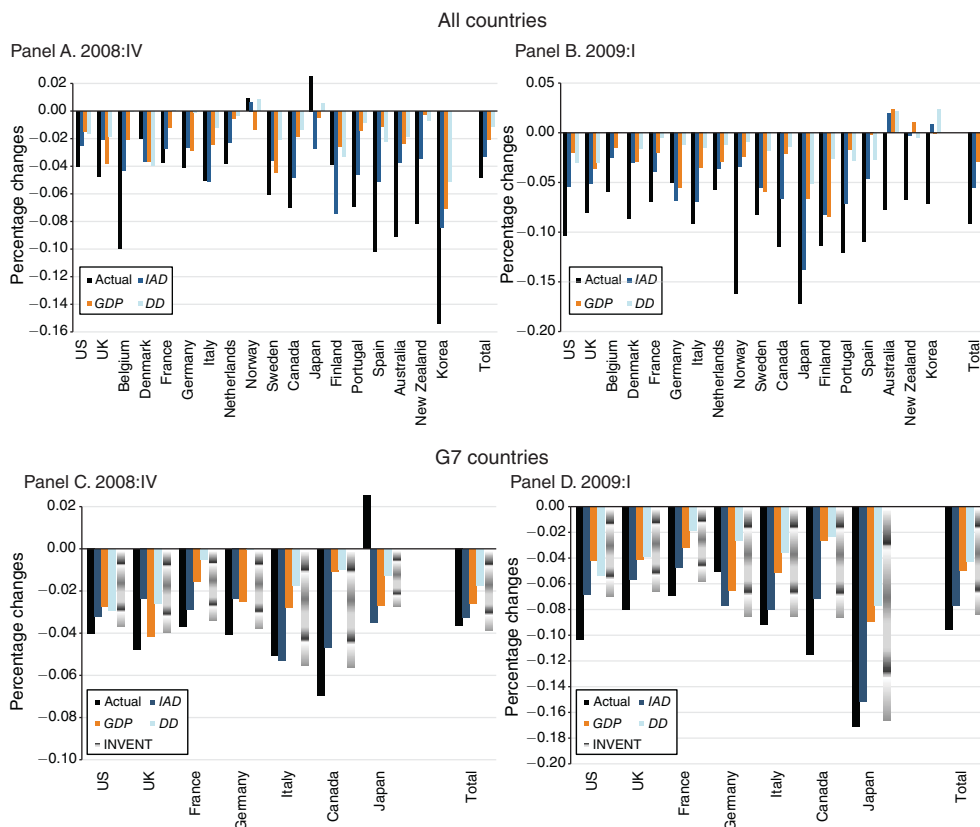


FIGURE 8. ACTUAL VERSUS FITTED VALUES OF REAL IMPORT GROWTH DURING THE GTC

Notes: The bars labeled “INVENT” in the bottom panels represent fitted values from the *IAD* specification where contemporaneous and lagged values of changes in inventories (expressed as a percentage of GDP) are also added as explanatory variables.

and 2009:I, respectively, while only 43 percent and 32 percent is explained by the GDP-based specification. Results for the G7 (bottom panels) are even more striking. On average, using *IAD* explains 89 percent and 80 percent of the average fall in imports in the G7, against 71 percent and 52 percent when GDP is used. In panels C and D of Figure 8, an additional (gray-shaded) bar is included for each country, corresponding to the predictions of the *IAD* specification controlling also for the demand component changes in inventories. Including changes in inventories helps improve the fit of the model. On average, using *IAD* and controlling for changes in inventories explains 104 percent and 86 percent of the average fall in imports in the G7 in 2008:IV and 2009:I, respectively.

The specification using *IAD* allows us to go further in investigating the relation between the composition of demand and the GTC, as well as in disentangling the contributions of direct and indirect import demand. Using the estimated coefficients from regression (5), we can decompose import growth for each country in the panel and compute the individual contribution of the four *IAD* components (*C*, *I*, *X*, and *G*) in explaining import fluctuations. Moreover, by recalling from (2) that the import

TABLE 5—IMPORT GROWTH DECOMPOSITION

	Percentage explained by:				
	$\Delta M$	<i>GDP</i>	<i>IAD</i>	<i>INV</i>	$P_M$
US	-10.4	39.8	75.6	8.2	-10.4
UK	-8.0	49.1	73.1	12.9	5.6
Japan	-17.1	49.2	90.8	15.7	-9.8
Germany	-5.1	133.6	177.1	17.8	-13.1
France	-7.0	45.6	76.1	22.3	-5.5
Italy	-9.2	58.7	99.9	11.3	-10.1
Canada	-11.5	28.3	74.6	10.8	-2.2
Average G7		57.7	95.3	14.1	-6.5
Australia	-7.7	-8.6	9.9		-3.9
Spain	-11.0	27.8	78.6		-12.0
Netherlands	-5.7	67.6	86.3		-3.9
Portugal	-12.1	30.0	81.6		-6.7
Norway	-16.2	9.0	11.9		7.1
New Zealand	-6.7	14.3	48.9		-11.7
Sweden	-8.2	85.1	87.4		0.3
Belgium	-6.0	68.2	103.2		-17.5
Finland	-11.4	92.6	96.2		-13.9
Denmark	-8.6	46.1	52.2		-8.7
Korea	-7.1	56.4	70.1		-25.4
Average all		49.6	77.4		-7.9

*Notes:* The second column reports quarterly import growth in 2009:I for the 18 countries in our panel. The third and fourth columns report the percentage of import growth explained by the explanatory variables *GDP* and *IAD* in equation (5). The last two columns show the percentage of import growth explained by the explanatory variables *INV* and  $P_M$  in the regression featuring *IAD* as demand variable. Negative values indicate that the explanatory variable accounts for import growth in the opposite direction of the one observed.

content of each expenditure component is computed as the sum of the direct and indirect import content, we can decompose the contribution of *IAD* into the contributions of direct and indirect import demand.

Tables 5 and 6 show these decompositions for 2009:I. The second column in each of the tables reports actual quarterly import growth rates for the 18 countries in the panel. The third and fourth columns in Table 5 report the percentage of import growth explained by the explanatory variables *GDP* and *IAD* in equation (5). The last two columns show the percentage of import growth explained by the additional explanatory variables changes in inventories, *INV*,<sup>25</sup> and relative import prices,  $P_M$ , in the regression using *IAD* as demand variable. Table 6 further decomposes the predictive power of *IAD* into the individual contribution of each demand component and into the contribution of direct and indirect import demand (notice that the sum of the contributions of *C*, *X*, *I*, and *G*, and the sum of direct and indirect contributions in Table 6 are both equal to the contribution of *IAD* in Table 5).

Several results are worth noting. First, the percentage of import growth explained by *IAD* alone is in general very high, sometimes close to 100 percent, and, in most of the cases, much higher than the percentage explained by *GDP* alone (in the cases of Germany, however, both specifications produce a larger-than-observed

<sup>25</sup> This decomposition is available only for the G7 countries for the reason explained above.

TABLE 6—INDIVIDUAL CONTRIBUTION OF *IAD* COMPONENTS

	Percentage explained by:						<i>Direct</i>	<i>Indirect</i>
	$\Delta M$	<i>C</i>	<i>X</i>	<i>I</i>	<i>G</i>			
US	-10.4	2.1	31.6	41.9	0.0	21.2	54.3	
UK	-8.0	8.0	28.9	34.4	1.9	23.9	49.3	
Japan	-17.1	3.2	76.1	12.7	-1.2	6.4	84.4	
Germany	-5.1	-1.0	94.1	88.2	-4.2	43.4	133.6	
France	-7.0	0.2	53.3	23.7	-1.1	11.5	64.6	
Italy	-9.2	3.8	68.0	28.1	-0.1	14.3	85.6	
Canada	-11.5	1.4	31.6	43.0	-1.4	24.6	49.9	
Average G7		2.5	54.8	38.8	-0.9	20.8	74.5	
Australia	-7.7	-1.7	-8.3	21.8	-2.0	11.4	-1.5	
Spain	-11.0	7.3	46.4	26.8	-1.9	16.8	61.8	
Netherlands	-5.7	8.3	51.3	30.3	-3.6	21.4	64.9	
Portugal	-12.1	6.2	48.3	29.6	-2.5	18.3	63.3	
Norway	-16.2	2.0	3.3	9.4	-2.8	6.6	5.3	
New Zealand	-6.7	5.2	-1.4	45.4	-0.4	32.4	16.5	
Sweden	-8.2	1.1	31.8	55.4	-1.0	33.7	53.7	
Belgium	-6.0	3.2	66.4	33.9	-0.3	20.9	82.3	
Finland	-11.4	5.1	68.4	23.7	-0.9	12.7	83.4	
Denmark	-8.6	9.8	28.0	16.3	-1.9	13.9	38.3	
Korea	-7.1	8.5	51.6	15.7	-5.7	8.9	61.2	
Average all		4.0	42.7	32.2	-1.6	19.0	58.4	

*Notes:* The table decomposes the predictive power of *IAD* looking at the contributions of each demand component and of the direct and indirect import demand (notice that the sum of the contributions of *C*, *X*, *I*, and *G*, and the sum of the direct and indirect contributions in this table are both equal to the contribution of *IAD* in Table 5). Negative values indicate that the explanatory variable accounts for import growth in the opposite direction of the one observed.

fall in imports, with the specification using GDP doing better than the *IAD* one). On average for the G7, *IAD* alone explains 95 percent of the fall in imports during the trough of the GTC against about 58 percent explained by GDP. These percentages decrease for the full sample of countries to 77 percent and 50 percent, respectively. Second, the contribution of  $P_M$  is negative for most of the countries, meaning that relative import prices generally decreased in 2009:I, hence, contributing an increase rather than a decrease in imports over the same quarter (remember that the coefficient of  $P_M$  in Table 3 is negative). Third, looking at the individual demand components, two main facts emerge: First, private and government consumption growth contribute only marginally to explaining the fall in imports in 2009:I, the former explaining at most about 10 percent of it in a few countries, such as Denmark, the United Kingdom, and the Netherlands, and the latter explaining an even lower percentage (and often implying an increase rather than a decrease in imports as a result of the fact that government consumption was increasing in most of the countries following the implementation of countercyclical fiscal policies). Second, while investment and exports indeed explain most of the fall in imports, the main driver of the fall varies substantially across countries, making it possible to identify countries that experienced an “export-driven” or an “investment-driven” import collapse. The United States, Canada, Sweden, and New Zealand are among the countries that experienced an “investment-driven” import collapse, although the percentage of the import fall explained by exports is also high for some of them. Japan, France, Italy, Spain, the Netherlands, Portugal,

Belgium, Finland, and Korea instead experienced an “export-driven” import collapse. Finally, in some countries, such as the United Kingdom and Germany, both components of demand played roles of more similar magnitude in explaining the fall in imports.<sup>26</sup>

Finally, decomposing the contribution of *IAD* into the contribution of direct and indirect import demand shows that most of the fall in imports during the GTC was driven by a fall in the indirect import demand, i.e., the demand of imports induced by the expenditure on domestically provided goods and services, which include imports of intermediate inputs from foreign suppliers, as well as imports that are already incorporated in capital, and intermediate inputs acquired from domestic suppliers. This is not surprising given the large fall in investment and exports during the GTC and the fact that they are the most intermediate import-intensive components. We therefore believe that this result is very much in line with Levchenko, Lewis, and Tesar (2010), who emphasize the role of intermediate inputs. To summarize, according to our investigation, there is no major “puzzle” in the magnitude of the fall in world trade observed during the recent financial crisis. Trade fell mostly because demand crashed globally and did so particularly in its most import-intensive component—investment. Moreover, the strong relationship between exports and imports in each country, linked to the increased internationalization of production and the strong dependence of the tradable sector on imported inputs, contributed to the simultaneity and unprecedented severity of the trade collapse. Our approach and results confirm Marquez’s (1999) argument that using standard measures of aggregate demand, such as GDP or domestic demand, in trade equations may be misleading, and more so in periods in which the more import-intensive components of aggregate demand (i.e., investment and exports) fluctuate much more than the others, such as the 2008–2009 crisis.

### C. Trade Elasticities over the Business Cycle

Since the specification using *IAD* performs well in explaining the 2008–2009 Great Trade Collapse, it is important to understand whether the superiority of *IAD* against standard alternatives shown in Table 3 comes from a better fit only during recession periods, when highly import-intensive demand components tend to fall on average more than the components that are relatively less import-intensive (as shown in Figure 6), or survives also when those periods are taken out of the sample. This is a relevant question to gauge the ability of our new proposed measure of demand to replace standard demand measures in empirical works aimed at explaining trade fluctuations. Moreover, since not all recessions are crises and not all crises are global, such as the 2008–2009 one, we perform two alternative estimations for the recession periods, one in which we exclude the recent global crisis and one where we include it.

Table 7 shows the result of the regressions (5) estimated separately for three different data samples, one including expansion periods only, labeled “Exp.,” one all recession periods but the 2008–2009 crisis, labeled “Rec.,” and one all recessions

<sup>26</sup> Results for 2008:IV, which we do not show here to save space, are broadly similar and provide the same country classification.

TABLE 7—EXPANSIONS VERSUS RECESSIONS

	IAD specification			GDP specification		
	Exp.	Rec.	GTC	Exp.	Rec.	GTC
<i>Panel A. L = 0</i>						
$\Delta \ln(D)_t$	0.99*** (0.0956)	0.91** (0.4794)	1.64*** (0.2002)	0.74** (0.2835)	1.52*** (0.4651)	2.56*** (0.3097)
$\Delta \ln(P_M)_t$	-0.16** (0.0641)	-0.45*** (0.1578)	-0.29** (0.1061)	-0.16** (0.0732)	-0.40*** (0.1157)	-0.21** (0.0866)
$R^2$	0.29	0.36	0.51	0.09	0.32	0.33
Observations	1,737	121	207	1,737	121	207
<i>Panel B. L = 1</i>						
$\sum \Delta \ln(D)_{t-l}$	1.48***	1.78***	2.31***	1.51***	3.38***	3.27***
$\Delta \ln(P_M)_t$	-0.15** (0.0564)	-0.33** (0.1599)	-0.31*** (0.0888)	-0.14** (0.0663)	-0.28*** (0.1188)	-0.25*** (0.0723)
$R^2$	0.34	0.53	0.62	0.14	0.49	0.42
Observations	1,737	121	207	1,737	121	207

*Notes:* The table reports estimates of panel regressions of the form (5) performed on our set of 18 countries. A dummy  $p_{c,t}$  is added to the model, which takes value equal to 1 if country  $c$  is in recession at time  $t$  and 0 otherwise.  $D$  is the demand measure used in each regression, which in this table corresponds to  $IAD$ , our new import intensity-adjusted measure of demand. Panel B reports the cumulative coefficients ( $l = 0, 1$ ) of  $IAD$ .  $R^2$  is the in-sample coefficient of determination. Robust standard errors are reported in parentheses. The analysis uses quarterly data from 1985:1 to 2011:IV.

\*\*\*Significant at the 1 percent level.

\*\*Significant at the 5 percent level.

\*Significant at the 10 percent level.

including the 2008–2009 crisis, labeled “GTC.”<sup>27</sup> Here, we compare the results from the equation using our new import intensity-adjusted measure of demand and the specification using GDP, this latter being, in general, the preferred measure in the empirical trade literature. In the bottom panel of Table 7, we report directly the sum of the coefficients on contemporaneous and lagged demand to facilitate the comparison between the two specifications. Several results are worth mentioning. First, both specifications do better at estimating real import growth during recession times, i.e., in periods when the fall in demand is particularly crucial to explain the behavior of trade. Second, the regression using  $IAD$  outperforms the one using GDP during both phases of the cycle in terms of goodness of fit—the improvement from using  $IAD$  being even larger in the expansionary phases of the cycle. This shows that the results in Table 3 are not driven only by extreme events, but they apply to the entire estimation period. Third, the elasticity of imports to demand generally varies between recessions and expansions, with some important distinctions to be made.

Starting with the results of expansions and recessions excluding the GTC episode, the import elasticity to GDP doubles during recessions and is above three when one lag of the exogenous variables is included in the regression. Instead, when  $IAD$  is used as demand measure, the elasticity of imports to demand is broadly stable across

<sup>27</sup> As in the previous section, recessions are defined as two consecutive quarters of negative real GDP growth. Table 7 presents the results for the full set of countries. Results for the G7, which are broadly similar, are shown in Table A3 in the online Appendix.



expansions and recessions. Turning to the recession sample this time *including* the 2008–2009 crisis, we again observe a substantial increase of the elasticity of imports to GDP compared to expansionary phases—the contemporaneous elasticity increases by a factor of 3.5 against a twofold increase when the GTC is excluded. In the case of *IAD*, we also observe an increase of the import elasticity, although much lower than in the case of the model using GDP, and a substantial increase of the in-sample fit. The increase in the elasticity estimates in both specifications suggests that the 2008–2009 global crisis was indeed an exceptional event. In particular, results in Table 7 suggest that nonlinearities in the relation between imports and aggregate demand still persist when *IAD* is used as a measure of demand. This may be due to the role of other factors not accounted for in our simple model of imports, such as financial constraints, the analysis of which is beyond the scope of this paper. However, our simple model is enough to explain most of the GTC episode, as shown in Section IIIB, and to reduce significantly the elasticity difference between different phases of the cycle.

Results in Table 7 corroborate the idea that using GDP as a demand measure in trade equations may be misleading as it delivers highly volatile estimates of demand elasticities that may indicate the presence of structural breaks even when this is not the case. To further explore the possible occurrence of structural breaks in the estimated demand coefficients, we estimate regressions of the form (5) with ten-year rolling windows. Figure 9 shows the evolution of panel import elasticities to GDP and *IAD* for the G7 countries over the period 1985:I–2011:IV (dates in the *x*-axis correspond to the final quarter of each ten-year rolling window). The figure shows a marginal increase in the panel *IAD* elasticity over time from about 1.2 in the nineties to roughly 1.5 in the last years of the sample without any visible evidence of structural break in the import-demand relationship. The estimated panel GDP elasticity (black line) instead shows a noticeable increase over time and highlights two periods of marked increase: the first, temporary, in the period including the 2001 US recession, and the second one, more pronounced, starting with the GTC and enduring till the end of the sample.

As a final exercise, we have analyzed the elasticities of the different components of aggregate demand and how these change over the cycle. Table 8 reports the results of a regression where the components of demand are used as independent demand variables in regression of the form (5). As expected, the coefficient of government spending is not statistically different from zero, in line with our finding that this category of expenditure has very low import content. Meanwhile, the coefficient of private consumption is high, at 0.56, potentially reflecting the high share of private consumption in demand (70 percent of GDP in the United States, to take an example). The two columns on the right show regression results, where the sample is split into recessions and expansions, to uncover the evolution of the elasticities during the business cycle. The results indicate that the coefficient of private consumption is a lot higher during recessions (0.96) than during expansions (0.36), whereas the elasticity of investment is very similar during recessions (0.24) and during expansions (0.28). These findings are in line with our event case analysis, reported in Figure 6, which shows that, during recessions, imports fall by a larger magnitude than private consumption, but by a similar magnitude than investment, due to the fall in the most import intensive categories of expenditure, implying therefore a higher coefficient

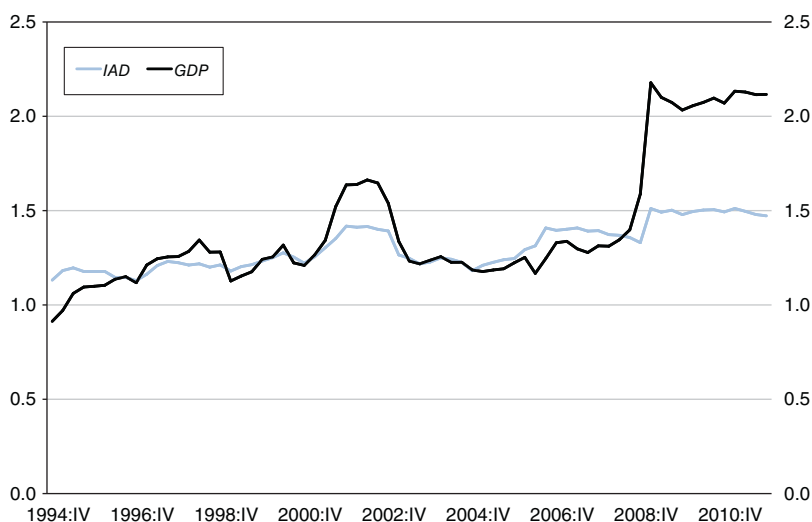


FIGURE 9. EVOLUTION OF IMPORT DEMAND ELASTICITIES OVER TIME

Notes: The figure reports the evolution of the contemporaneous coefficients of the alternative demand measures *GDP* and *IAD* estimated using panel regression of the form (5) performed on the G7 countries with ten-year rolling windows.

TABLE 8—ELASTICITIES OF DEMAND COMPONENTS

	All countries		
	Full sample	Expansions	Recessions
$\Delta \ln(C)_t$	0.56*** (0.1287)	0.36*** (0.0895)	0.96*** (0.20636)
$\Delta \ln(G)_t$	0.15 (0.1435)	0.19 (0.1370)	-0.19 (0.3632)
$\Delta \ln(I)_t$	0.30*** (0.0255)	0.28*** (0.0271)	0.24*** (0.0545)
$\Delta \ln(X)_t$	0.46*** (0.0444)	0.40*** (0.0536)	0.72*** (0.0604)
$R^2$	0.43	0.30	0.65
Observations	1,944	1,737	207

Notes: The table reports the estimates of panel regressions of the form  $\Delta \ln M_{c,t} = \delta_c + \beta_C \Delta \ln C_{c,t} + \beta_G \Delta \ln G_{c,t} + \beta_I \Delta \ln I_{c,t} + \beta_X \Delta \ln X_{c,t} + \beta_P \Delta \ln P_{M,c,t} + \varepsilon_{c,t}$  performed on our set of 18 countries and on the G7. Robust standard errors are reported in parentheses. The analysis uses quarterly data from 1985:1 to 2011:IV.

- \*\*\*Significant at the 1 percent level.
- \*\*Significant at the 5 percent level.
- \*Significant at the 10 percent level.

on the latter. Finally, the coefficient of exports increases during recessions (to 0.72, from 0.40 during expansions). This is again consistent with the evidence from Figure 6 that exports generally fall by less than imports during recessions (notice that the recession sample here means all recessions, including the Great Trade Collapse, where, differently from previous recessions, world exports and imports fell by a similar magnitude, as reported on panel B of Figure 6).

To conclude, our new proposed import intensity-adjusted measure of demand performs well in explaining import trade fluctuations over different phases of the business cycle. Using *IAD* in empirical import equations delivers demand elasticities that are broadly stable over the cycle and do not show any evidence of structural breaks, differently from import elasticities to standard measures of aggregate demand or to individual demand components. This suggests that taking into account changes in the composition of aggregate demand is indeed crucial to understanding the cyclical evolution of trade flows, especially during periods, such as the GTC, when highly import-intensive demand components tend to fall on average more than the components that are relatively less import-intensive.

#### IV. Conclusion

This paper proposed a new empirical model of international trade flows, based on an import intensity-adjusted measure of aggregate demand. While standard empirical trade models typically use GDP (or domestic demand) as measure of aggregate demand, we argue that there is value added in giving different weights to the components of GDP, which typically have very different import intensities. In particular, the analysis of the new OECD Input-Output tables shows that, in general, investment is significantly more import intensive than private consumption, which in turn is more import intensive than government consumption expenditure. In addition, we also find that exports are very import intensive.

Carefully disentangling the effects of investment, private and government consumption, and exports turns out to improve the goodness of fit of the model significantly, and it is especially important in the context of the 2008–2009 crisis, during which these different components of aggregate demand evolved very differently. In particular, investment and exports decreased most significantly over this period, whereas government spending remained robust, supported largely by the fiscal packages put in place by governments in response to the crisis. Recognizing that investment and exports are more import intensive than private and government consumption helps explain why regressions using standard measures of aggregate demand that do not account for differences in import intensity typically underestimate the fall in trade that took place in 2008–2009. Moreover, the high import intensity of exports contributes to explaining the synchronicity of the trade collapse across countries. We reported key stylized facts on these developments, put also in historical perspective, and provided evidence in support of our novel measure of demand (and a theoretical foundation in the Appendix). We showed that using the import intensity-adjusted measure of demand proposed in this paper can significantly enhance the performance of empirical trade models.

#### APPENDIX: *IAD* THEORY

The theoretical foundation for the regression equation with *IAD* as the correct measure of aggregate demand and an unrestricted elasticity is a production possibilities frontier with imports understood to be inputs in total output determination and aggregated into a single variable. The construct follows Feenstra (2003a, chapter 3)

and a series of articles by Kohli (1978; 1990a, b; 1993), but we think of output as demand-driven on the way to thinking of imports as demand-driven.<sup>28</sup>

The total output (or GDP) function in Feenstra (2003a, chapter 3) is usually written as a function of prices. Omitting time indexes to save on notation, let  $\mathbf{Y}$  be the vector of outputs,  $\mathbf{P}$  be the price vector of these outputs,  $\mathbf{M}$  be imports,  $\mathbf{P}_M$  be the price vector of imports, and  $\mathbf{F}$  be the vector of primary factors of production.<sup>29</sup> Given a convex technology  $T$  (function of  $\mathbf{Y}$ ,  $\mathbf{M}$ , and  $\mathbf{F}$ ), the efficient economy is assumed to determine outputs of individual goods and imports to maximize total output (GDP) subject to prices and the endowments of primary factors. Let GDP be described by the function  $v(\cdot)$  of  $\mathbf{P}$ ,  $\mathbf{P}_M$ , and  $\mathbf{F}$  defined as

$$v(\mathbf{P}, \mathbf{P}_M, \mathbf{F}) \equiv \max_{\mathbf{Y}, \mathbf{M}} \mathbf{P}\mathbf{Y} - \mathbf{P}_M\mathbf{M} \mid \mathbf{Y} \in T(\mathbf{Y}, \mathbf{M}, \mathbf{F}).$$

In this setup, the demand for imports is given by the partial derivative  $-v_{\mathbf{P}_M}(\mathbf{P}, \mathbf{P}_M, \mathbf{F})$ , while the supply of output is given by  $v_{\mathbf{P}}(\mathbf{P}, \mathbf{P}_M, \mathbf{F})$ .

To think now of imports as demand-driven, we need to use the market clearing condition for output,  $v_{\mathbf{P}}(\mathbf{P}, \mathbf{P}_M, \mathbf{F}) = \mathbf{D}$ , where  $\mathbf{D}$  is the demand vector. Define the new GDP function  $V(\mathbf{D}, \mathbf{P}_M, \mathbf{F})$  as function of the demand vector  $\mathbf{D}$ , import prices  $\mathbf{P}_M$ , and primary factors  $\mathbf{F}$  as follows. Let

$$\tilde{v}(\mathbf{D}, \mathbf{P}_M, \mathbf{F}) \equiv \min_{\mathbf{P}} v(\mathbf{P}, \mathbf{P}_M, \mathbf{F}) - \mathbf{P}\mathbf{D}.$$

The first-order condition for this problem is the market clearing condition for output, which can be solved for the market clearing price. Then we can write the GDP function as

$$(A1) \quad V(\mathbf{D}, \mathbf{P}_M, \mathbf{F}) \equiv \tilde{v}(\mathbf{D}, \mathbf{P}_M, \mathbf{F}) + \mathbf{D} \tilde{v}_D(\mathbf{D}, \mathbf{P}_M, \mathbf{F}).$$

Import demand is therefore given by the partial derivative

$$(A2) \quad M(\mathbf{D}, \mathbf{P}_M, \mathbf{F}) = -V_{\mathbf{P}_M}(\mathbf{D}, \mathbf{P}_M, \mathbf{F}).$$

Given this result, we can obtain the desired import demand equation in two ways: One relies on assuming that the GDP function is approximated by a translog function, in the spirit of Kohli (1978; 1990a, b; 1993) and Feenstra (2003a, chapter 3).<sup>30</sup> The alternative consists of imposing the translog assumption directly on the import demand function in (A2). We show the result for each of these approaches below.<sup>31</sup>

<sup>28</sup> We are grateful to James Anderson for suggestions that led to the development of this foundation.

<sup>29</sup> All prices are in real terms.

<sup>30</sup> See also Kee, Nicita, and Olarreaga (2008), who focus on the estimation of import demand elasticities to prices, and Harrigan (1997).

<sup>31</sup> The translog function has been shown to have appealing empirical properties in a variety of contexts in addition to the work reviewed in Feenstra (2003a, chapter 3). For instance, Bergin and Feenstra (2000, 2001) show that a translog expenditure function makes it possible to generate empirically plausible endogenous persistence in macro and international macro models by virtue of the implied demand-side pricing complementarities. Feenstra (2003b) shows that the properties of the translog expenditure function used by Bergin and Feenstra (2000, 2001) hold also when the number of goods varies. Bilbiie, Ghironi, and Melitz (2012) find that translog preferences and endogenous producer entry result in markup dynamics that are remarkably close to US data. Rodríguez-López (2011) extends

### A. Translog GDP Function

Let  $P_M$  denote the scalar import price index in what follows. Suppose that the GDP function  $V(\mathbf{D}, P_M, \mathbf{F})$  is described by the following translog function:<sup>32</sup>

$$\begin{aligned}
 \text{(A3)} \quad \ln V(\mathbf{D}, P_M, \mathbf{F}) &= \alpha + \sum_k \mu_k \ln D_k + \mu_P \ln P_M + \sum_f \mu_f \ln F_f \\
 &+ \frac{1}{2} \sum_k \sum_j \lambda_{kj} \ln D_k \ln D_j + \frac{1}{2} \lambda_P^2 (\ln P_M)^2 \\
 &+ \frac{1}{2} \sum_f \sum_h \lambda_{fh} \ln F_f \ln F_h + \sum_k \sum_f \phi_{kf} \ln D_k \ln F_f \\
 &+ \ln P_M \sum_k \phi_k \ln D_k + \ln P_M \sum_f \phi_f \ln F_f.
 \end{aligned}$$

The translog function (A3) implies that the share of total imports (scalar)  $M$  in GDP,  $s_M^V$ , is linear in the (log) components of aggregate demand:

$$\begin{aligned}
 \text{(A4)} \quad s_M^V &\equiv \frac{\partial \ln V(\mathbf{D}, P_M, \mathbf{F})}{\partial \ln P_M} = \frac{P_M V_{P_M}(\mathbf{D}, P_M, \mathbf{F})}{V(\mathbf{D}, P_M, \mathbf{F})} = \frac{P_M(-M)}{V} \\
 &= \mu_P + \lambda_P \ln P_M + \sum_k \phi_k \ln D_k + \sum_f \phi_f \ln F_f.
 \end{aligned}$$

Second-order terms in the translog GDP function are crucial for the import share to deviate from the Cobb-Douglas share  $\mu_P$ . Note that, since imports are an input to GDP, the import share  $s_M^V$  is negative. In (A4), we used the short-hand notation  $-M \equiv V_{P_M}(\mathbf{D}, P_M, \mathbf{F})$  and  $V \equiv V(\mathbf{D}, P_M, \mathbf{F})$ .

Consider now the absolute value of the import share:  $P_M M/V$ . Differentiating this expression and defining percent deviations from steady state, we have

$$(\hat{P}_M + \hat{M} - \hat{V}) | \bar{s}_M^V |,$$

the model of trade and macro dynamics with heterogeneous firms in Ghironi and Melitz (2005) to include nominal rigidity and a translog expenditure function. He obtains plausible properties for exchange rate pass-through, markup dynamics, and cyclical responses of firm-level and aggregate variables to shocks.

<sup>32</sup> See Feenstra (2003a, chapter 3) for the parameter restrictions that are usually imposed on the translog GDP function (as function only of prices and factor endowments) to ensure homogeneity of degree 1 and symmetry. Some restrictions would be different for our transformed function. However, we do not rely on any of these restrictions below, so they can be safely ignored for our purposes.

where, for any variable  $Q$ ,  $\hat{Q} \equiv dQ/\bar{Q}$ ,  $d$  denotes the differentiation operator, and overbars denote levels along the steady-state path. Note that, for small enough perturbations,  $\hat{Q} \equiv dQ/\bar{Q} \approx d\ln Q = \ln Q - \ln \bar{Q}$ . It follows that

$$\begin{aligned} (\hat{P}_M + \hat{M} - \hat{V}) | \bar{s}_M^V | &\approx (d\ln P_M + d\ln M - d\ln V) | \bar{s}_M^V | \\ &\approx - \left( \lambda_P d\ln P_M + \sum_k \phi_k d\ln D_k + \sum_f \phi_f d\ln F_f \right), \end{aligned}$$

where the second approximate equality follows from differentiating the expression of the import share in (A4) after changing sign. Rearranging this equation yields

$$\begin{aligned} \text{(A5)} \quad d\ln M &\approx (d\ln V - d\ln P_M) \\ &\quad - \frac{1}{|\bar{s}_M^V|} \left( \lambda_P d\ln P_M + \sum_k \phi_k d\ln D_k + \sum_f \phi_f d\ln F_f \right). \end{aligned}$$

Differentiating (A3), we have

$$\begin{aligned} d\ln V &= \sum_k \mu_k d\ln D_k + \mu_P d\ln P_M + \sum_f \mu_f d\ln F_f \\ &\quad + d \left[ \frac{1}{2} \sum_k \sum_j \lambda_{kj} \ln D_k \ln D_j + \frac{1}{2} \lambda_P^2 (\ln P_M)^2 + \frac{1}{2} \sum_f \sum_h \lambda_{fh} \ln F_f \ln F_h \right] \\ &\quad \left[ + \sum_k \sum_f \phi_{kf} \ln D_k \ln F_f + \ln P_M \sum_k \phi_k \ln D_k + \ln P_M \sum_f \phi_f \ln F_f \right]. \end{aligned}$$

For simplicity, assume that all the second order terms in (A3) are constant at their steady-state levels (or that their variation around the steady-state path is negligible). Then,

$$d\ln V = \sum_k \mu_k d\ln D_k + \mu_P d\ln P_M + \sum_f \mu_f d\ln F_f,$$

and substituting this into (A5) yields

$$\begin{aligned} \text{(A6)} \quad d\ln M &\approx \left( \sum_k \mu_k d\ln D_k + \mu_P d\ln P_M + \sum_f \mu_f d\ln F_f - d\ln P_M \right) \\ &\quad - \frac{1}{|\bar{s}_M^V|} \left( \lambda_P d\ln P_M + \sum_k \phi_k d\ln D_k + \sum_f \phi_f d\ln F_f \right) \\ &= \sum_k \left( \mu_k - \frac{1}{|\bar{s}_M^V|} \phi_k \right) d\ln D_k + \left( \mu_P - 1 - \frac{1}{|\bar{s}_M^V|} \lambda_P \right) d\ln P_M \\ &\quad + \sum_f \left( \mu_f - \frac{1}{|\bar{s}_M^V|} \phi_f \right) d\ln F_f. \end{aligned}$$

Introduce time indexes, allow for time variation in the coefficients on aggregate demand components, and define

$$\begin{aligned}\beta_{k,t} &\equiv \mu_{k,t} - \frac{1}{|\bar{s}_M^V|} \phi_{k,t}, \\ \beta_P &\equiv \mu_P - 1 - \frac{1}{|\bar{s}_M^V|} \lambda_P, \\ \beta_f &\equiv \mu_f - \frac{1}{|\bar{s}_M^V|} \phi_f,\end{aligned}$$

where we impose the restrictions  $\beta_{k,t} > 0$  and  $\beta_P < 0$ . Note that the first definition implicitly assumes that the share of imports in GDP is constant along the steady-state path. Using these definitions,

$$d \ln M_t \approx \sum_k \beta_{k,t} d \ln D_{k,t} + \beta_P d \ln P_{M,t} + \sum_f \beta_f d \ln F_{f,t}.$$

First-differencing this relation yields

$$\Delta d \ln M_t \approx \sum_k \Delta (\beta_{k,t} d \ln D_{k,t}) + \beta_P \Delta d \ln P_{M,t} + \sum_f \beta_f \Delta d \ln F_{f,t}.$$

Assume that the effect of growth in the deviations of factor endowments from the steady-state path is also negligible:  $\sum_f \beta_f \Delta d \ln F_{f,t} \approx 0$ .<sup>33</sup> Then,

$$\Delta d \ln M_t \approx \sum_k \Delta (\beta_{k,t} d \ln D_{k,t}) + \beta_P \Delta d \ln P_{M,t},$$

or:

$$\begin{aligned}(A7) \quad \Delta \ln M_t - \Delta \ln \bar{M}_t &\approx \sum_k \Delta [\beta_{k,t} (\ln D_{k,t} - \ln \bar{D}_{k,t})] \\ &\quad + \beta_P \Delta (\ln P_{M,t} - \ln \bar{P}_{M,t}).\end{aligned}$$

Assume that imports, aggregate demand, and import prices are growing at constant rates along the steady-state path. Then,  $\Delta \ln \bar{M}_t - \sum_k \Delta (\beta_{k,t} \ln \bar{D}_{k,t}) + \beta_P \Delta \ln \bar{P}_{M,t}$  is a constant, which we denote  $\delta$ , and we can rewrite equation (A7) as

$$\Delta \ln M_t \approx \delta + \sum_k \Delta (\beta_{k,t} \ln D_{k,t}) + \beta_P \Delta \ln P_{M,t}.$$

To a first order, we reduced import growth to an increasing function of aggregate demand growth and a decreasing function of growth in import prices.

<sup>33</sup> Note that the regression equations based on C.E.S. demand also abstract from a direct effect of changes in factor endowments.

Next, assume that there exists a  $\beta_D > 0$  such that  $\beta_{k,t} = \beta_D \omega_{k,t}$ . Then,

$$\Delta \ln M_t \approx \delta + \beta_D \sum_k \Delta (\omega_{k,t} \ln D_{k,t}) + \beta_P \Delta \ln P_{M,t}.$$

Finally, letting  $k = C, G, I, X$ ;  $D_C \equiv C$ ,  $D_G \equiv G$ ,  $D_I \equiv I$ ,  $D_X \equiv X$ , and recalling the definition  $IAD_t \equiv C_t^{\omega_{C,t}} G_t^{\omega_{G,t}} I_t^{\omega_{I,t}} X_t^{\omega_{X,t}}$  returns

$$(A8) \quad \Delta \ln M_t \approx \delta + \beta_D \Delta \ln IAD_t + \beta_P \Delta \ln P_{M,t}.$$

This—or, more precisely, its stochastic version—is the benchmark regression equation of the same form as (4), with  $IAD$  as the correct measure of aggregate demand, and with unrestricted aggregate demand elasticity  $\beta_D$ .<sup>34</sup>

In principle, one could econometrically estimate the individual coefficients  $\beta_{k,t}$  by estimating

$$\Delta \ln M_t = \delta + \sum_k \Delta (\beta_{k,t} \ln D_{k,t}) + \beta_P \Delta \ln P_{M,t} + \varepsilon_t,$$

where  $\varepsilon_t$  is the error term, at the cost of degrees of freedom. Our approach is to impose the coefficients  $\omega_{k,t}$  from the Input-Output tables (subject to the normalization  $\sum_k \omega_{k,t} = 1$ ) and use the constructed aggregate variable  $IAD_t$  in the stochastic version of (A8), identifying the common constant coefficient  $\beta_D$ .

### B. Translog Import Function

An alternative to the approach above would be to assume instead that the import function  $M = -V_{P_M}(\mathbf{D}, P_M, \mathbf{F})$  is directly described by the translog function:

$$(A9) \quad \begin{aligned} \ln M &= \alpha + \sum_k \beta_k \ln D_k + \beta_P \ln P_M + \sum_f \beta_f \ln F_f \\ &+ \frac{1}{2} \sum_k \sum_j \lambda_{kj} \ln D_k \ln D_j + \frac{1}{2} \lambda_P^2 (\ln P_M)^2 \\ &+ \frac{1}{2} \sum_f \sum_h \lambda_{fh} \ln F_f \ln F_h + \sum_k \sum_f \phi_{kf} \ln D_k \ln F_f \\ &+ \ln P_M \sum_k \phi_k \ln D_k + \ln P_M \sum_f \phi_f \ln F_f, \end{aligned}$$

where  $\beta_P < 0$ .<sup>35</sup>

<sup>34</sup> As Feenstra (2003a, chapter 3) notes, the approach we followed—treating exports and imports as an output and input, respectively, in the production process, and defining exports and imports independently from consumption—is sensible if exports are differentiated from domestic goods and imports are mainly intermediates. Both are empirically plausible assumptions.

<sup>35</sup> We again omit parameter restrictions we do not rely on below.



In this case, the *IAD*-based regression equation essentially follows from first-differencing (A9) under the assumption that second-order terms and factor endowments are constant over time. Introducing time indexes and allowing for time variation in the coefficients  $\beta_k$ , this yields

$$\Delta \ln M_t = \sum_k \Delta (\beta_{k,t} \ln D_{k,t}) + \beta_P \Delta \ln P_M.$$

Assuming next that  $\beta_{k,t} = \beta_D \omega_{k,t}$  and proceeding as in the case of the translog GDP function, we obtain

$$(A10) \quad \Delta \ln M_t = \beta_D \Delta \ln IAD_t + \beta_P \Delta \ln P_{M,t}.$$

Except for the constant included in the regression and the error term, this is again the benchmark regression equation with *IAD* as the correct measure of aggregate demand in import determination.

The advantage of this approach to obtaining the regression equation is that it does not rely on the approximations used with the translog GDP function and, therefore, it is not restricted to small perturbations around the steady-state path (which certainly do not describe the 2008–2009 collapse). On the other hand, the assumption of a translog GDP function is more conventional in the literature. Importantly, though, both approaches provide a justification for the same import demand and regression equation.

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