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Measuring Fifty Years of Trade Globalization

Abstract: Although trade globalization is a multi-faceted phenomenon, researchers often capture its magnitude by trade volume alone. In order to gain a deeper understanding of the phenomenon we propose measures that also account for the interconnectedness of countries, for geographical distance, and for the role of individual sectors in bilateral trade. We also improve upon existing indices by moving from a country-level analysis (internationalization) to a truly global perspective (globalization). We measure trade globalization using data from CHELEM (CEPII) over a period of 50 years, covering 72 countries for the sub-period 1967–1990 and 84 countries for 1994-2016. The results show substantial increases in all dimensions of globalization, despite substantial differences between the measures, highlighting the need to analyze globalization with a comprehensive set of indicators. Regarding the number of positive bilateral trade flows, globalization was almost completed by 2016. The importance of distance also diminished throughout the period analyzed, but neighboring countries still share stronger trade relations. Results indicate that trade globalization for high-tech sectors varies significantly from the evolution seen in other sectors, especially large, low-tech sectors. The latter tend to show the highest level of trade globalization over the whole period, but the former group could catch up considerably in the future.

Key words: globalization, trade interdependencies, multidimensional, measures, distance, sectors.

JEL Codes: F10, F14.

1. Introduction

Globalization is one of the most prominent topics in economics among academics and policy makers, and in the broader public debate. The first to introduce the term "globalization" into the economic literature were Naisbitt (1982) and Levitt (1983), who describe the evolution from nationally acting firms to global market players and highlight the important role of technological change in facilitating global trade. In this respect, OECD (2005) refers to globalization as a complex, multidimensional integration process in which the increase in the mobility of production factors reduces the importance of distance (and space).

In this paper we restrict the analysis to one of the most important economic aspects of globalization – trade globalization – ignoring, therefore, other aspects of the phenomenon, such as its cultural, ecological, legal, political, and social dimensions. The distinction between internationalization and globalization is noteworthy: whereas in the context of internationalization the nation state remains the central point of investigation (Scholte, 2008), globalization emphasizes the interdependencies of countries that result in deeper trade relations. This integration process is yet far from being completed as digitalization is projected to further reduce trade costs, thereby increasing world trade by 2% annually until 2030 (WTO, 2018).

Over the last decades considerable effort has been undertaken to advance the measurement of globalization and create a deeper understanding of its components. Multidimensional measures – such as the widely applied KOF Globalisation Index (Dreher, 2006; for an update see Gygli, Haelg, Potrafke, and Sturm, 2019) – aim to measure the variety of influential economic, social, and political factors. However, these approaches still follow a country-level perspective. They can therefore provide a magnitude of indicators at the national level but neglect the single most important factor that distinguishes globalization from internationalization: interconnectedness. As affirmed by De Lombaerde and Iapadre (2008, pp. 174-175), "*the most important unsettled issue is that of defining and correctly representing the geographic space of the process. The available indicators still rely on a misleading identification of globalization with a country's openness to the rest of the world, seen as a unique partner, without paying due attention to the geographic*

diversification and reach of its international relationships". Aiming to overcome this gap in the literature, we propose a set of indicators to measure the different facets of trade globalization.

We contribute to the literature at four main levels. First, by proposing new measures of trade globalization that account for its several relevant dimensions, namely the number of bilateral flows, geographic distance, volume, and number of sectors involved in trade. Second, we adopt a global approach instead of conducting, as is common, a country-level analysis, thereby shifting the focus from internationalization to globalization. Third, we make the distinction between bounded and unbounded dimensions of trade globalization, allowing us to capture, in the first case, how far we are from the maximum level of trade globalization. Fourth, at the empirical level, we conduct a detailed quantification of trade globalization over a period of 50 years (1967-2016).

The paper is structured as follows. The literature review, in Section 2, discusses meaningful definitions of globalization and provides an overview of existing globalization measures. In Section 3 we propose new trade globalization measures that can incorporate the interconnectedness of countries, distance, and a sectoral component. In section 4 we present the data used in our empirical analysis. In Section 5 we evaluate the evolution of trade globalization during the period 1967-2016. In Section 6 we complement this evidence with results at the sectoral level. In Section 7 we present some final remarks.

2. Defining and Measuring (Trade) Globalization

2.1. Defining Globalization

We can identify two major strands of definitions in the literature highlighting different aspects of economic globalization. The first focuses on the connection effect that globalization exerts on countries. Globalization thus "*reflect[s] increased economic interdependence of countries. Such phenomena include flows of goods and services across borders, reductions in policy and transport barriers to trade, international capital flows, multinational activity, foreign direct investment, outsourcing, increased exposure to exchange rate volatility, and immigration*" (Goldberg and Pavcnik, 2007, p. 41). McGrew (1992, p. 15) stresses that globalization involves "*the widening, deepening and speeding up of worldwide interconnectedness*". Norris (2000, p. 155) completes this view by characterizing the phenomenon as "*a process that erodes national boundaries,*

integrates national economies, cultures, technologies and governance, and produces complex relations of mutual interdependence."

The second strand of literature focuses on globalization as a synonym for the decline in trade costs and positive effect on global trade flows. Harvey (1989) uses the expression "*time-space compression*" to express the idea that technological innovation in the areas of communication and transport have helped to overcome distance more easily. Along the same lines, Friedman's famous book "*The World Is Flat*" (Friedman, 2005) describes factors leading to the "*death of distance*" (Cairncross, 1997) that have fostered the establishment of global value chains. Keohane, Nye, and Joseph (2000, p. 106) emphasize that "*for a network of relationships to be considered 'global', it must include multicontinental distances*". Nevertheless, the discussion of the extent to which distance still matters and whether "*the world is not flat*" after all (Christopherson, Garretsen, and Martin, 2008) is still ongoing.

To sum up, globalization reflects not only the increase of economic interdependencies between countries, but also widening and deepening of these economic interconnections. With the special focus of this paper on trade globalization, these interdependencies also manifest in outsourcing processes and the establishment of global value chains, implying that globalization affects not only the number of countries and volume of trade but also the number of sectors involved in trade.

2.2. (Trade) Globalization Measures

As (trade) globalization and the understanding of its development have become central topics in economics, its measurement has become crucial to advancing our knowledge. Global trade volume and openness to trade have long been the most straightforward indicators of globalization. One reason for this is availability of rich data in terms of number of countries and time span, allowing researchers to describe the evolution of globalization since the 19th century (Federico and Tena-Junguito, 2017). Nevertheless, they do not allow conclusions to be drawn regarding the structure and causes of the development of (trade) globalization. Starting in the early 2000s, researchers have proposed multidimensional indices to capture globalization in its multifaceted nature, including economic, political, social, and environmental aspects. Trade is identified as a key component of economic globalization.

One of the first composite indices was the Foreign Policy/A.T. Kearney Index (A.T. Kearney, 2001, 2007). This aims to measure the degree to which countries are connected and the degree to which they are affected by globalization. However, the index has been criticized on various grounds. Whereas Scholte (2002) disapproved of its limited theoretical foundation and relevance, Lockwood (2004) highlighted its limited robustness due to the fact that weights for variables were chosen arbitrarily, and because of problems associated with measuring openness to trade without considering the impact of differences in country size. Lockwood (2004) and Heshmati (2006) propose several adjustments to overcome these limitations.

Given the weaknesses of the A.T. Kearney Index, others proposed multidimensional indices that are more elaborate and methodologically robust, following guidelines summarized in the OECD Handbook on Constructing Composite Indicators (2008). One is the Maastricht Globalization Index (Martens and Zywietz, 2006; Martens and Raza 2009; for an updated version see Figge and Martens, 2014) which builds on the World Development Indicators and widens the perspective of globalization to environmental dimensions as well as to trade in military arms as a share of the military budget. Moreover, the authors aim to control for exogenous factors to counteract the naturally higher degree of openness of smaller countries. Another is the KOF Globalisation Index, introduced by Dreher (2006). It is the most widely used globalization measure as outlined in the overview by Potrafke (2015). Dreher, Gaston, Martens, and Van Boxem (2010) claim the advantage of the KOF index when compared to the Maastricht Index is that the latter is no more than a simple additive composite index, whereas KOF uses statistical analysis to more robustly assign weights to the variables. The update of the Maastricht Globalization Index by Figge and Martens (2014) addresses this weakness, introducing more robust weighting schemes. It is also important to mention the New Globalization Index proposed by Vujakovic (2010), as it is the only multidimensional index that considers distance between the countries. Nevertheless, it does not account for the number of countries involved in trade and cannot shed light on the inherent trade structure.

Table 1 presents an overview of common characteristics of multidimensional indices. The number of indicators, the time span, and number of countries studied by the indices varies widely, with the KOF Index outperforming the others in all three categories in terms of coverage.

[Insert Table 1 here]

Vujakovic (2010) uses nine indicators to measure economic globalization, two of them directly addressing trade globalization. In the KOF Index, trade as a percentage of GDP accounts for only 11% of economic globalization. The CSGR Index measures economic globalization using four indicators. One of them is trade, which receives 83.29% of the total weight. Thus, while all multidimensional indices use trade as a proxy for economic globalization, the weight assigned to this dimension varies widely. Moreover, most use openness to trade as the single proxy for trade globalization, considering neither absolute trade volume nor the bilateral interdependencies between countries. Therefore, with regard to trade globalization, these indices should be considered one dimensional and simple indicators as they relate each country's exports to GDP and report values for every country separately. There is a long tradition of using a country's exports as a proxy for trade globalization. Several authors also use exports plus imports in relation to GDP to account for the differences in country sizes and avoid problematic interpretations due to the higher probability of small countries being more open to trade than larger countries (for an overview see Squalli and Wilson, 2011). However, these indicators do not capture interdependencies or distance.

As Figge and Martens (2014) point out, the abovementioned indices are constructed at the national level and their aim is to provide a ranking and information about a country's international competitiveness in a globalized world. Most do not even propose an aggregated metric to measure globalization at the global level, with the exception of the KOF. For this, it would be necessary to leave behind the single country perspective, as is done in network analysis.

When applied to trade globalization network analysis can be advantageous, as countries are treated as being "*embedded in the whole web of trade relationships*" (De Lombaerde, Iapadre, McCranie, and Tajoli, 2019, p. 497). Thus, more attention can be given to the relationship between countries through the structure of trade flows (De Benedictis and Tajoli, 2011). Moreover, De Benedictis, Nenci, Santoni, Tajoli, and Vicarelli (2014) highlight that trade relations between two countries should not be viewed in isolation from developments in other countries, since all are interconnected through the network. Ignoring this web of interdependencies underestimates the complexity of globalization. Kali and Reyes (2007) use network analysis to highlight differences in the strength of trade linkages by distinguishing between global and regional trade networks for the period 1992 to 1998. Barigozzi, Fagiolo, and Mangioni (2011), using data from the 1990s and early 2000s, identify clusters of countries that form trade sub-networks due to their strong

interlinkages with one another, while trade with other countries remains significantly lower. Arribas, Pérez, and Tortosa-Ausina (2009) assume the process of globalization is completed when trade is equally distributed among countries and measure the gap between actual globalization and perfect international integration. While this approach is obviously interesting, it does not take overall trade volume into account.

Squartini, Fagiolo, and Garlaschelli (2011) and Barigozzi et al. (2011) used network analysis to study commodity-specific globalization trends for 97 product groups from 1992 to 2002/2003. They perform their analysis at the sectoral level and investigate a trade web for each sector to highlight geographical differences between the trading patterns of goods such as coffee and steel. However, due to data requirements, the analysis can only be performed for a small number of sectors. Network analysis thus sheds light on interconnectedness of countries and the structure of bilateral trade relationships, but ignores trade volume.

2.3. Research Gaps

This discussion reveals two critical research gaps. First, existing measures are unable to capture all relevant dimensions of trade globalization (Scholte, 2008; Martens, Caselli, De Lombaerde, Figge, and Scholte, 2015). Second, most trade globalization measures adopt a country-level perspective. This leads to a neglect of geographical distribution and diversification of trade as well as to an underestimation of countries' integration.

The main objective of the present paper is to address these research gaps. Our approach adds to the existing literature at four main levels. First, we introduce a set of measures that allows the user to capture a more comprehensive concept of trade globalization, taking into account not only the number of countries' bilateral trade relationships, but also distance and the number of sectors involved. Second, we avoid the country-level perspective, following instead a truly global approach. Third, we distinguish between bounded and unbounded dimensions of trade globalization. Finally, we provide a detailed quantification of trade globalization over a long period of time, from 1967 to 2016.

3. Measures of Trade Globalization

We propose a set of trade globalization measures that incorporate interdependencies and distance between countries as well as sectoral components of international trade:

Trade Globalization = f (Volume of trade, Number of bilateral relations, Distance, Number of sectors) (1)

While the first dimension does not have an upper bound, the others are bounded. This gives us a benchmark to which current levels can be compared. In this study we capture both bounded and unbounded dimensions of trade globalization, thereby providing a more comprehensive evaluation of the phenomenon.

We take the matrices of bilateral trade as the starting point of our analysis. A generic element of the matrix, x_{iht}, represents exports from country i to h, in period t. I denotes the number of exporting countries and H the number of importing countries. Since no country trades with itself, the number of relevant elements of each matrix is $I(H-1)$.

The first and most commonly considered dimension of trade globalization is trade volume. In order to capture this, we obtain:

$$R_t = \frac{\sum_{i=1}^{I}\sum_{h=1}^{H} x_{iht}}{\sum_{i=1}^{I}\sum_{h=1}^{H} x_{iht-1}}. \quad (2)$$

Then, we calculate:

$$R'_t = R'_{t-1} R_t \quad (3)$$

with $R'_{1967} = 1$.

This corresponds to the unbounded dimension of trade globalization, as it compares the actual volume of trade with the corresponding value at the beginning of the period under scrutiny.

With regard to the bounded dimension, the maximum value is obtained when all sectors trade in all bilateral relations. We introduce three measures of trade globalization, all of them ranging from 0 (minimum level of trade globalization) to 1 (maximum level of trade globalization).

Our first (and simplest) index captures the percentage of bilateral relations with positive trade in the total number of country pairs at the world level in year t:

$$G1_t = \frac{\sum_{i=1}^{I}\sum_{h=1}^{H} v_{iht}}{I(H-1)} \quad (4)$$

where v_{iht} distinguishes positive from non-positive bilateral trade flows:

$$v_{iht} = \begin{cases} 1 \; if \; x_{iht} > 0 \\ 0 \; if \; x_{iht} = 0 \end{cases}. \quad (5)$$

Aiming to capture the distance travelled by trade, we consider a new measure – $G2_t$ – capturing the proportion of the total distance among all the countries in which positive trade exists:

$$G2_t = \frac{\sum_{i=1}^{I}\sum_{h=1}^{H} Dist_{iht} v_{iht}}{\sum_{i=1}^{I}\sum_{h=1}^{H} Dist_{iht}} \quad (6)$$

where $Dist_{iht}$ is the distance between i and h. $G1_t$ and $G2_t$ range between 0 (no trade between any country pair) and 1 (trade in all bilateral relations).

The final aspect is sectoral dimensions. We argue that trade globalization is higher when more sectors ($s = 1, 2, ..., S$) are involved in trade. Therefore, we calculate a new measure incorporating this. We first obtain Z_t which represents the average number of sectors involved in bilateral trade:

$$Z_t = \frac{\sum_{i=1}^{I}\sum_{h=1}^{H} c_{iht}}{I(H-1)} \quad (7)$$

where:

$$c_{iht} = \sum_{s=1}^{S} b_{ihst} \quad (8)$$

and

$$b_{ihst} = \begin{cases} 1 \; if \; x_{ihst} > 0 \\ 0 \; if \; x_{ihst} = 0 \end{cases}. \quad (9)$$

Calculating the ratio between Z_t and S (total number of sectors), we get the percentage of sectors with trade, allowing us to obtain $G3_t$:

$$G3_t = G2_t^{\frac{Z_t}{S}}. \quad (10)$$

The maximum level of trade globalization regarding its bounded dimensions occurs when $G3_t = 1$, meaning, as mentioned above, that all sectors are traded in all bilateral relations.

4. Data

Our data come from CHELEM (CEPII) using ISIC, 4 digit-level (147 sectors). Taking into consideration the important political changes in the first half of the 1990s, namely the disintegration of the USSR, Yugoslavia, and Czechoslovakia, we are forced to consider two different series: (i) 1967-1990 (72 countries, including the three just named); (ii) 1994-2016 (84

countries).[1] The countries included are identified in Table A.1 in the Annex. They represent around 96% of world GDP. For each year of the sub-period 1967-1990, we have: (i) a matrix of bilateral trade flows, in overall terms, including 5,112 elements; (ii) similar matrices for 147 sectors. This information corresponds to more than 18 million bilateral trade flows. For the sub-period 1994-2016, we consider 6,972 elements in the matrix, adding up to almost 25 million bilateral trade flows. Altogether, we consider around 43 million bilateral trade flows. Figure 1 summarizes the empirical approach followed.

[Insert Figure 1 here]

Our analysis is restricted to manufacturing, since data for services are unavailable for our sample and time span. Yet even though trade in services has increased over the last decade it only accounts for only 21% of total trade in 2017 and is projected to increase to 25% in 2030, implying that our data capture the major part of international trade (WTO, 2018).

5. Overall Evidence

The exponential growth of world trade during the second half of the 20th century is well-established empirically. The role of falling trade costs (due to greater efficiency in transportation infrastructures, falling communication costs, and lower tariffs) as well as the collapse of communism help explain this trend, especially since the 1990s (Rodrigue, 2017). Yet there are also periods of decline and stagnation in world trade, as shown in Figure 2. The most prominent of these can be explained by the two oil price shocks in the 1970s, the bursting of the dot-com bubble, and the largest worldwide recession since World War II in 2009 (WTO, 2018).

[Insert Figure 2 here]

5.1 Bilateral Relations and Distance in Trade Globalization

The current understanding of the role of distance in bilateral trade linkages and the extent to which sectors are involved in trade globalization is very limited. These aspects are central in our analysis. Together with the number of positive trade flows, they represent the bounded dimensions of trade

[1] Therefore, comparisons between the two periods should be approached with caution.

globalization. The literature suggests distance plays an important role in bilateral trade relations: Chortareas and Pelagidis (2004) stress that increases in trade volume tend to be regional rather than global; Bhagwati (1995) refers to the *spaghetti bowl phenomenon*. Additionally, De Lombaerde et al. (2019) show that trade globalization strengthens ties between countries that have long-established trade relations and distance still matters even though new countries have become part of the international trade network since the 1960s.

[Insert Figure 3 here]

We begin our analysis with the number of bilateral trade relationships and the importance of distance. In Figure 3 we show evidence that $G1_t$ and $G2_t$ were already high in the 1960s and close to their upper bounds in 2016 (Figure 3, Panel (3a)). Results for $G1_t$ indicate that 83.53% of all possible bilateral trade relations were already in place in 1968. This percentage grew to 99.02% in 2016. The percentage of positive bilateral trade relationships increased almost monotonically. However, the size of the increases varies over time. On average, $G1_t$ increased by 0.53% annually in the first sub-period and 0.29% in the second sub-period. This slower increase can be interpreted as an indication that trade globalization had almost reached its full potential. In only four years do we find small decreases in the level of $G1_t$: 1971, 1983, 1985, and 2012. Three of these years fall into the first part of the period studied (1971, 1983, and 1985). Nevertheless, these small negative changes are negligible when compared to the increases over the full period.

Examining our data in greater detail, we find that in 1968, only four countries in the sample were exporting to all other countries – the United States, Japan, Sweden, and Finland. Fewer than half of all 72 countries were exporting to Bangladesh and Brunei, and Albania also was not well integrated into the global trade network. Brunei was the country with the fewest trading partners. It traded with only 12 of the 71 other countries in 1968, and with 69 of the 83 other countries in 2016. At the same time, the "average country" had 59 trading partners in 1968 and 82 in 2016. By 1980, the number of countries having established positive trade relationships with all other countries had tripled relative to 1968, driven mainly by better integration of the most remote countries (for instance, Bolivia increased the number of its trading partners from 31 to 45 while Bangladesh went from 40 to 64).

During the 1980s globalization accelerated even more. The number of countries having established trade linkages with all other countries doubled during this decade, and the average number of trade linkages reached 93.74%. Again, the development was driven by the most remote countries – Brunei for example increased its number of trading partners from 20 in 1980 to 38 in 1990; Cameroon went from 43 to 60; and Gabon and Vietnam, which had traded with 40 and 41 countries in 1980, traded with 56 in 1990. Interestingly, the number of countries trading with at least 80% of all other countries increased only slightly.

With the enlarged dataset starting in 1994, the absolute number of bilateral trade relations increased enormously. Taking the average number of trade relationships as our yardstick we find that this holds especially for newly established countries like Bosnia and Herzegovina, Kazakhstan, Kyrgyzstan, and Macedonia, as well as – to a certain extent – the Baltic countries. Altogether, the percentage of positive trade relations was slightly lower in 1994 than in 1990.

In 2016, 66 of the 84 countries evaluated had positive export relationships with all other countries in the sample, whereas in 1994 only 25 had exported to all other countries (17 of them were European). However, at the end of our period, we see hardly any further trade integration at the lower bound of the sample. The least integrated countries do not, or only slightly, increase the number of countries they trade with.

Turning to the importance of distance in understanding the development of trade relationships, the analysis of the gap between $G1_t$ and $G2_t$ provides useful insights. This gap was largest in 1968 and has fallen since. This convergence process suggests bilateral trade is first established between spatially closer countries and then spreads to more distant places. To complement the analysis of distance, we calculate two very simple additional metrics: (i) the percentage of total trade occurring between countries with a common border; and (ii) the percentage of total trade occurring between countries with a maximum distance of 3,000 km. For the most recent sub-period (1994-2016; 84 countries), the percentage of trade between countries sharing a common border fell from 27.71% in 1994 to 24.13% in 2016. In the same period, the second measure evolves from 53.65% to 47.93%. In conclusion, the evidence supports the idea that declining trade costs as well as better access to international transportation systems facilitated the integration of peripheral and less developed countries into the global trade network, making distance a less important barrier to trade.

5.2 Sectors Involved in Bilateral Trade Relations

The evidence presented in Panel (3b) of Figure 3 shows a different picture to Panel (3a). In contrast to the results of $G1_t$ and $G2_t$, the sectoral dimension of trade globalization is far from complete. The results show that in 1968 an average of only 21.82% of sectors were involved in each bilateral trade (i.e., on average, 32.08 of 147 sectors were traded in bilateral relationships). The steady increase in Z_t over time is, however, remarkable: in the first sub-period, the average number of sectors increased to 45.02 in 1980, and to 52.75 in 1990. This suggests countries diversify as trade relations intensify. The establishment of new countries had a decreasing effect on the average number of sectors involved. Therefore, the second sub-period started with an average of 50.51 sectors in 1994, growing to 65.74 in 2005, and 74.80 in 2016 (50.88% of the total number of sectors). Nevertheless, while the average number of sectors increases steadily, the boundary of 147 sectors is unlikely to be reached any time soon. Moreover, there is notable variation between country pairs. The more industrialized countries are more diversified than developing countries, though the latter have caught up substantially over time.

Figure 4 shows that 47.40% of all bilateral relations involved fewer than 10 sectors in 1968. This went down to 10.10% in 2016. It is noteworthy that the first cases of bilateral relations involving more than 140 sectors were between neighboring countries: between France and Italy; and Belgium and France in 1970. We need to wait until 1990 to observe trade relations involving all sectors (in the country pairings USA-Canada, Germany-Switzerland, and exports of the former USSR to seven other countries, mainly from Eastern Europe). Thus, trade barriers and distance still seem to play a significant role when it comes to intensifying trade relations. Altogether, $G3_t$ shows a clear positive trend as it grows from $G3_{1968}$ = 0.172 to $G3_{2016}$ = 0.502, with an average annual growth rate of 3.02% in the first sub-period and 2.16% since 1994.

[Insert Figure 4 here]

5.3 Bounded and Unbounded Dimensions of Trade Globalization

In Figure 5 we show the relationship between changes in R_t' and changes in $G3_t$ to highlight the commonalities and differences in the evolution of bounded and unbounded dimensions of trade

globalization. The growth trend of R'_t is remarkable, with an average annual growth rate of 5.68% in the first sub-period and 5.05% since the 1990s. The growth of the bounded dimensions, captured through $G3_t$, was considerably lower. Generally, the change in trade volume was much more affected by cyclical fluctuations than in $G3_t$: whereas there were six years of contractions in trade volume[2], there were only two years in which $G3_t$ fell (1982 and 1983). In fact $G3_t$ grew even during the Great Recession of 2009, emphasizing the need to study trade globalization with a more comprehensive set of indicators.

[Insert Figure 5 here]

6. Sectoral Characteristics and Their Relevance in Globalization

We now replicate the overall analysis for each of the 147 ISIC 4-digit sectors. The full list of sectors is presented in Table A.2 in the Annex. Three dimensions of trade globalization can be considered: number of flows, distance, and trade volume. Using the sectoral matrices, R'_{st}, $G1_{st}$, and $G2_{st}$ are obtained, with the obvious adjustments, as in equations (3), (4), and (6).

6.1 Evidence at the Individual Sectoral Level

When we analyze the development of sectoral trade globalization in greater detail it is crucial to account for the significant differences in sector sizes.[3] Figure 6 therefore shows the levels of both $G2_{st}$ and R'_{st} relative to the respective sectoral weights for six representative points in time. The figure documents: (i) low levels of trade globalization in the 1960s; (ii) tremendous increases over time; (iii) significant differences between the sectors; and (iv) significant differences between the bounded and unbounded dimensions.

[2] $R_t < 1$ occurred in 1975, 1982, 1986, 2001, 2009, and 2015. The strongest decrease in trade volume was reported in 2009 ($R_{2009} = 0.823$).

[3] Throughout the investigation period, the sectors in our sample were very heterogeneous in size: we observe a small number of large sectors and many small sectors. The size of the individual sectors did not remain constant over time; yet the initial size of the sector influences the sectoral growth potential. It is therefore important to put the growth rates in trade globalization into perspective: high growth rates in small sectors need to be interpreted differently from the same growth rates in large sectors. By accounting for sector size, we are also able to highlight the structural change that takes place over time.

Concerning trade volume, we find that R'_{st} was below 1.30 in 1968 for every single sector. Its growth remained modest in the 1970s and 1980s, with only 29 sectors reaching a level of R'_{st} higher than 5. From the 1990s on, however, sectoral trade volume growth increased significantly, with 32 sectors reaching levels higher than 10 in 1996. By 2016, R'_{st} is greater than 10 in 84 sectors, and 16 sectors had values even greater than 50.[4] As already described, the size of the sectors is critical for interpreting the level of R'_{st}: whereas most sectors with very high growth rates were very small, the electronic equipment as well as the TV & radio sectors were characterized not only by very high increases in R'_{st} but also by significant increases in sector weight, highlighting the important role these played in the overall development.

The trend toward greater trade globalization is also evident from the evolution of the average level of $G2_{st}$. While 1968 saw an average of only 0.161 (with the upper bound being 1), the average was 0.255 in 1986. Nevertheless, the development in the bounded dimensions was far less pronounced than in the unbounded dimension. In 2016 the average level of $G2_{st}$ is 0.450, still leaving manifold possibilities for sectoral trade globalization to increase in the future. Looking even more closely, we find the number of sectors with $G2_{st} < 0.2$ fell from 97 in 1968 to 40 in 1996, and to 20 in 2016. Meanwhile, the number of sectors with $G2_{st}$ between 0.6 and 0.8 was zero until 1996, but increased to 41 of 147 sectors in 2016. Until 1986, fabrics & textile fibers and basic chemicals were the two sectors with the highest levels of trade integration in $G2_{st}$. Since then, the plastics sector has gained more importance, such that it became the most globalized sector in 2016, with $G2_{st} = 0.812$. In comparison to $G2_{st}$, the results for $G1_{st}$ suggest an even higher level of sectoral trade globalization, implying distance is important at the sectoral level as well. In fact, the average value of $G1_{st}$ was 0.218 in 1968 and reached 0.509 in 2016.

[Insert Figure 6 here]

6.2 Sectoral Trade Globalization according to R&D Levels

We complement our analysis by including sectors' R&D intensity. We distinguish between high-technology (HT), medium-high-technology (MHT), medium-low-technology (MLT), and low-technology (LT) sectors (according to the OECD classification). We observe a clear shift in

[4] Some sectors experienced extraordinary high growth rates due to their very small sizes. These sectors, such as TV, could not be displayed in the figures, as otherwise the growth rates of the majority of sectors would not be visible.

exports since the 1960s, from lower-tech to high-tech sectors. The latter increase their share from 10.51% in 1968 to 27.25% in 2016. At the same time, the low-tech and medium-low-tech sectors suffered the greatest declines, leaving the medium-high-tech sectors as the largest group over the whole investigation period (with a share of 34.56% in 1968 and 31.22% in 2016, respectively). In terms of growth in trade volume, the evolution of the high-tech sectors is remarkable, above all since the 1990s.

Concerning the bounded dimensions of trade globalization, Figure 7 shows the level of the phenomenon is negatively related to the level of R&D-intensity. Specifically, the high-tech sectors were characterized by the lowest level of trade globalization in 1968 (with $G1_{HT,1968}$ = 0.525) and continued to be so in 2016 (with $G1_{HT,2016}$ = 0.921). The low-tech sectors, conversely, were always the most globalized ones, advancing from an initial level of $G1_{LT,1968}$ = 0.737 to $G1_{LT,2016}$ = 0.961. The catch-up of the medium-low and medium-high tech sectors toward full integration is also noteworthy. We can conclude therefore that the number of positive bilateral trade relations increased significantly over time for all R&D categories. While differences between the results for $G1_t$ and $G2_t$ were very small in the overall picture, the very low levels of $G2_{HT,t}$ show the importance of distance for these sectors when they set out to establish trade relations at the beginning of our period. Studying Figure 7, panels (7a) and (7b) together reveals that globalization first involves sectors with low R&D requirements, which can be adopted by developing countries and industrialized countries alike. The export of high-tech sectors involves greater investments in labor and capital, and evolves much more slowly. The lower degree of trade integration in $G1_{HT,t}$ and $G2_{HT,t}$ can also be explained by the fact that some of these sectors were almost insignificantly small in the 1960s. As they grew in importance due to innovations in the information and communication sectors (WTO, Institute of Developing Economies, OECD, World Bank, and China Development Research Foundation, 2019), so did trade.

[Insert Figure 7 here]

So far we have seen that bounded and unbounded dimensions can vary widely in their growth rates, but that all dimensions of trade globalization increase over time. Turning to R&D-intensity, we find that the annual change in R' is very low in the first sub-period for all groups. This change is much more pronounced in the second sub-period, and while this holds for all groups of sectors, the effect is much more pronounced in the high-tech sectors. This development is partially driven

by a sector-size effect because high-tech sectors were smaller on average than other sectors. The higher annual growth rates in the high-tech and medium-high-tech sectors' bounded dimensions ($G2$) show the catch-up toward the already more globalized low-tech and medium-low-tech sectors, supporting our interpretation of the evidence presented in Figure 7. We furthermore find a very strong positive correlation between the absolute number of bilateral trade relationships and volume of trade for all technology classes (above 0.95 for all four technology categories and for both sub-periods). Interestingly, changes in R' do not necessarily coincide with changes in $G2$, implying that while bounded and unbounded dimensions move in the same direction, the pace can be quite different. This once again highlights the need to study a wide variety of indicators to successfully map trade globalization.

[Insert Figure 8 here]

7. Conclusion

This paper adds to the literature by: (i) considering over a long time span the interdependencies between countries, rather than treating countries as isolated entities; (ii) proposing a set of bounded and unbounded dimensions to gain a deeper understanding of the underlying forces; and (iii) analyzing the sectoral evolution of trade globalization, at the individual level and with the help of R&D categories, to establish a more in-depth understanding of the phenomenon.

From an empirical point of view, we present evidence that trade globalization increased significantly in all dimensions over time. Our approach innovates insofar as it allows us to highlight differences between the individual dimensions. We can provide evidence that both the initial levels and evolutions varied considerably and deserve more detailed investigation.

With respect to the number of bilateral relations and distance, we were able to show that trade globalization was already advanced in the late 1960s, but expanded further to approach almost its upper bounds in 2016. Altogether, our results point to the existence of a gradual "*death of distance*": even those countries that were not well-integrated into the world trade network in the 1960s significantly increased the number of their trading partners, regardless of distance, by 2016.

A closer look at sectoral trade globalization, however, reveals great potential for further integration: the average share of sectors involved in bilateral trade linkages increased from one

fifth in 1968 to one half in 2016, with stronger linkages between neighboring countries. Again, we found a disaggregated analysis of individual sectors and their R&D characteristics to be beneficial, as it highlighted the existence of strong heterogeneity at the sectoral level. We find the low-tech sectors to be the most globalized, and to remain so despite the catch-up of other sectors. We found the development of some medium-high-tech and high-tech sectors particularly noteworthy. These were small in sectoral size and in trade volume at the beginning of the period but experienced very high growth rates.

Thus, we were able to show that trade globalization should be understood not only as a multidimensional phenomenon, but that these different dimensions evolve at different rates, allowing us to draw finely differentiated conclusions regarding the level of trade integration already achieved. In terms of number of countries, trade integration has almost reached its upper bound; however, protectionist policies could have a detrimental effect in the future. We find full trade integration regarding the number of sectors to be far from complete, implying potential advantages of international trade have not yet been seized.

The evidence discussed in this paper concerns a long period of time (50 years) and clearly shows some key trends in the evolution of trade globalization. Nevertheless, the very recent health emergency due to the world-level diffusion of COVID-19 raises serious doubts about the evolution of the different trade globalization dimensions in the near future.

Lockdowns in many countries lead to significant supply shocks and supply disruptions. The importance of China in worldwide manufacturing processes and the vulnerability of global supply chains became evident in the first months of 2020 with the automobile and textile sectors being important examples (Baldwin and Tomiura, 2020). Moreover, policy measures forced people to stay at home leading to demand shocks as well. The impact on international trade in the short-run is already visible and could turn into more long-term effects as the largest global recession since World War II is likely to further weaken demand especially for expensive durable goods such as cars. Evenett (2020) adds to the analysis by focusing on recent trade policies that restrict exports in order to combat shortages of medical supplies such as masks and ventilators. In this regard, at least in the short run, production processes are likely to become more nationalized and more regionalized. By March 2020, more than 50 countries had already introduced export curbs on medical supply in order to limit the exposure to the need to buy medical equipment and other critical products on the world market. Evenett (2020) calls this policy "sicken-thy-neighbour"

making clear the detrimental effects of such a policy as the production processes are slowed down, are reduced or come to a halt as international supply chains do not work effectively any more under this kind of export reduction trade policy.

Baldwin and Tomiura (2020) moreover highlight that especially supply disruptions in China, Germany, Japan and the USA are likely to have far-reaching effects on the production processes of other countries due to their importance in supply chains and the creation of other countries‘ value added in many different sectors – not only those critical to the health sector alone. To make a rough estimate about the impact of the pandemic on world GDP and world trade, researchers try to compare the events with the single most significant disturbances that have occurred since World War II so far, i.e. the “Great Trade Collapse” which occurred following the financial crisis in 2009. Compared to this situation, the impact of Covid-19 on the world is projected to be far more significant as both supply and demand were affected. Thus, the World Trade Organization predicted in April 2020 a fall in global trade between 13 and 32 per cent for the current year, indicating also the high degree of uncertainty of the future economic development during this pandemic (WTO, 2020). However, as the health crisis and its impact on leading economies as well as trade unfold, it becomes ever more likely that the impact on trade globalization is more profound – at least in the short run – than during 2008/2009 as restrictions on free mobility are still in place.

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Table 1: Multidimensional indicators of globalization

Index	Authors	Number of indicators (economic dimension)	Other dimensions	Distance	Time frame	Number of countries
A.T. Kearney / Foreign Policy Globalisation Index	A.T. Kearney (2001), Lockwood (2004)	11-14 (2-4)	Political, cultural, environmental, personal contacts	No	1998-2009	72 (from 2007 onwards)
CSGR Globalization Index	Lookwood and Rodeano (2005)	16 (4)	Social, political	No	1982-2004	26 in1982; 103 in 2004
KOF Index	Dreher (2006), Gygli et al. (2019)	23 (8)	Political, social, cultural	No	1970-2017	208
Maastricht Globalisation Index	Martens and Zywietz (2006), Figge and Martens (2014)	11 (3)	Political, social & cultural, technological, environmental	No	2000 - 2008, 2012	117
New Globalization Index	Vujakovic (2010)	21 (9)	Political (environmental), social	Yes	1995-2005	70

Figure 1: Empirical approach

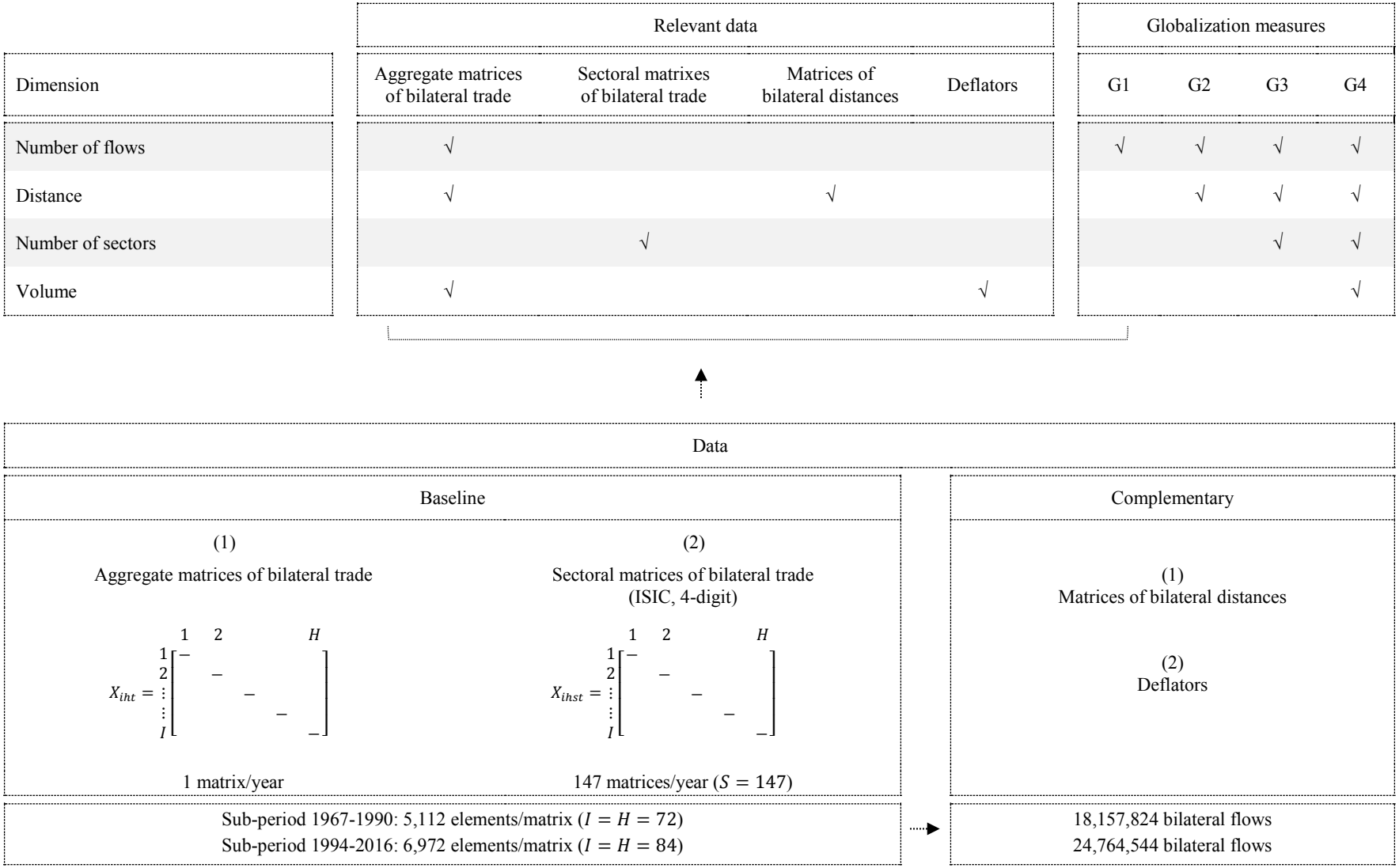
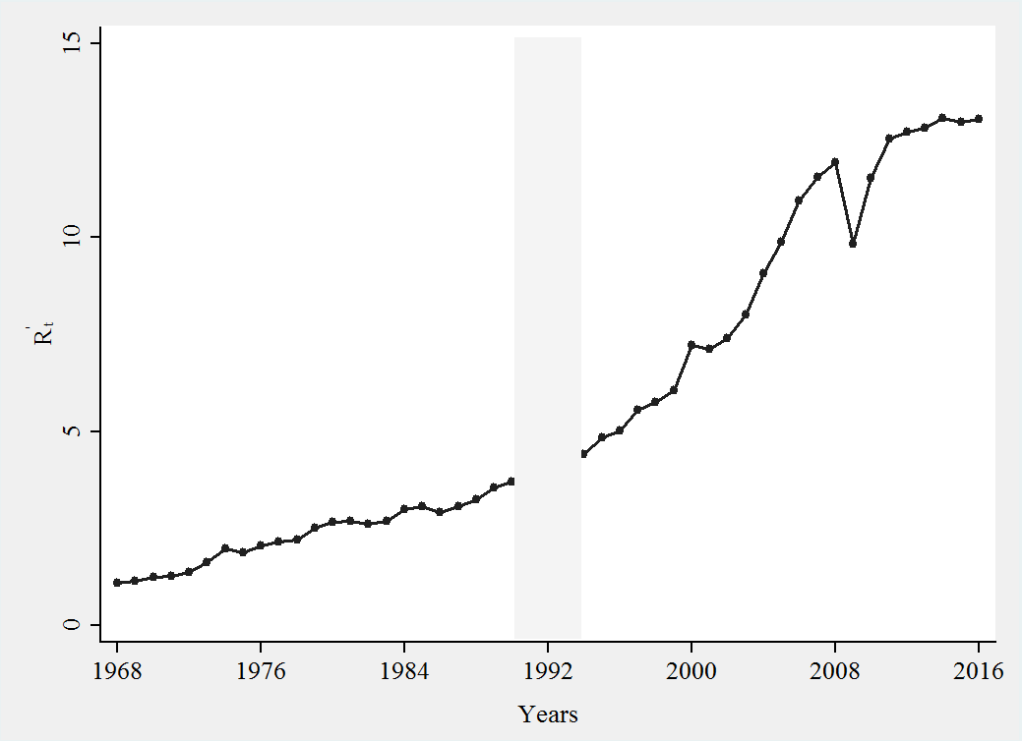
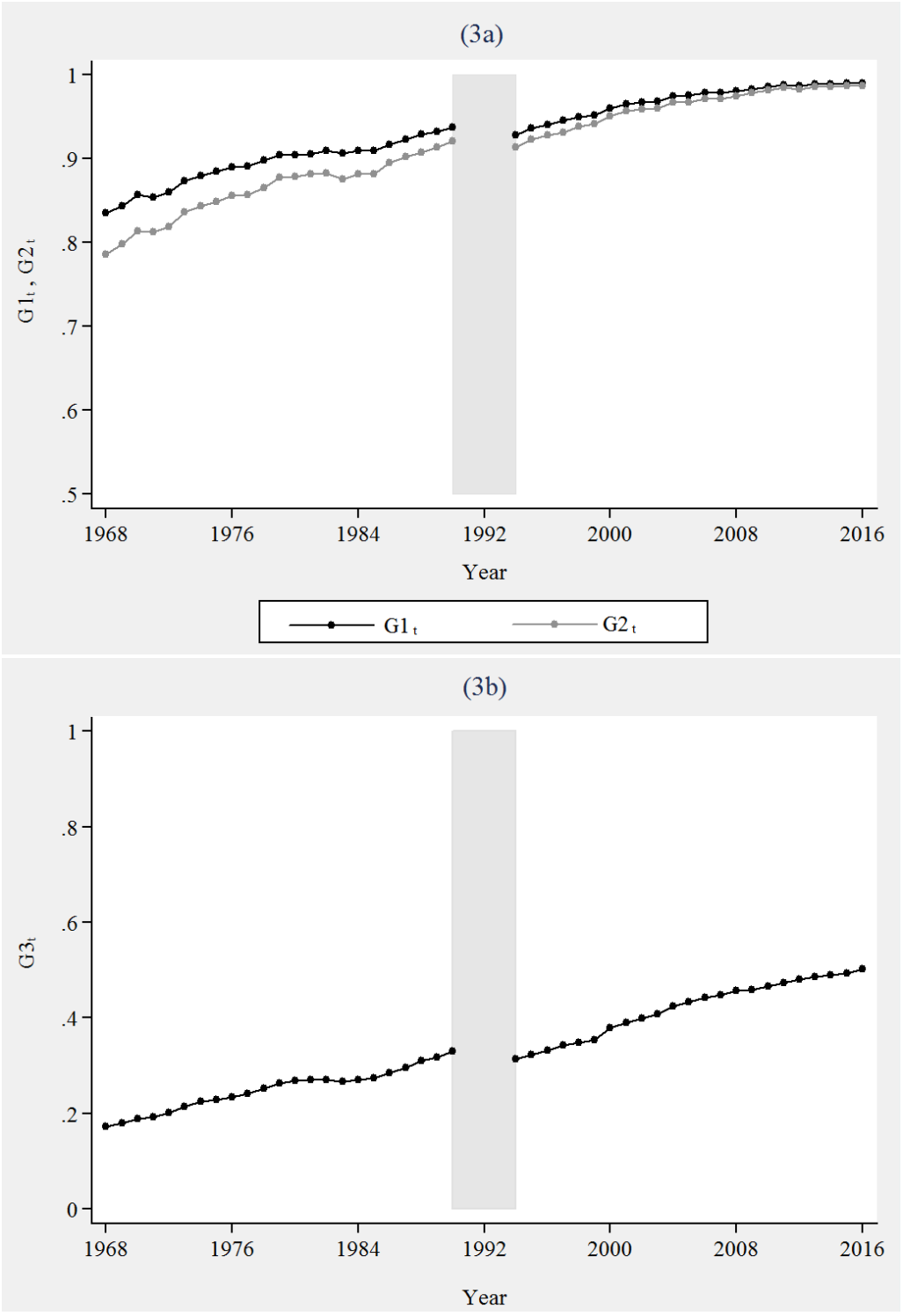


Figure 2: Evolution of trade volume



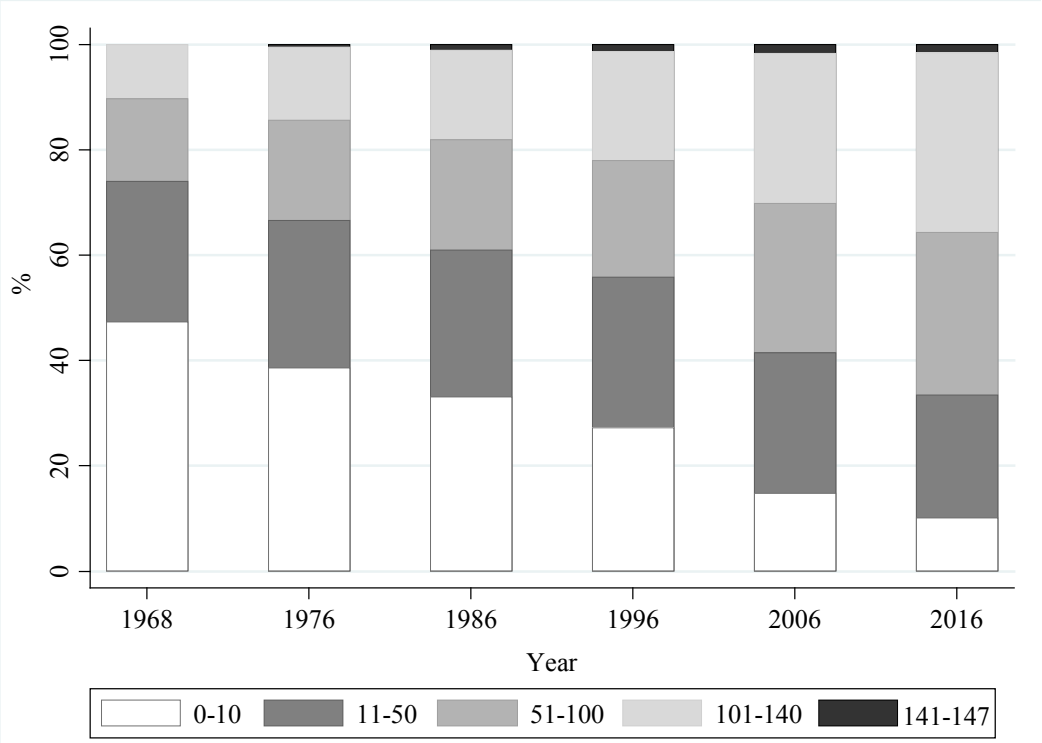
Note: R_t' captures the unbounded dimension of trade globalization, corresponding to a comparison between the actual volume of trade and the corresponding value at the beginning of the period under scrutiny.

Figure 3: Bounded dimensions of trade globalization



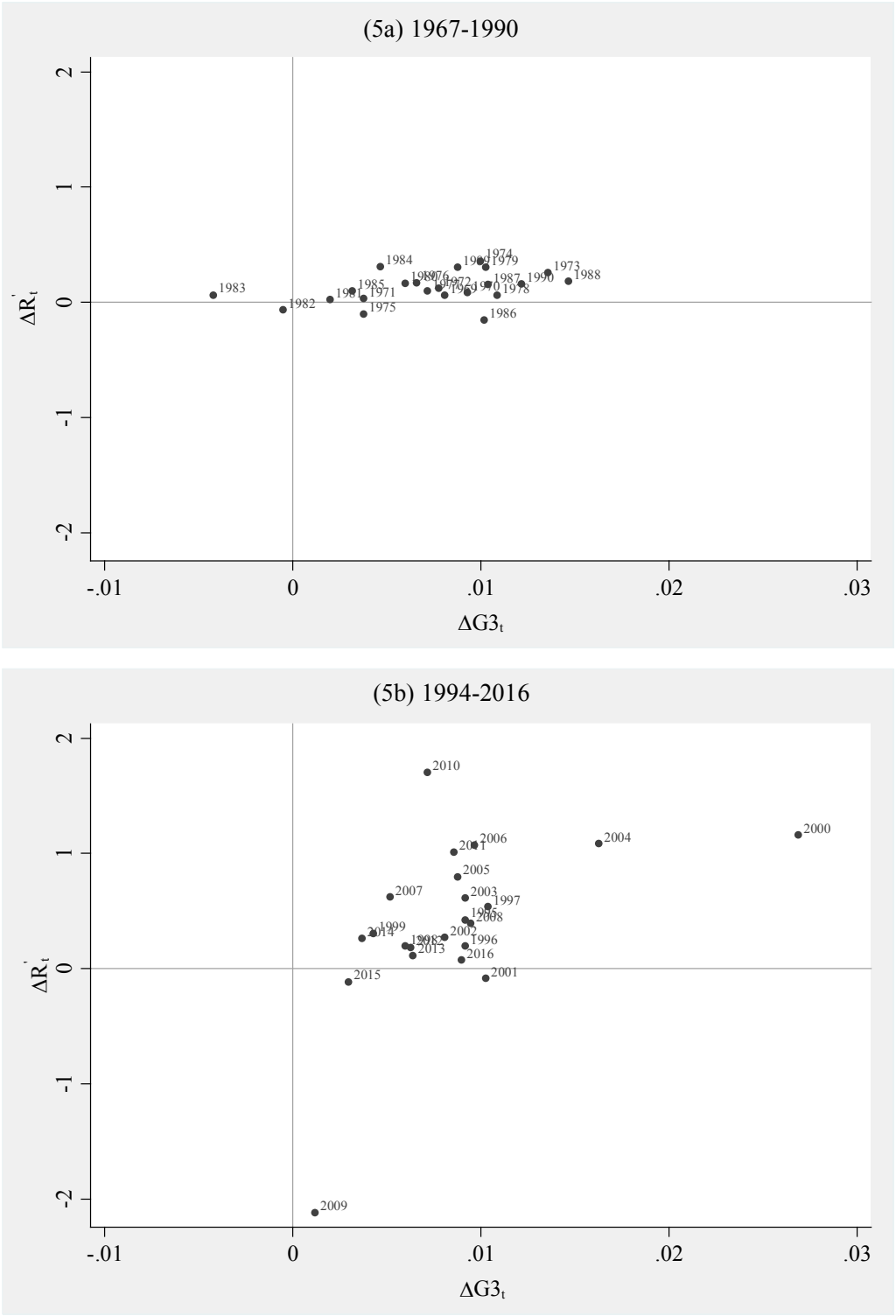
Note: In panel (3a), $G1_t$ represents the percentage of bilateral relations with positive trade in the total number of country pairs at the world level and $G2_t$ incorporates the distance travelled by trade, capturing the proportion of the total distance among all the countries in which positive trade exists. In panel (3b), $G3_t$ is built from $G2_t$ by adding the sectoral dimension of trade globalization. $G3_t = 1$ when all sectors are traded in all bilateral relations.

Figure 4: Number of sectors per bilateral trade flow



Note: For each of the years considered, the number of sectors involved in each bilateral trade relation was calculated. For the first sub-period, this corresponds to obtaining the number of sectors traded in each of the 5,112 flows; while for the second sub-period, 6,972 flows were analyzed. Thereafter the flows were classified into five categories: 0-10 sectors per flow; 11-50; 51-100; 101-140; and 141-147.

Figure 5: Bounded and unbounded dimensions of trade globalization



Note: this figure displays the relationship between changes in R_t' (capturing the unbounded dimension of trade globalization) and changes in $G3_t$ (bounded dimensions of trade globalization).

Figure 6: Trade globalization - an analysis per sector

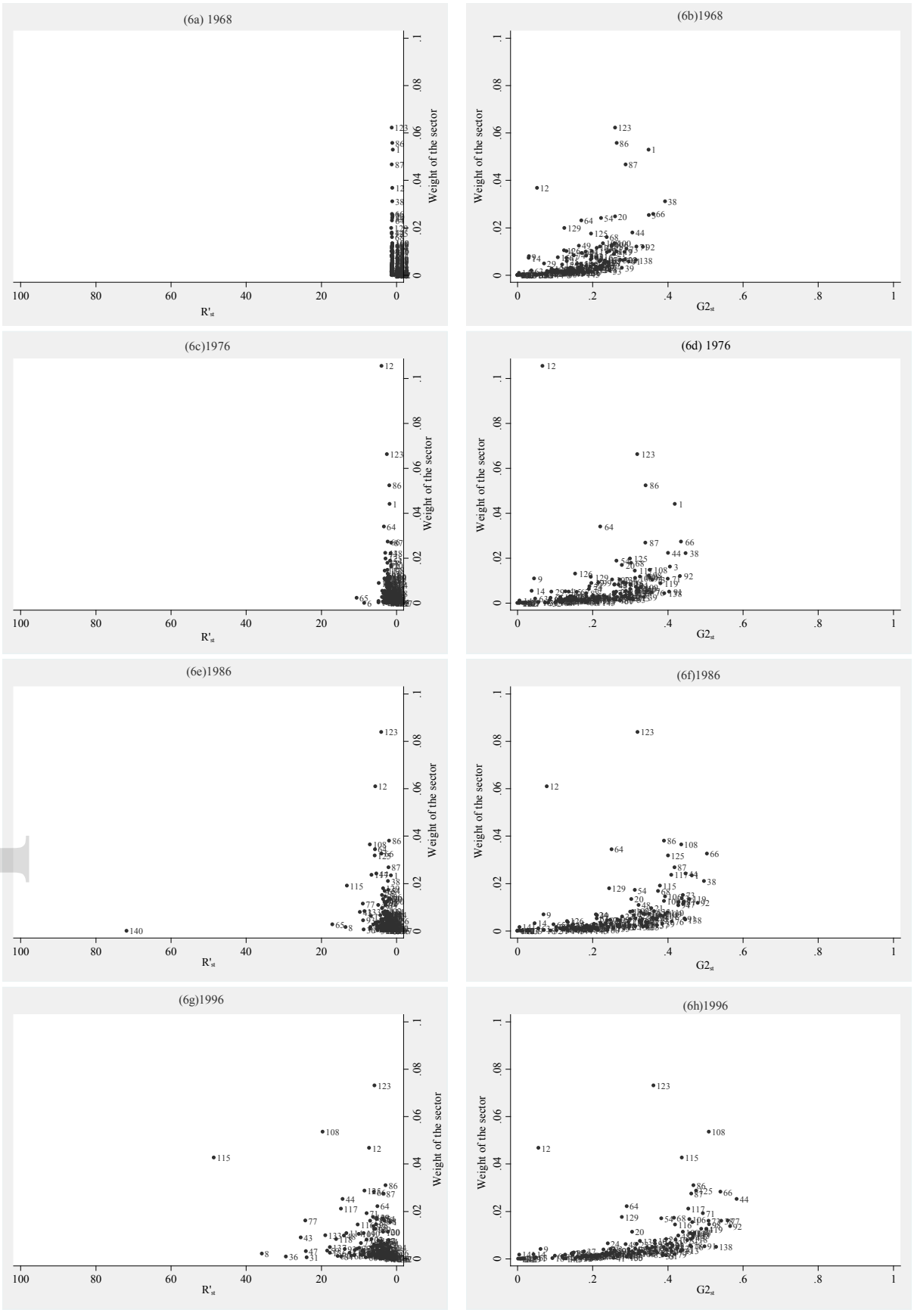
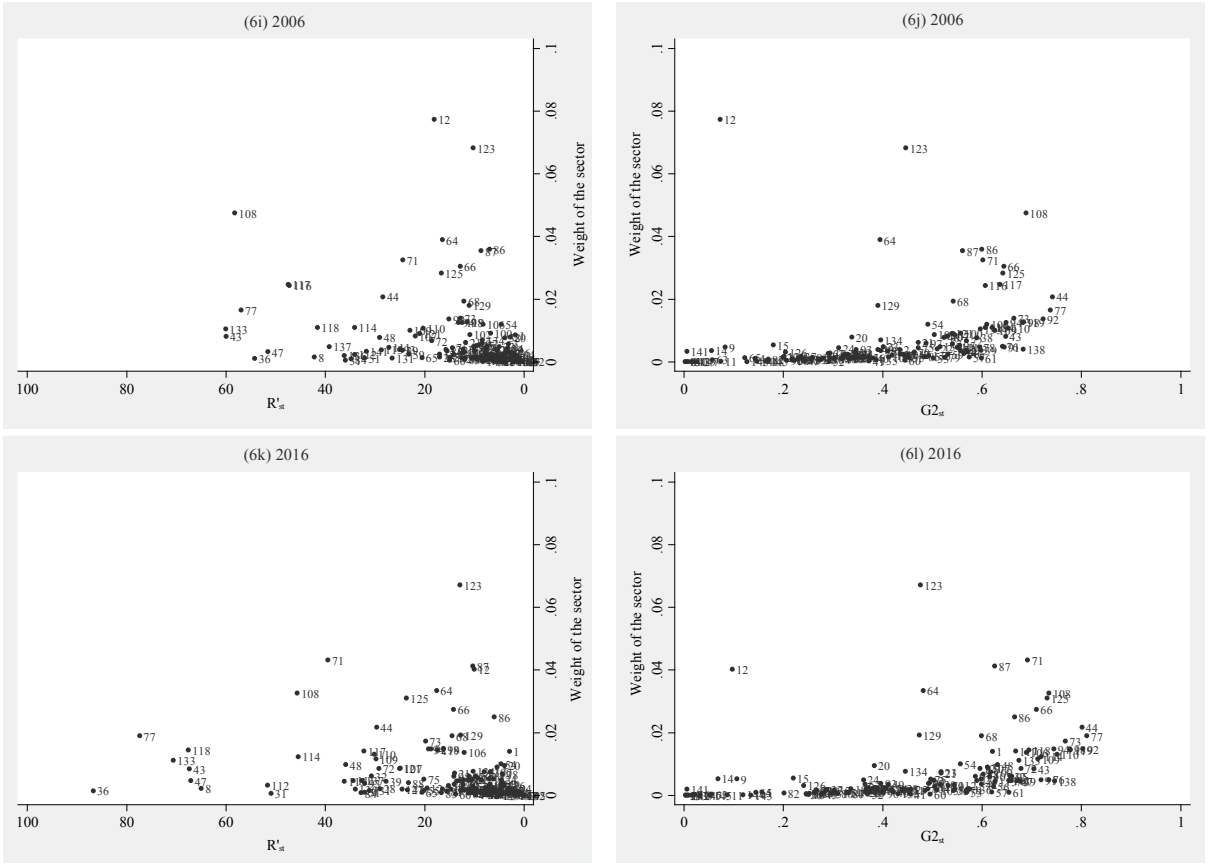
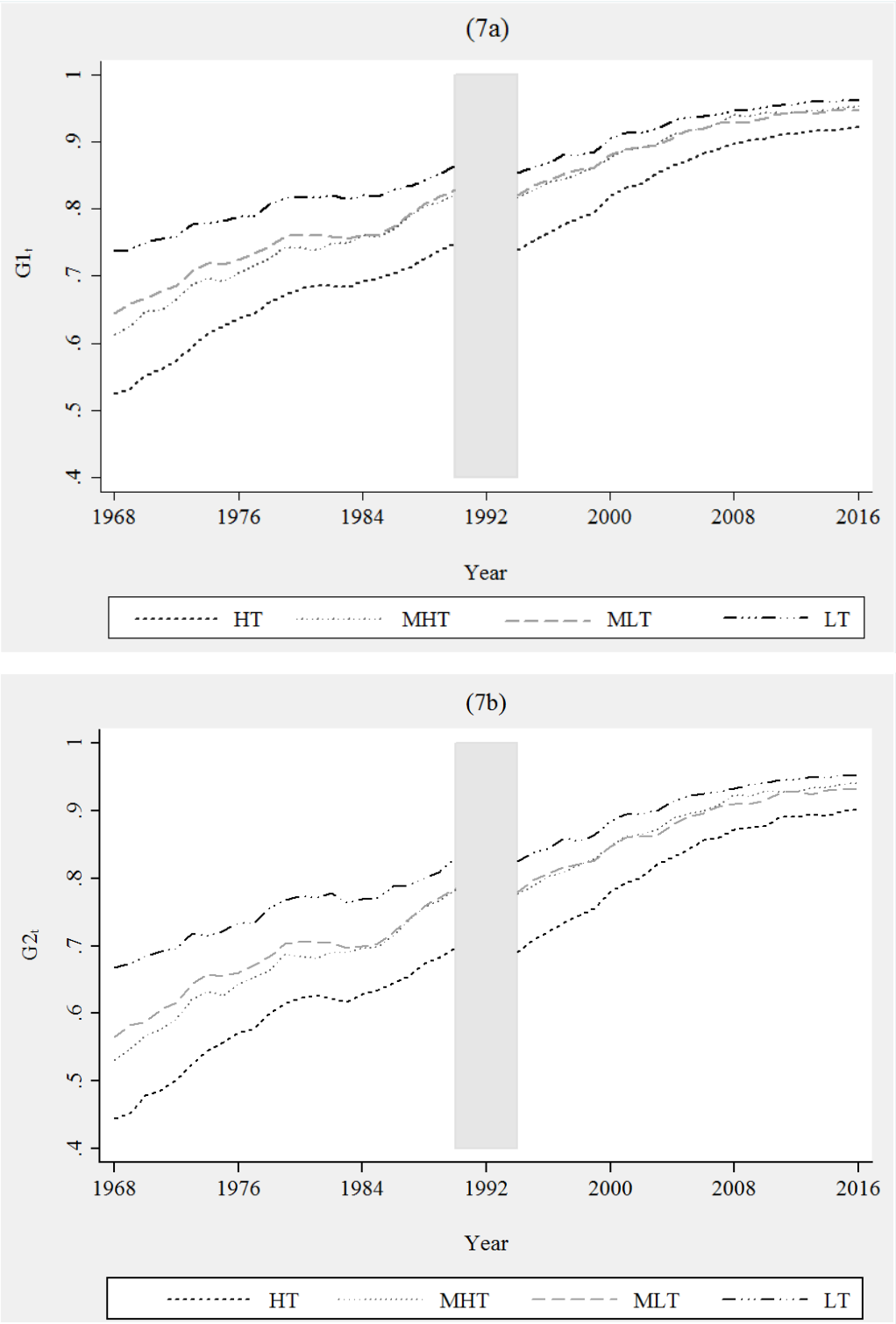


Figure 6: Trade globalization - an analysis per sector (cont.)



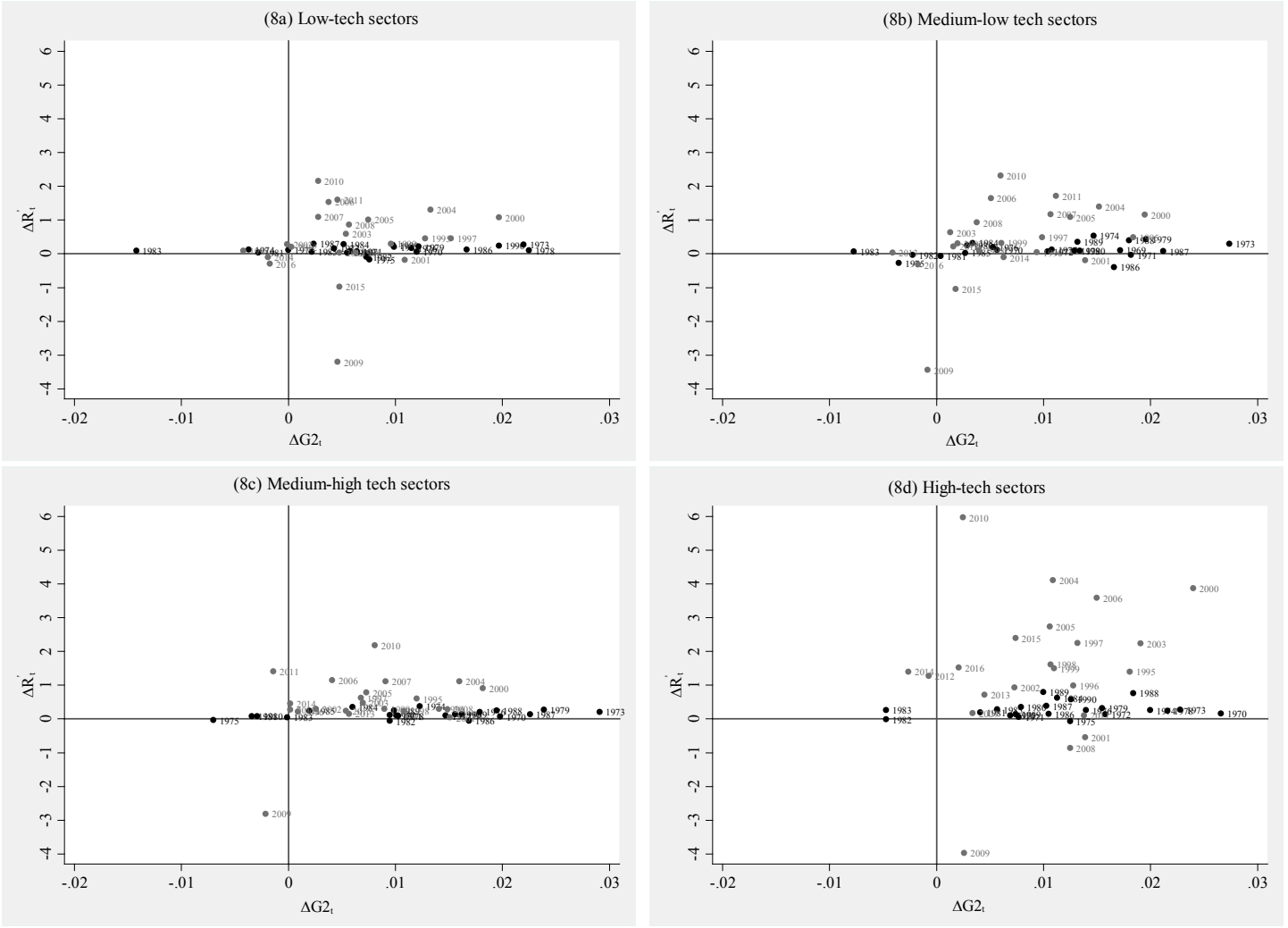
Note: These panels show evidence concerning the levels of both $G2_{st}$ and R'_{st} relative to the respective sectoral weights for six selected years. In each year, sectors with $R' > 100$ are excluded from the graphs. The number of sectors excluded by this criterion is: 0 sectors in 1968; 4 sectors in 1976 (0.02% of the total in terms of volume of trade); 4 sectors in 1986 (0.10% of the total); 5 sectors in 1996 (0.18% of the total); 6 sectors in 2006 (4.23% of the total); and 7 sectors in 2016 (7.83% of the total).

Figure 7: Sectoral trade globalization according to R&D intensity – bounded dimensions



Note: In this figure sectors are grouped into 4 categories: high-technology (HT); medium-high-technology (MHT); medium-low-technology (MLT); and low-technology (LT) sectors (according to the OECD classification). Panel (7a) shows for each of the categories the evolution of $G1_t$ while in panel (7b) a similar analysis concerns the evolution of $G2_t$.

Figure 8: Bounded and unbounded dimensions of trade globalization – an analysis by R&D intensity



Note: This figure displays the relationship between changes in R_t' (capturing the unbounded dimension of trade globalization) and changes in $G2_t$ (bounded dimensions of trade globalization) for each of the four R&D categories.