What Place does Luxembourg hold in Global Value Chains?

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Abstract

The paper analyses the place held by Luxembourg in global value chains (GVC) by relying on trade in value added data retrieved from OECD inter-country input-output tables, available over the period 1995-2011. The analysis is multifaceted as the role of Luxembourg in GVC is analyzed across 50 advanced and emerging market economies, at the country level, at the sector level and over time. Results show that Luxembourg acts as an important chain-link in GVC as evidenced by its strong upstream and downstream interconnections with other partner countries. Luxembourg is primarily a buyer of foreign value added and less a seller of domestic value added. The major part of Luxembourg's GVC trading partners is located in Western Europe suggesting that the supply chain network is not global for Luxembourg but rather regional. Notwithstanding this, the share of East Asian and Eastern European emerging countries - albeit relatively low compared to advanced economies - is increasing over the period of analysis. A similar observation prevails for the geographical breakdown of the origin (destination) of foreign (domestic) value added for domestic (foreign) final demand at the end of the value chain. The analysis unveils that Luxembourg possesses a comparative advantage in GVC in the finance and insurance industry. It is from the latter sector that the country retrieves the most important share of value added from GVC participation.

Keywords: International trade, Global value chains, Gross trade statistics, Trade in value added statistics, Inter-country input-output tables

JEL codes: D57, F14, F20, F21, F23

Contact: gabriele.difilippo@bcl.lu. **Disclaimer:** This paper should not be reported as representing the views of the Banque centrale du Luxembourg or the Eurosystem. The views expressed are those of the author and may not be shared by other research staff or policymakers in the Banque centrale du Luxembourg or the Eurosystem.

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Non-Technical Summary

Over the recent decades, the paradigm of international trade has changed. The lowering of trade barriers as well as the reduction in transportation and communication costs allowed producers and notably multinational companies to locate the various production stages of a product in different sites across the world according to their competitive advantage. The production process has thus become more geographically and vertically fragmented giving birth to global value chains. In global production chains, intermediate products are shipped across countries multiple times, with each exporting country providing some value added - often depending on its specialization - until the product is eventually imported for final consumption. GVC have become a prominent feature of world trade as evidenced by the substantial increase of worldwide trade flows in intermediate products compared to trade flows in final products.

Against this background, the paper analyses the place held by Luxembourg - a small open economy - in the global value network *vis-à-vis* other advanced and emerging market economies. The paper relies notably on trade in value added statistics retrieved from OECD inter-country input-output tables, available over the period 1995-2011. The paper undertakes a multifaceted analysis by investigating the role of Luxembourg in GVC within a sample of 50 advanced and emerging market economies, at the country level, at the sector level and over time.

Results show that Luxembourg acts as an important chain-link in GVC as evidenced by its strong upstream and downstream interconnections in GVC with other partner countries. Luxembourg trades a larger amount of intermediate products imported from abroad while it exports a lower amount of domestically produced intermediate products. This is generally the case of small open economies. The latter usually source more intermediate products from abroad in GVC than larger economies where, given their size, a longer part of the value chain is domestic and hence a higher share of intermediate products is produced domestically.

The major part of Luxembourg's GVC trading partners is located in Western Europe suggesting that the supply chain network is not global for Luxembourg but rather regional. Notwithstanding this, the share of East Asian and Eastern European emerging countries - albeit relatively low compared to advanced economies - is increasing over the period of analysis. A similar observation prevails for the geographical breakdown of the origin (destination) of foreign (domestic) value added for domestic (foreign) final demand at the end of the value chain.

Eventually, the analysis shows that Luxembourg possesses a comparative advantage in GVC in the finance and insurance industry. It is from the latter sector that the country retrieves the most important share of value added from GVC participation.

Résumé Non Technique

Au cours des dernières décennies, le paradigme du commerce international a changé. L'abaissement des barrières commerciales ainsi que les réductions des coûts de transport et de communication ont permis aux producteurs et notamment aux entreprises multinationales de localiser les différentes étapes de production d'un produit dans différents sites à travers le monde, en fonction de leur avantage concurrentiel. Le processus de production est ainsi devenu plus fragmenté géographiquement et verticalement, donnant naissance à des chaînes de valeur mondiales (en anglais, *global value chains* ou GVC). Dans ces chaînes de production, les produits intermédiaires sont exportés plusieurs fois entre pays, chaque pays exportateur apportant une valeur ajoutée dans la conception du produit - souvent en fonction de sa spécialisation – jusqu'à ce que le produit soit finalement importé pour la consommation finale. Les GVC sont devenues une caractéristique proéminente du commerce international, comme en témoigne la progression substantielle des flux commerciaux de produits intermédiaires au niveau mondial par rapport aux flux commerciaux de produits finis.

Dans un tel contexte, le document analyse la place du Luxembourg - une petite économie ouverte - dans le réseau mondial des chaînes de valeur. A cette fin, le document s'appuie notamment sur des données de commerce extérieur en valeur ajoutée (en anglais, *trade in value added*) extraites des tableaux d'entrées-sorties inter-pays fournis par l'OCDE et disponibles sur la période 1995-2011. Le document entreprend une analyse multiforme en analysant le rôle joué par le Luxembourg dans les GVC au sein d'un échantillon de 50 économies avancées et émergentes, au niveau du pays, au niveau sectoriel et à travers le temps.

Les résultats montrent que le Luxembourg joue un rôle important dans les chaînes de valeur mondiales, comme en témoignent les fortes interconnexions avec ses pays partenaires en amont et en aval des chaînes de valeur mondiales. Dans ces dernières, le Luxembourg importe plus de valeur ajoutée étrangère qu'il n'exporte de valeur ajoutée domestique. C'est généralement le cas des petites économies ouvertes qui, compte tenu de leur taille, s'appuient généralement plus sur l'importation de produits intermédiaires en provenance de l'étranger dans les GVC. *A contrario*, dans les grandes économies développées, une part plus importante de produits intermédiaires est produite au niveau domestique, étant donné que leur taille leur permet d'avoir des chaînes de production domestiques plus longues.

Au sein des GVC, la majeure partie des partenaires commerciaux du Luxembourg est située en Europe de l'Ouest, ce qui suggère que le réseau des chaînes de valeur est plutôt régional que mondial. Malgré cela, la part des émergents d'Asie de l'Est et d'Europe de l'Est - bien que relativement faible par rapport aux économies avancées - augmente au cours de la période analysée. Une observation similaire

prévaut pour la ventilation géographique de l'origine (la destination) de la valeur ajoutée pour la demande finale domestique (étrangère) de produits finis, à la fin des chaînes de valeur.

Enfin, l'analyse montre que le Luxembourg possède un avantage comparatif sur les chaînes de valeur mondiales dans le secteur de la finance et de l'assurance. C'est de ce dernier secteur que provient la part la plus importante de valeur ajoutée du Luxembourg émanant de sa participation aux chaînes de valeur mondiales.

1. Introduction

Over the recent decades, the paradigm of international trade has changed. The lowering of trade barriers as well as the reduction in transportation and communication costs allowed producers and notably multinational companies to better optimize their production processes by locating the various production stages of a product in different sites across the world according to their competitive advantage. The production process has hence become more geographically and vertically fragmented giving birth to global value chains (*a.k.a.* global production chains or global value networks). In global production chains, intermediate products are shipped across countries multiple times, with each exporting country providing some value added - often depending on its specialization - until the product is eventually imported for final consumption. Gereffi and Fernandez-Stark (2011) define global value chains (GVC) as "*the full range of activities that firms and workers do to bring a product from its conception to its end use*". GVC have become a prominent feature of world trade as evidenced by the substantial increase of worldwide trade flows in intermediate products compared to trade flows in final products (Miroudot *et al*. (2009), De Backer and Norihiko (2012), UNCTAD (2015)).

Against this background, the paper analyses the place held by Luxembourg - a small open economy - in the global value network *vis-à-vis* other advanced and emerging market economies. To this aim, the paper relies on trade in value added statistics retrieved from OECD inter-country input-output tables, available over the period 1995-2011. The paper undertakes a multifaceted analysis by investigating the role of Luxembourg in GVC within a sample of 50 advanced and emerging market economies[1], at the country level, at the sector level and over time.

The paper highlights the following results. Across OECD countries, Luxembourg features the highest dependence to trade. Foreign trade contributes strongly to economic activity and domestic employment. Trade in intermediate products represents the majority of foreign trade in Luxembourg. In this regard, the country appears to be deeply integrated in GVC as it features the highest degree of GVC participation across the considered countries. Luxembourg's GVC participation is characterized by a strong backward participation and a relatively low forward

[1] The sample of selected advanced and emerging market economies covers the following countries: AT, AU, BE, BR, CA, CH, CL, CN, CY, CZ, DE, DK, EE, ES, FI, FR, GR, HK, HU, ID, IE, IL, IN, IS, IT, JP, KH, KR, LT, LU, LV, MT, MX, MY, NL, NO, NZ, PL, PT, RU, SE, SG, SI, SK, TH, TR, UK, US, VN and ZA.

participation. This means that Luxembourg trades a larger amount of intermediate products imported from abroad while it exports a lower amount of domestically produced intermediate products. In other words, Luxembourg is primarily a buyer of foreign value added and less a seller of domestic value added. This is generally the case of small open economies. The latter usually source more intermediate products from abroad in GVC than larger economies where, given their size, a longer part of the value chain is domestic and hence a higher share of intermediate products is produced domestically. Moreover, Luxembourg's GVC participation is characterized by an involvement in long, increasing and internationally-oriented production chains whether on the sourcing side or on the selling side. The country thus features strong upstream and downstream interconnections in GVC with other partner countries. This suggests that Luxembourg acts as an important chain-link in the global value network.

The major part of Luxembourg's GVC trading partners is located in Western Europe (by order of importance, Germany, Belgium, Switzerland, France, the United Kingdom and Italy) implying that the supply chain network is not global for Luxembourg but rather regional. Notwithstanding this, the share of East Asian and Eastern European emerging countries - albeit relatively low compared to advanced economies - is increasing over the period of analysis.

At the sector level, Luxembourg's GVC participation is concentrated in the finance and insurance industry. It is from this specific sector that the country retrieves the most important share of value added from GVC. This is notably evidenced by the position of this sector at the extremity of the GVC smile curve. The latter observation concurs with the fact that Luxembourg captures large benefits from GVC participation in the finance and insurance industry in terms of inward FDI, employment and economic activity.

In addition, the analysis shows that across the considered countries, Luxembourg possesses a revealed comparative advantage in GVC in the finance and insurance industry. This comparative advantage is maintained over time in the sample of countries.

Eventually, the main ultimate foreign consumers of Luxembourg's value added are located in Western Europe. Outside Europe, the United States are an important final customer. Notwithstanding this, the share of East Asian and Eastern European emerging countries, albeit relatively low compared to advanced economies, is increasing over the period of analysis. At the sector level, Luxembourg's ultimate consumers are primarily located in the finance and insurance industry, followed by business and real estate services and the transport and telecom

industry. On the other side of the chain, the providers of foreign value added to Luxembourg's final demand share similar geographical characteristics. However, at the sector level, the main providers of foreign value added to Luxembourg's final demand originate primarily from business and real estate services and less from the finance and insurance sector. This suggests that the Luxembourg's finance and insurance industry is able to satisfy domestic needs, in addition to foreign ones.

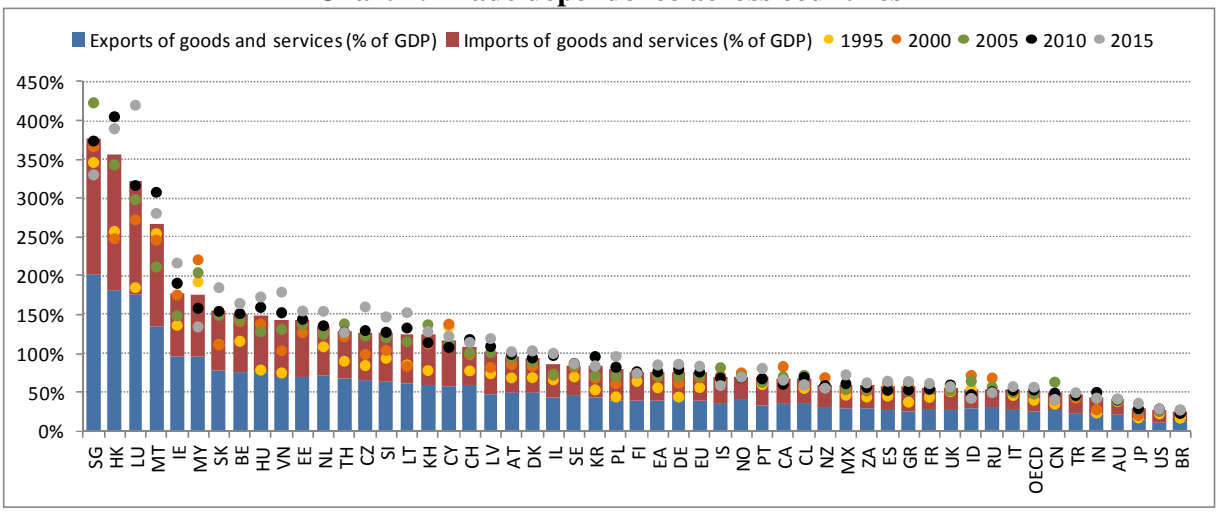
The remainder of the paper is organized as follows. Section 2 assesses the importance of international trade in Luxembourg, in terms of contribution to economic activity and employment. Section 3 defines the data and exposes the differences between gross trade statistics and trade in value added statistics. Sections 4 and 5 analyze the role of Luxembourg in GVC, respectively on the producers' side and on the final consumers' side, based on trade in value added statistics. Section 6 concludes and provides further ways of research that could be of interest for Luxembourg. The paper comes with a detailed appendix that clarifies *via* a step-by-step approach how trade in value added metrics are derived from inter-country input-output tables.

2. Importance of international trade for Luxembourg

2.1 Trade dependence

Chart 1 presents the average ratio of trade dependence for selected advanced and emerging market economies (EMEs) over the period 2000-2016. It also shows the evolution of this ratio for the years 1995, 2000, 2005, 2010 and 2015. Trade dependence represents the combined weight of total trade (gross exports and gross imports) in an economy as a percentage of GDP.

Chart 1: Trade dependence across countries



Source: World Bank (NE.EXP.GNFS.ZS for exports-to-GDP, NE.IMP.GNFS.ZS for imports-to-GDP), average over the period 2000-2016.

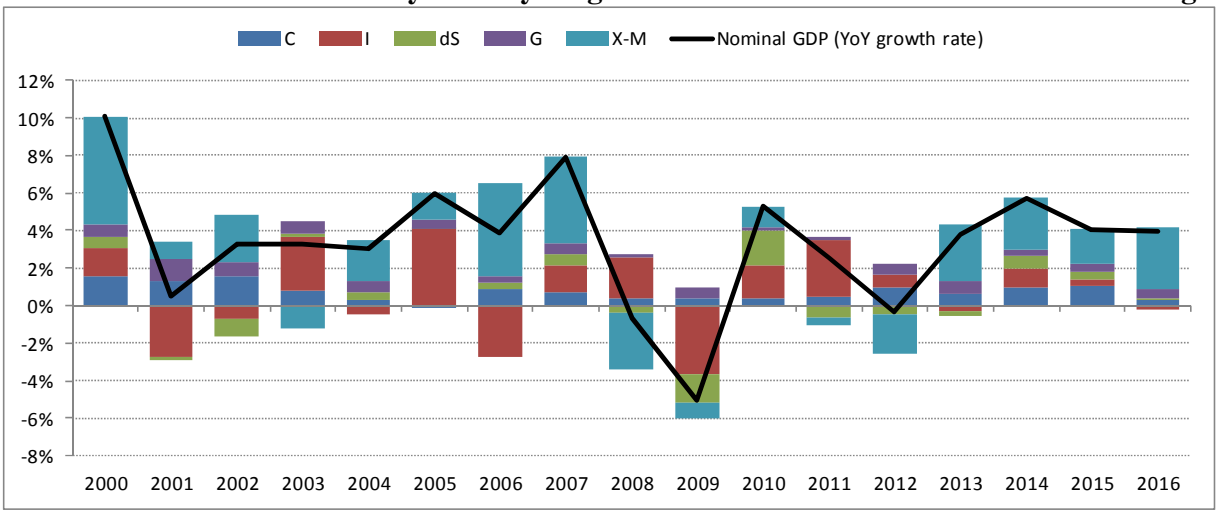
Across OECD economies, Luxembourg presents the strongest dependence to international trade with a share of foreign trade in goods and services (gross exports plus gross imports) representing more than 322% of GDP on average over the period 2000-2016. Across the considered countries and based on the same metric, Luxembourg holds the third place, just behind Singapore (377% of GDP) and Hong Kong (355% of GDP). Over time, trade dependence has increased for the majority of the considered economies, including Luxembourg. This suggests that the degree of dependence of domestic producers on foreign markets (for gross exports) has become stronger as is the degree of reliance of domestic demand on foreign supply of goods and services (for gross imports). As gross trade flows are defined as the sum of final,

intermediate and re-export/re-import products, this means that one of these components could account for an important share of gross trade flows. With regard to this observation, potential explanations will be provided later in the paper.

2.2 Trade contribution to economic growth

Chart 2 focuses on the case of Luxembourg and presents the contribution of the various demand components to GDP: consumption (*C*), investment (*I*), changes in private inventory (*dS*) and net trade (*X-M*). The respective contributions of each GDP component are presented in percentage points so that the sum of the components is equal to the year-on-year growth rate of nominal GDP. For example, in 2016, nominal GDP grew by 4.18%. In percentage points (pp), the various demand components contributed to 0.30 for consumption, -0.21 for investment, 0.07 for changes in private inventory, 0.52 for government spending and 3.28 for net trade[2].

Chart 2: Contribution to the year-on-year growth rate of nominal GDP for Luxembourg



Source: STATEC. For a given demand component *A*, the contribution in percentage points to the year-on-year growth rate of nominal GDP is calculated as follows: $C_{A,t}=(A_{t-1}/Y_{t-1})\text{x}[(A_t/A_{t-1})-1]$ or equivalently, $C_{A,t}=(A_t-A_{t-1})/Y_{t-1}$, with *Y* representing GDP. Notations: consumption (*C*), investment (*I*), changes in private inventory (*dS*), government spending (*G*), gross exports (*X*), gross imports (*M*), net trade (*X-M*).

Over the period 2000-2016, net trade stands as the most important demand component driving economic activity in Luxembourg. Indeed, for an average nominal GDP growth rate of

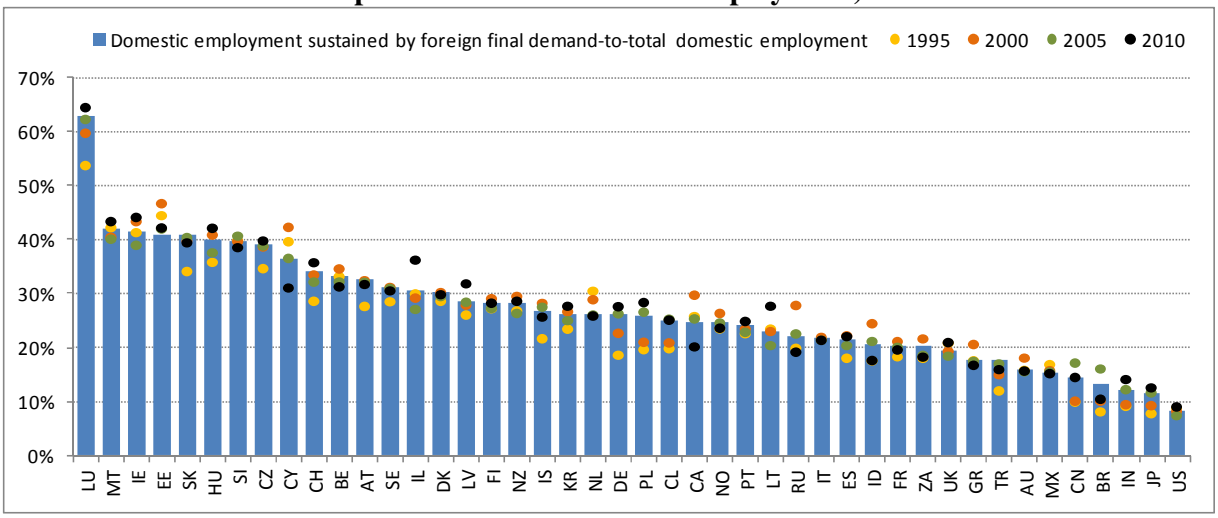
[2] Note that gross imports and gross exports have opposite effects on GDP. Gross exports add to GDP while gross imports subtract. Thus if the country is running a trade deficit (surplus), net trade will subtract (add) to GDP. As Luxembourg runs a trade surplus over the considered period, net trade adds to GDP.

3.37% from 2000 to 2016, the contribution of each demand component amounts to 0.74pp for consumption, 0.49pp for investment, 0.04pp for changes in private inventory, 0.53pp for government spending and 1.57pp for net trade. In other words, net trade accounts approximately for 46% of the average year-on-year nominal growth rate of GDP over the period 2000-2016.

2.3 Trade contribution to employment

The trade sector is also a substantial driver of employment in Luxembourg[3]. Indeed, Chart 3 shows that on average, over the period 2000-2011, domestic employment sustained by foreign final demand accounts for 62.8% of total employment. According to OECD statistics[4], the sector that benefits the most from foreign final demand in term of employment is the finance and insurance industry.

Chart 3: Domestic employment sustained by foreign final demand across countries (in percent of total domestic employment)



Source: http://stats.oecd.org/, Industry and Services\ Structural Analysis Database (STAN)\ Input Output Database\ Trade in employment: Core Indicators, *EMPN_FFDEM*, average over the period 2000-2011 (based on available data).

Across countries, the share of employment sustained by foreign final demand is larger for small economies (*e.g.* Luxembourg, Malta, Ireland, Cyprus, *etc.*) and lower for larger economies

[3] Similar evidence is found in Sousa *et al.* (2012), Arto *et al.* (2015), Rueda-Cantuche and Sousa (2016) and OECD (2016a).

[4] Source: http://stats.oecd.org/, Industry and Services\ Structural Analysis Database (STAN)\ Input Output Database\ Trade in employment: Core Indicators, *EMPN_FFDEM*, average over the period 2000-2011 (based on available data).

(*e.g.* the United States, Japan, India, Brazil, China, *etc.*). This result is in line with OECD (2016a) which shows that the importance of trade for employment is influenced by the size of countries and also by the type of activity in which countries specialize in. Across OECD economies, Luxembourg features the largest share and is the unique country to present a share of domestic employment embodied in foreign final demand above 50%. Moreover, this share trends upward since 1995 for Luxembourg; an observation that differs across countries.

Altogether, the above observations suggest that Luxembourg retrieves a lot of benefits from international trade, in terms of economic activity and employment. The analysis of trade in value added statistics (sections 4 and 5) will provide some explanations for this observation.

3. Data

3.1 From gross trade statistics...

Gross trade figures are the standard and official measure of a country's trade flows. Gross trade statistics measure trade by recording products crossing the national customs borders. For example, gross exports are defined as the sum of exports of domestic products and re-exports. Exports of domestic products cover goods and services processed in the domestic economy with the need of domestic intermediate products and/or the requirement of imports of intermediate products from foreign economies. Gross exports can thus include the value of any foreign intermediate products that are used in domestic production. Re-exports - in the sense of entrepot trade - are exports of foreign products in the same state as previously imported *i.e.* without further domestic processing or transformation[5,6].

[5] One should distinguish re-exports in the sense of entrepot trade from re-exports within global value chains. In the case of re-exports as entrepot trade, the product does not undergo any transformation. In other words, re-export products do not contain any value added from the country that imported them and then re-exports them. Re-packing, splitting into lots, sorting or grading, marking and the like are not considered as undergoing the process of transformation (Lim (2013)). In the case of re-export within the global value chain, the product undergoes a transformation. In other words, re-export products within GVC contain domestic value added from the country that imported them as intermediate products from a foreign country for processing (or value adding) and then re-exports them back to the foreign country.

[6] Similarly, gross imports of a country are defined as the sum of imports of foreign products and re-imports. Gross imports of foreign products cover goods and services processed in foreign economies. Re-imports - in the sense of entrepot trade - are imports of domestic products in the same state as previously exported, *i.e.* without further

A common criticism of gross trade data is that they disregard the fact that intermediate products used in the production process of a product and exported from one country may be imported from several other countries. In the presence of intermediate trade, gross trade data record several times the value of intermediate products traded between countries before the products actually reach the final consumer. In other words, gross trade data overstate the value that a country contributes to its exports, leading to a measurement issue illustrated by a double-counting or a multiple-counting of trade flows (Koopman *et al*. (2014)). As a consequence, along the value chain, the country of the final producer appears as capturing most of the value of products traded, while the role of countries providing intermediate products upstream can be overlooked[7].

This argument is even more compelling given that intermediate trade has become a key feature of international trade (Miroudot *et al*. (2009), De Backer and Norihiko (2012), UNCTAD (2015)). Indeed, at the global level, the average share of intermediate products amounted to 56.91% of total trade (defined as exports plus imports of intermediate and final products) in 1995. This share grew at an average year-on-year rate of 0.7% over the period 1995-2011 to reach 63.42% of total trade in 2011. At the country level, the majority of foreign trade in goods and services deals with intermediate products (Chart 4). In the case of Luxembourg, the average share of intermediate products (exports plus imports of intermediate goods and services) over the period 2000-2011 amounts almost to 70% of foreign trade (exports plus imports of final and intermediate goods and services) while the share of final products represents only 30% of foreign trade (Chart 4). When reported to gross output[8], Luxembourg features the highest percentage of intermediate trade across the considered countries, with an average amount of trade in intermediate products equal to 72% of gross output over the period 2000-2011 (Chart 5).

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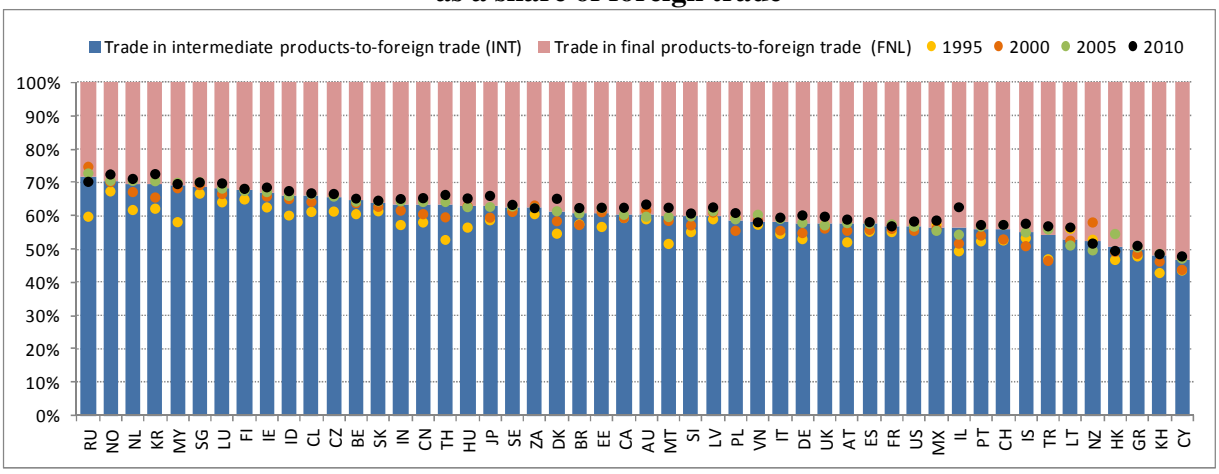
foreign processing. As such, they do not contain any foreign value added. Conversely, re-import products within GVC contain foreign value added by a foreign country that imported them as intermediate products from a given country for processing and then re-exports them back to this latter country.

[7] See Koopman *et al*. (2014), notably p. 467-469 and Appendix B.

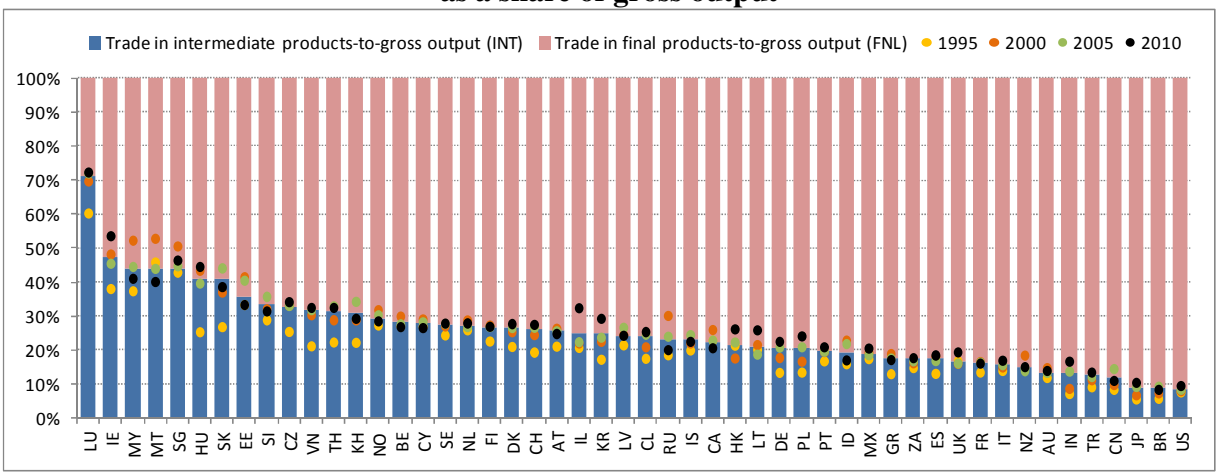
[8] Gross output is a much broader measure of economic activity than gross domestic product (GDP). Gross output can be measured as the sum of a country's gross value added (*i.e.* the value of final products) and intermediate consumption (*i.e.* the value of intermediate products used to produce final products), in a given period of time. Gross domestic product (*a.k.a.* net output or gross value added) is equal to the sum of value added *i.e.* the difference between gross output and intermediate consumption, in a given period of time.

Chart 4: Gross trade in intermediate products *versus* gross trade in final products as a share of foreign trade



Source: OECD-TiVA database (December 2016), average 2000-2011, based on available data. Calculations: *INT*=(*EXGR_INT*+*IMGR_INT*)/(*EXGR*+*IMGR*); *FNL*=(*EXGR_FNL*+*IMGR_FNL*)/(*EXGR*+*IMGR*).

Chart 5: Gross trade in intermediate products *versus* gross trade in final products as a share of gross output



Source: OECD-TiVA database (December 2016), average 2000-2011, based on available data. Calculations: *INT*=(*EXGR_INT*+*IMGR_INT*)/*PROD*; *FNL*=(*EXGR_FNL*+*IMGR_FNL*)/*PROD*.

The importance of intermediate trade relates to the fact that the production site of a firm can become worldwide thanks to trade liberalization (*e.g.* lower trade barriers), lower transportation cost, progress and cost reduction in Information and Communication Technologies, acceleration in technical progress (which allows for standardization of production) and organizational innovations. Hence, producers of goods and services can optimize their production processes by locating the various production stages in different sites across the world (often the most profitable places that allow reducing costs) *via* outsourcing and offshoring of

activities[9]. The production process becomes geographically and vertically fragmented. This implies that one key feature of world trade is that the final goods and services bought by final consumers are composed of intermediate products from various countries around the world, blurring the concept "*made in a given country*", as products are actually "*made in the world*".

Global Value Chains (GVC) describe this international functional and spatial fragmentation of production processes. Gereffi and Fernandez-Stark (2011) define GVC as "*the full range of activities that firms and workers do to bring a product from its conception to its end use*". GVC have become a prominent feature of world trade. Their development has been mainly driven by multinational enterprises (MNEs) in their pursuit of competitive advantage and profits. By carrying out specific parts of the production process in certain countries, costs are minimized through economies of scale as well as specialization, in addition to local cost advantages (*e.g.* lower unit labor costs, tax benefits, *etc.*). Within the GVC process, intermediate products are shipped across borders multiple times, with each exporting country providing some value added, until the product is eventually imported for final consumption. Each time products cross national borders they are registered as gross trade flows, meaning that gross trade statistics double-count, triple-count or multiple-count international trade flows[10].

3.2 ...to trade in value added statistics

To address the measurement issue in gross trade data, economists have developed methods and datasets to better estimate the value that a country contributes or adds to foreign trade flows. This is notably the case of trade in value added (TiVA) statistics[11,12]. Retrieved from

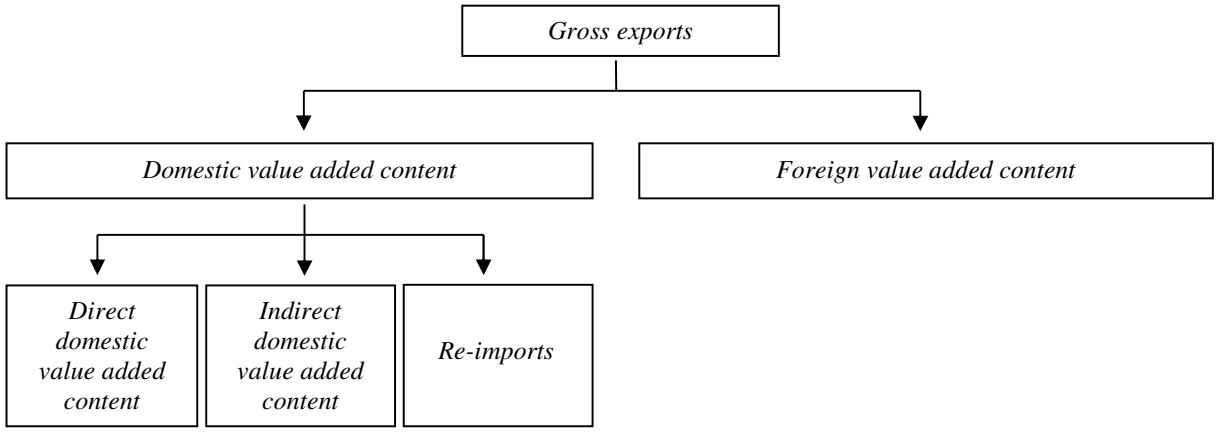
[9] Outsourcing involves the contracting out of a business process (*e.g.* payroll processing, claims processing) and operational and/or non-core functions (*e.g.* manufacturing, facility management, call center support) to another party. Offshoring is the relocation of a business process from one country to another; typically an operational process (such as manufacturing) or supporting processes (such as accounting). Grossman and Rossi-Handsberg (2008) favor the term "offshoring" to the more popular "outsourcing" when talking about GVC. Indeed, the latter suggests that tasks formerly performed in-house are now being purchased at arms-length, whereas the former implies that tasks formerly undertaken in one country are now being performed abroad. In other words, offshoring includes not only foreign sourcing from unrelated suppliers, but also the migration abroad of some of the activities conducted by a multinational firm.

[10] To better understand the measurement issue of multiple-counting, see Appendix B.

[11] For example, the OECD computes Trade in Value Added (TiVA) indicators from the OECD Inter-Country Input-Output (ICIO) tables (http://oe.cd/icio) which describe inter-country, inter-industry flows of intermediate goods and services as well as the country and industry origins of goods and services to meet final demand. The OECD TiVA indicators are available for 62 countries, 34 industries, over the period 1995-2011 (http://www.oecd.org/industry/ind/measuringtradeinvalue-addedanoecd-wtojointinitiative.htm). Other entities

inter-country input-output tables[13], TiVA data consider the value added by each country in the production of goods and services that are consumed worldwide. As such, they allow for a better understanding of the role of an economy in international trade compared to gross trade statistics. In this regard, TiVA statistics provide a decomposition of the value of gross exports into several components. Chart 6 shows a basic example:

Chart 6: Basic decomposition of gross exports



Gross exports can first be decomposed into two main components: domestic value added and foreign value added. Domestic value added exports correspond to the domestic contribution to exported products. Foreign value added exports reflect the foreign contribution to exported products. The foreign value added stems from trade in intermediate products within the global value network[14].

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contributed to develop ICIO tables and related indicators: the European Commission's World Input-Output Database (WIOD; http://www.wiod.org/home), the Asian Development Bank's Input-Output Tables (https://www.adb.org/data/icp/input-output-tables), the UNCTAD's Eora Multi-Region Input-Output (MRIO) database (http://worldmrio.com/), *etc*. For more information, see http://www.wiod.org/otherdb.

[12] Caution is still required when using trade in value added statistics (Sturgeon (2015)). Indeed, the latter are estimates and underlying data are not perfect owing to inconsistencies across countries and lack of complete bilateral trade in services data. In addition, several assumptions are used, notably the hypothesis that firms are treated as homogeneous. As a consequence, results must be interpreted with caution.

[13] An inter-country input-output (ICIO) table is a combination of national input-output tables and trade data that breaks down the use of goods and services according to the country of their origin (Powers (2012)).

[14] Trade in intermediate products within the global value network refer to trade in intermediate goods and services imported by the domestic country, processed in the domestic economy and then exported to third economies in the global value network.

Domestic value added combines three components: direct domestic value added, indirect domestic value added and re-imports of domestic value added (Chart 6).

Direct domestic value added regroups domestic value added exported and directly consumed abroad plus domestic value added exported and processed in a foreign economy and directly consumed in this foreign economy. Direct domestic value added thus reflects the direct contribution made by a country in producing a product for export. The latter product does not imply trade in GVC as it does not require foreign intermediate products in its production process.

Conversely, indirect domestic value added and re-imports involve trade flows in intermediate products between two or more countries within GVC. Indeed, indirect domestic value added includes intermediate products that the direct (or initial) foreign importer embodies into other intermediate products, which are then exported to third countries. Indirect value added thus reflects the indirect contribution of domestic supplier industries to the production of final goods and services. Re-imports cover the domestic value added content of intermediate exports that finally returns home. Re-imports thus reflect the domestic value added that was exported by a given country as intermediate products to a foreign country for further processing. Then, the former country re-imports this intermediate product for further processing in domestic industries or for final use.

The above components of gross exports can themselves be decomposed into further sub-components to reach the final decomposition of gross exports as introduced by Koopman *et al*. (2014) into nine sub-components[15]. Appendix A provides a detailed description of the latter decomposition. This section stops at the above basic decomposition as it is necessary and sufficient to carry on the analysis.

To proceed with the analysis, the paper retrieves trade in value added statistics from OECD inter-country input-output (ICIO) tables. The latter are available for 62 countries and 34 industries over the period 1995-2011. The OECD produces ICIO tables based on different sources: the national accounts, the supply and use tables (SUTs), the national input-output tables (IOTs) and merchandise and services trade statistics[16].

[15] See Koopman *et al*. (2014), p. 482.

[16] The national accounts gather the main components of expenditures (household and non-profit institutions serving households (NPISHs) final consumption, general government final consumption, gross fixed capital formation (GFCF), valuables, changes in inventories, exports and imports of goods and services both with free on board valuation), the output and value added by industry at basic prices and the tourism satellite account. The supply tables regroup the products supplied by each industry along with the distribution margins, the taxes less subsidies margins

4. Global value chains: the producers' side

4.1 Domestic *versus* foreign value added shares of gross exports

Chart 7 decomposes the average value of gross exports as shares of foreign value added[17] and domestic value added[18] for selected advanced and emerging market economies over the period 2000-2011. The chart also presents the evolution of the foreign value added content in gross exports for the years 1995, 2000, 2005 and 2010 (given available data).

Within the selected sample of countries, Luxembourg presents the highest percentage of foreign value added content in gross exports and the least percentage of domestic value added content in gross exports. Thus, on average over the period 2000-2011, 56% (respectively, 44%) of Luxembourg's gross exports consist in value that was added in a foreign country (respectively, in Luxembourg). This suggests a strong involvement of Luxembourg in GVC compared to the other countries in the sample.

Between 1995 and 2010, the share of foreign value added in gross exports has increased in Luxembourg. This pattern can be observed across a majority of advanced and emerging market economies (Chart 7). This suggests increasing international and vertical fragmentation of production at the global level.

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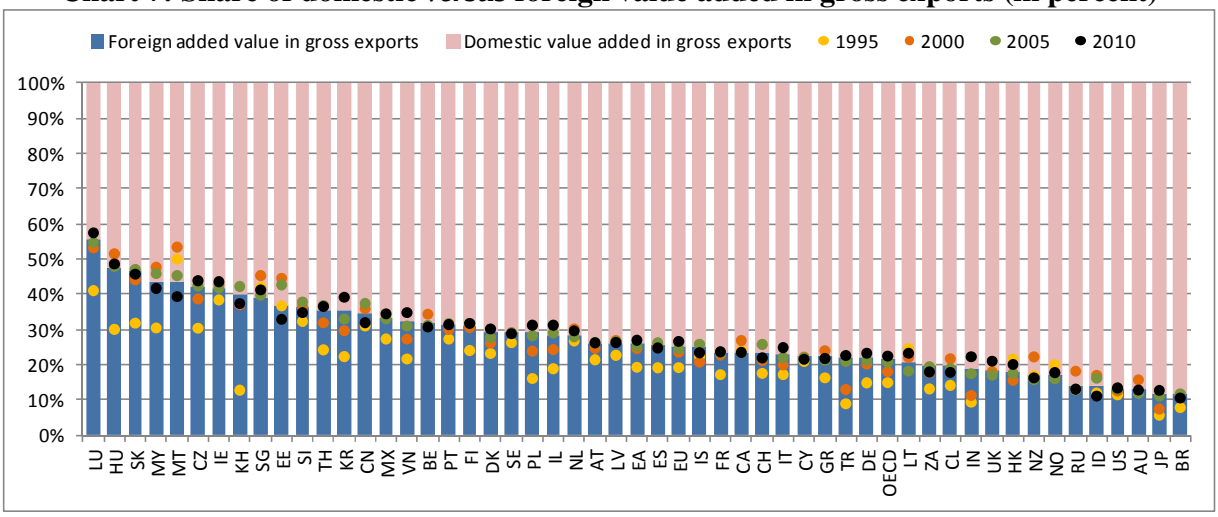
and the imports (valued at cost, insurance and freight). The use tables - provided at purchasers' price and at basic price - contain the products used by each industry in the domestic country and/or imported from abroad. The national input-output tables - provided at basic prices - contain the use and supply of goods and services industry-by-industry and/or product-by-product. The merchandise trade contains the exports and imports of goods including re-exports and re-imports. The services trade covers both inflows and outflows of services. For more details, see OECD (2015), "National Data Requirements for Inclusion in the Current TiVA Data Infrastructure", December 2015, available at http://www.oecd.org/sti/ind/tiva/tivasourcesandmethods.htm.

[17] The foreign value added content of gross exports corresponds to the value added of intermediate products that were imported in order to produce intermediate or final products (goods or services) to be exported. The measure is also often referred to as vertical specialisation. Source: OECD, https://data.oecd.org/trade/import-content-of-exports.htm#indicator-chart. See Appendix A for further details.

[18] The domestic value added content of gross exports is an estimation of value added, by an economy, in producing goods and services for export. This measure combines three elements: the domestic value added sent to consumer economy, the domestic value added sent to third economies and the domestic value added re-imported in the economy. Source: OECD, https://data.oecd.org/trade/domestic-value-added-in-gross-exports.htm#indicator-chart. See Appendix A for further details.

Chart 7: Share of domestic *versus* foreign value added in gross exports (in percent)



Source: OECD-TiVA database (December 2016), average 2002-2011, based on available data.

Chart 8 focuses on the case of Luxembourg and presents a decomposition of gross exports over the period 1995-2011. It shows the respective contributions of the components of gross exports to the year-on-year growth rate of gross exports (Chart 8.1) and the shares of the respective components in gross exports (Chart 8.2). The considered components are the ones defined in section 3.2: the direct domestic value added (*EXGR_DDC*), the indirect domestic value added (*EXGR_IDC*), re-imports (*EXGR_RIM*) and the foreign value added (*EXGR_FVA*).

Over the period 1995-2011, gross exports present a positive growth cycle in 1998-2000 and 2002-2008 (Chart 8.1). Gross exports faced four major downward shocks: a fall in 1997 potentially explained by the global economic slowdown in the aftermath of the Asian financial crisis (ECB (1999)), a fall in 2001 presumably related to the fall in global economic activity following the crash of the internet bubble in global stock markets, a slowdown in 2005 possibly due to a global economic slowdown in the background of a steep rise in oil prices (WTO (2005)) and a fall in 2009 in the wake of the 2007-2008 global financial crisis. From the first shock to the fourth one, the contribution of the components pertaining to trade flows within GVC (*EXGR_IDC*, *EXGR_RIM* and *EXGR_FVA*) increased substantially. As a matter of fact, in 1997, the majority of the slowdown in gross exports was due to export flows outside GVC and notably direct domestic value added export flows (*EXGR_DDC*, Chart 8.1). Conversely, in 2009, the majority of the slowdown in gross exports was due to export flows within GVC and notably foreign value added export flows (*EXGR_FVA*, Chart 8.1). The latter observation has also been evidenced in the literature for other countries (Baldwin (2009), Constantinescu *et al*. (2015),

ECB (2016), IMF (2016)). Altogether, this suggests that over the period, trade flows within GVC are becoming more and more important in Luxembourg's gross exports.

The latter argument agrees with the fact that the share of gross export flows within GVC ([*EXGR_IDC+EXGR_RIM+EXGR_FVA*]/*EXGR*) is increasing over the period 1995-2011 (Chart 8.2). From 52.04% in 1995, the latter share reaches 69.27% in 2011; hence an average growth rate of almost 2% a year over this period. Conversely, the share of gross exports outside GVC approximated by the direct domestic value added, amounted to 47.96% in 1995 and fell to 30.73% in 2011; hence an average growth rate equal to -2.60% a year over this period.

Chart 8: Decomposition of gross exports for Luxembourg

Chart 8.1: Contribution to the year-on-year growth rate in gross exports

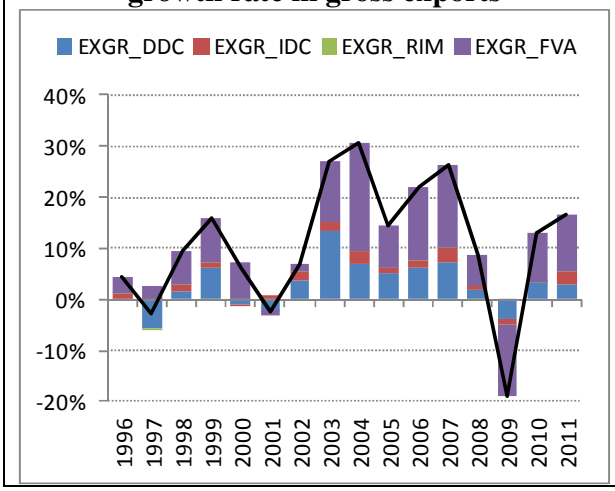
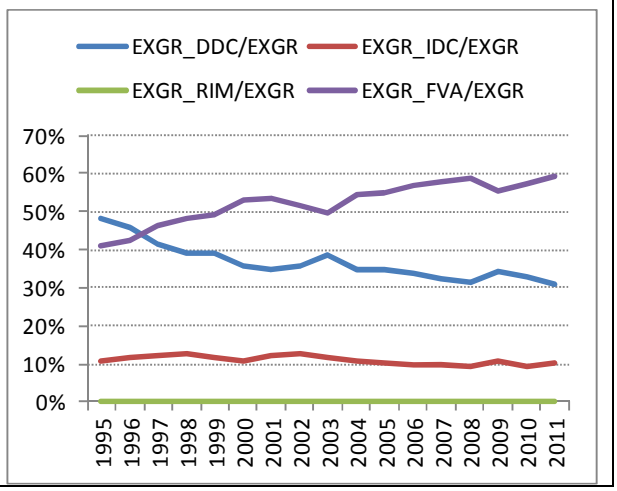


Chart 8.2: Share of gross exports



Source: OECD-TiVA database (December 2016), based on available data. In Chart 8.1, the black line represents the year-on-year growth rate of gross exports.

4.2 Participation in global value chains

Chart 9 computes the GVC participation index put forward by Koopman *et al.* (2014). The GVC participation index indicates the share of foreign intermediate products and domestically produced intermediate products used in third countries' exports. Expressed as a percentage of gross exports, it sums the foreign value added embodied in gross exports (*a.k.a.*

backward GVC participation) and the domestic value added embodied in third countries' gross exports (*a.k.a.* forward GVC participation)[19].

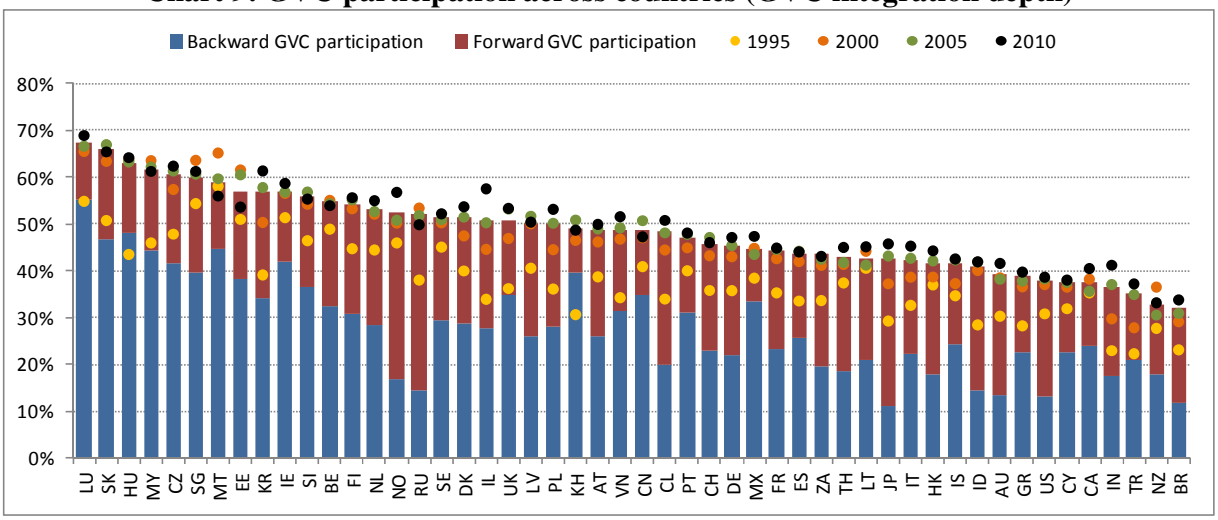
The backward GVC participation considers the importers' perspective (or buyers' perspective) of foreign value added. It assesses the amount of foreign value added embodied in intermediate products imported from a source country, included in exports and used in third countries' exports. The forward GVC participation refers to the exporters' perspective (or sellers' perspective) of domestic value added. It gauges the amount of domestic value added embodied in a country's exports that is used in other countries' exports.

According to OECD (2012), the GVC participation index indicates the extent to which a country is involved in a vertically fragmented production process. In other words, the GVC participation index indicates the depth of GVC integration of a given country.

Chart 9 shows that Luxembourg possesses the strongest GVC participation across the considered countries, accounting for around 68% of its total gross exports on average over the period 2000-2011. This suggests that Luxembourg is deeply integrated in the global value network, as a substantial part of its exports consists in foreign intermediate products and domestically produced intermediate products used in third countries' exports. Between 1995 and 2010, Luxembourg's GVC participation has increased. This evolution is similar across the majority of selected advanced and emerging market economies. This implies that Luxembourg and to some extent, the other considered countries, are expanding their role in the global production network but at the same time are becoming more exposed to changes in external factors.

[19] The forward GVC participation thus corresponds to a sub-component of the domestic value added in gross exports presented in Chart 7. Indeed, to assess a country's GVC participation, only products traded within GVC are considered. Amongst the components of gross exports, products traded outside GVC enter the category "direct domestic value added content of gross exports". Such a category gathers domestic value added exported abroad and directly consumed abroad (*a.k.a.* domestic value added in direct final product exports) and domestic value added exported abroad, processed in the foreign economy and subsequently consumed in this foreign economy (*a.k.a.* domestic value added in intermediate exports absorbed by direct importers). See Appendix A.

Chart 9: GVC participation across countries (GVC integration depth)



Source: OECD-TiVA database (December 2016), average 2000-2011, based on available data.

Chart 9 shows that Luxembourg's exports feature the strongest backward GVC participation and one of the lowest forward GVC participation across the considered countries. This means that Luxembourg trades a larger amount of intermediate products imported from abroad while it exports a lower amount of domestically produced intermediate products. In other words, Luxembourg is primarily a buyer of foreign value added and less a seller of domestic value added. This is generally the case of small open economies (*e.g.* Slovakia, Hungary, Malaysia, Czech Republic, Singapore, Malta, *etc.*) compared to larger countries (*e.g.* Brazil, Japan, Australia, the United States, India, Russia, *etc.*). Indeed, given their small size, the former usually source more intermediate products from abroad in GVC than larger developed economies. The latter usually benefit from longer domestic value chains and hence a higher share of intermediate products is produced domestically. In addition, trade in GVC is important for economies that benefit from offshoring such as Hungary, Luxembourg, Ireland, Malaysia, Slovakia (Miroudot and Cadestin (2017)) due to financial attractiveness (*e.g.* lower labor costs or more favorable taxation), skilled workforce and/or better business environment (*e.g.* political stability, quality of infrastructure, better living standards, *etc.*).

4.3 Position in global value chains

According to Koopman *et al*. (2014), the share of forward GVC participation relative to the share of backward GVC participation informs about the position of a country along the global value chain. If the forward participation is higher than the backward participation, the country is located more upstream in the production network *i.e.* in the first stages of production where it exports a lot of intermediate products abroad. Conversely, if the forward participation is lower than the backward participation, the country is positioned more downstream in the value chain *i.e.* specialized in the last stages of production where it imports a lot of intermediate products from abroad[20].

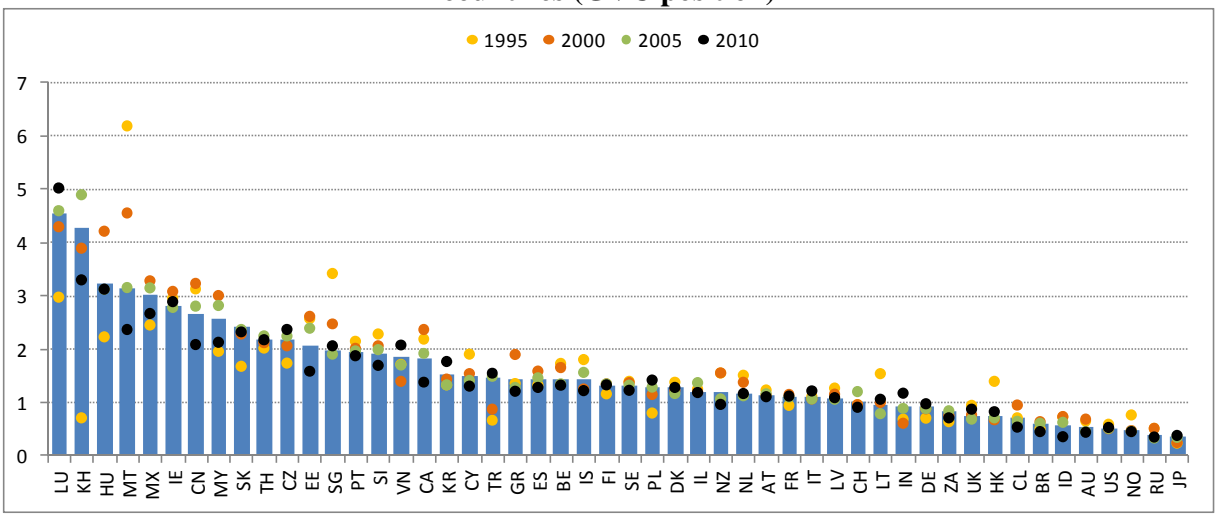
A country's position in the value chain usually depends on its comparative advantage and therefore the mix of labor skills and resource endowments it brings to the international production process (OECD (2016b)). In other words, a country can be upstream or downstream, depending on its specialization (OECD (2012)). Upstream activities usually relate to the production of raw materials or intangibles at the start of the production process (*e.g.* minimally processed or unprocessed materials, research and development, innovation, design, consulting, market intelligence, *etc*.). At the center of the value chain, countries are usually specialized in activities dealing with standardized, labor-intensive manufacturing jobs. At the end of the value chain, production activities become closer to final demand and usually regroup final assembly or customer services (*e.g.* logistics, distribution, *etc*.).

Chart 10 presents the average ratio of backward GVC participation-to-forward GVC participation over the period 2000-2011 together with its evolution for the years 1995, 2000, 2005 and 2010. Large economies (*e.g.* Japan, the United States, the United Kingdom, Germany) or countries that export commodities (*e.g.* Russia, Norway, Australia, Brazil, Chile, South Africa) are located on the right of the chart, hence more upstream in the value chain. Indeed, large economies import less intermediate products as a larger share is produced domestically, while commodity exporting countries export more intermediate products towards countries

[20] Koopman *et al*. (2014) define the GVC position index as the log of the domestic value added embodied in third countries' gross exports (*a.k.a.* forward GVC participation or upstreamness) to the foreign value added embodied in gross exports (*a.k.a.* backward GVC participation or downstreamness). Hence, the larger the GVC position index, the more upstream the country in the value chain. See Appendix C.

located more downstream in the value chain. Conversely, small economies and in particular those that benefit from offshoring (*e.g.* Luxembourg, Cambodia, Hungary, Malta, Mexico, Ireland, China, Malaysia, Slovakia, Thailand, Czech Republic) are located on the left of the chart hence more downstream in the value chain. These countries thus import more intermediate products whose value has been added by other countries situated more upstream in the chain. Downstream countries add intermediate products and value towards the end of the global production process.

Chart 10: Ratio of backward GVC participation-to-forward GVC participation across countries (GVC position)



Source: OECD-TiVA database (December 2016), average 2000-2011, based on available data.

Over time, the evolution of the ratio differs across countries in sign and magnitude. For some countries, the ratio increases (*e.g.* Czech Republic, India, Japan, Luxembourg, Poland, Turkey, *etc.*) while for others it decreases (*e.g.* Canada, China, Estonia, Indonesia, Malta, Slovenia, *etc.*). For Luxembourg, the ratio increases all over the period. This suggests that the country is moving more and more downstream in the global value chains.

4.4 Geographical breakdown

Given the strong GVC participation of Luxembourg, an important question pertains to the origin and destination of value added trade flows within GVC. Chart 11 provides a geographical breakdown of the origin of foreign value added and the destination of domestic value added. The charts are designed so that the buying side (Chart 11.1) sums up to the backward GVC participation, while the selling side (Chart 11.2) adds up to the forward GVC participation. As Luxembourg is primarily a buyer of foreign value added, the geographical breakdown into source countries could be of particular interest to identify which foreign sources add the most value to its exports.

On the buying side, on average over the period 2000-2011, the most important providers of foreign value added to Luxembourg within GVC are Germany (9.28%), Switzerland (5.96%), Belgium (5.52%), the United Kingdom (5.19%), the United States (5.14%), France (4.79%), Italy (3.71%) and the Netherlands (2.21%). The geographical origin of foreign value added is hence mostly European and in particular Western European. Indeed, on average over the period 2000-2011, 82% (respectively, 79%) of the foreign value added has been bought by Luxembourg from European economies (respectively, Western European economies)[21]. Notwithstanding this, between 1995 and 2011, the most important average growth rates concerning the origin of foreign value added in gross exports are found for specific economies located in East Asia (*e.g.* China, Hong Kong, India, Japan, Singapore and South Korea) and in Eastern Europe (*e.g.* Czech Republic, Hungary, Poland and Russia)[22]. This suggests that the geographical origin of foreign value added evolves over time.

[21] To be precise, European economies cover here Western European economies (AT, BE, CH, CY, DE, DK, ES, FI, FR, GR, IE, IS, IT, MT, NL, NO, PT, SE, UK) and Eastern European economies (CZ, EE, HU, LT, LV, PL, RU, SI, SK).

[22] Between 1995 and 2011, the average year-on-year growth rates in foreign value added originating from abroad amount to 18% for East Asia (China, Hong Kong, India, Japan, Singapore and South Korea), 16% for Eastern Europe (Czech Republic, Hungary, Poland and Russia), 6% for North America (Canada and the United States) and 5% for Western Europe (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom).

Chart 11: Origin and destination of trade in value added for Luxembourg

Chart 11.1: Origin of foreign value added in gross exports: Where does Luxembourg buy foreign value added?

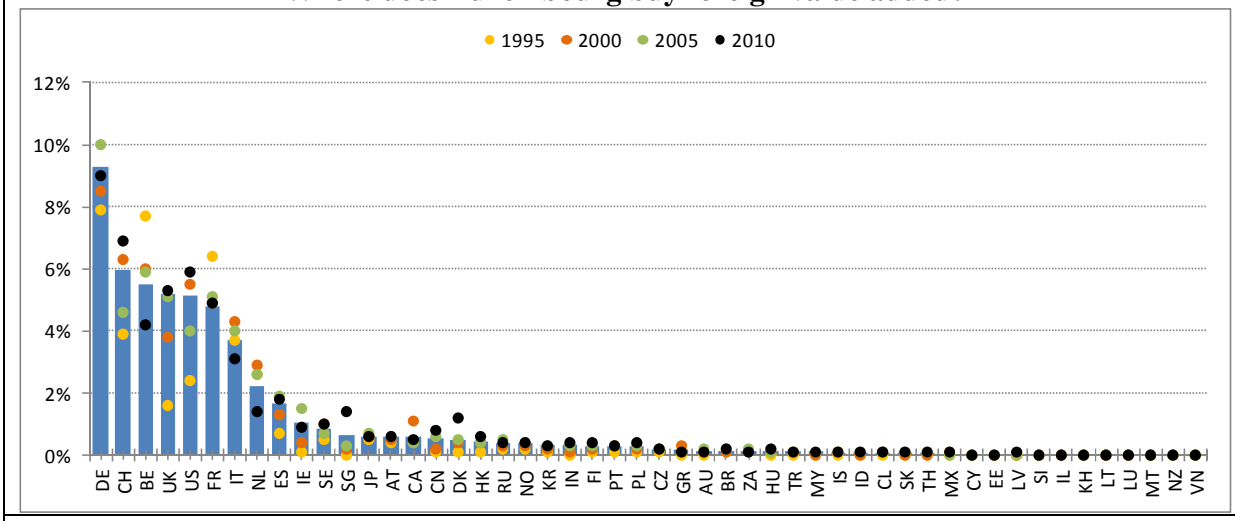
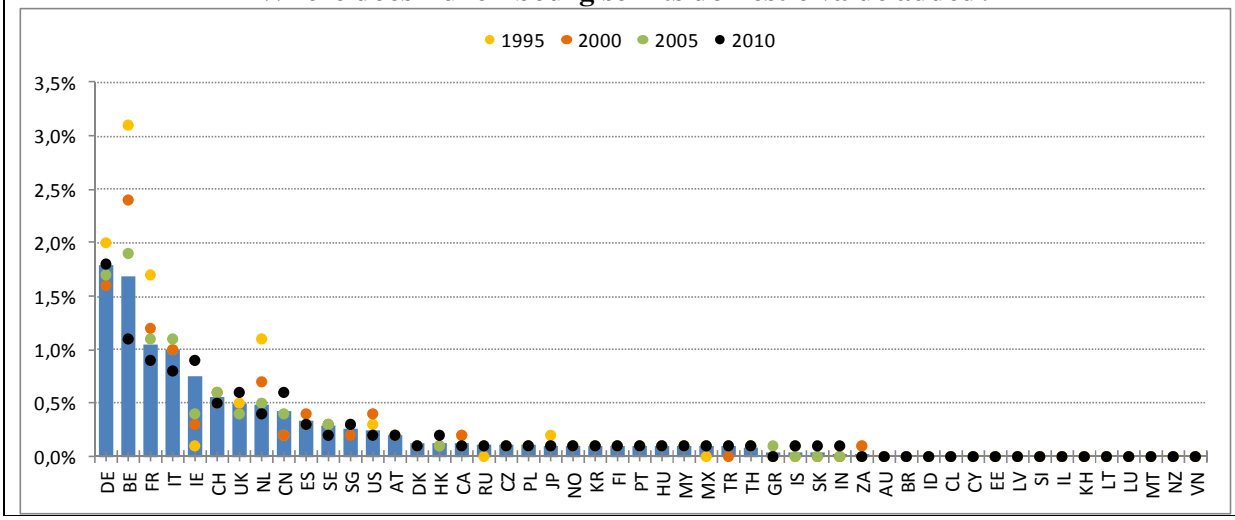


Chart 11.2: Destination of domestic value added in gross exports: Where does Luxembourg sell its domestic value added?



Source: OECD-TiVA database (December 2016), average 2000-2011, based on available data.

On the selling side, on average over the period 2000-2011, the most important buyers of Luxembourg's value added within GVC are Germany (1.78%), Belgium (1.69%), France (1.05%), Italy (1.01%), Ireland (0.75%), Switzerland (0.56%), the United Kingdom (0.50%), the Netherlands (0.48%) and China (0.42%). The destination of Luxembourg's value added is thus essentially European (on average 84% of the domestic value added sold within GVC, over the period 2000-2011) and especially Western European (on average 80% of the domestic value added sold within GVC, over the period 2000-2011). However, between 1995 and 2011, the

most important average growth rates concerning the destination of Luxembourg's value added are found for specific economies located in East Asia (China, Hong Kong and Singapore) and in Eastern Europe (Czech Republic, Hungary, Poland and Russia)[23].

As a result, whether on the buying side or on the selling side, the importance of emerging economies located in East Asia (*e.g.* China, India) and in Eastern Europe (*e.g.* Czech Republic, Hungary, Poland, Russia) as value added trading partners of Luxembourg within GVC is increasing, although their share remains relatively small in comparison to advanced economies. The importance of trade in value added flows with Western European countries (by order of importance, Germany, Belgium, Switzerland, France, the United Kingdom and Italy, when adding the respective country's shares in Charts 11.1 and 11.2) suggests that distance appears to matter in shaping bilateral value added trade flows in GVC[24] and also that the supply chain network is less global for Luxembourg but rather regional. The latter observation prevails also for other countries reviewed in the literature (Fontagné and Santoni (2017))[25].

4.5 Sectoral breakdown

GVC participation across sectors

Chart 12 provides a decomposition of Luxembourg's GVC participation at the sector level[26]. Luxembourg's GVC participation is concentrated in the services sector and in particular in the finance and insurance industry, revealing the country's specialization. The finance and

[23] Between 1995 and 2011, the average year-on-year growth rates in domestic value added going abroad amount to 10% for East Asia (China, Hong Kong, and Singapore), 8% for Eastern Europe (Czech Republic, Hungary, Poland and Russia), 5% for Western Europe (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom) and 2% for North America (Canada and the United States).

[24] Johnson and Noguera (2012b) highlighted a similar result and suggest that gravity effects could prevail for value added trade flows (Anderson (1979, 2011), Anderson and van Wincoop (2003), Head and Mayer (2013, 2014)). However, this remains to be tested empirically.

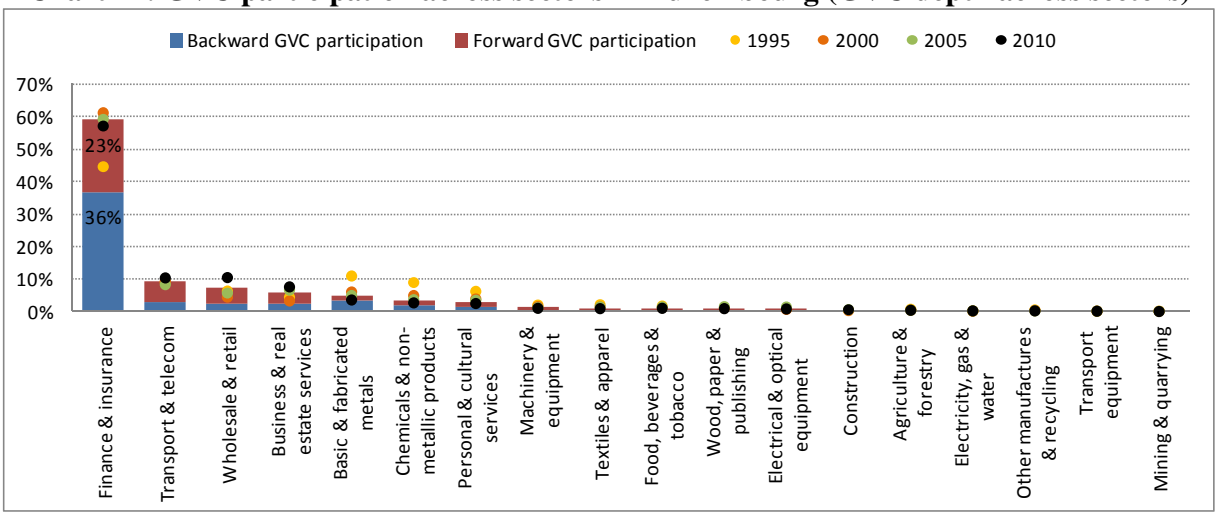
[25] Notice that the United Kingdom is also an important GVC partner for Luxembourg, whether on the buying side or on the selling side. Indeed, at the global level, the United Kingdom is the 4th most important provider of foreign value added to Luxembourg (Chart 11.1) and the 7th most important destination of domestic value added (Chart 11.2). As a result, the consequences of the Brexit should probably be examined in light of the latter observation. Investigating this issue in details goes beyond the scope of the paper.

[26] See Appendix F for a detailed description of the sector categories.

insurance industry is indeed the sector where most of the domestic value added is created from Luxembourg's participation in the global value network.

Luxembourg's exports in the finance and insurance sector are characterized by a high backward GVC participation (36%) and a lower forward GVC participation (23%). This means that the export content in finance and insurance products includes to a large extent foreign intermediate products.

Chart 12: GVC participation across sectors in Luxembourg (GVC depth across sectors)



Source: OECD-TiVA database (December 2016), average 2000-2011, based on available data.

In the finance and insurance sector, traditional intermediate products within the value chain are financial services and information. Firms involved in this value chain usually regroup private banks, asset management firms (*e.g.* investment funds), insurance companies, corporate cash management entities, *etc*. The activity of these firms boils down to raising funds by taking deposits or issuing securities and make loans or trade securities. The value chain goes from lenders to borrowers and the products can be divided into credit intermediaries and financial intermediaries[27].

[27] Note that domestic industries supporting the finance and insurance industry in Luxembourg (*e.g.* fiduciary companies, audit firms, accountants, law firms, telecommunication firms, *etc*.) may benefit directly or indirectly from spillover effects stemming from the important backward GVC participation in the finance and insurance industry (see Taglioni and Winkler (2016) p. 86). This spillover effect remains to be quantified empirically.

The importance of Luxembourg's GVC participation in the finance industry goes hand in hand with its status as a global financial center, hosting for example one of the most important fund industry in the world. As a matter of fact, the fund industry manages EUR 3943 billion of assets in 2017Q2 (EFAMA (2017)), placing Luxembourg as the leading investment fund centre in Europe and the second one at the global level, just behind the United States where the fund industry manages EUR 17856 billion of assets[28].

According to Bley (2015), in Luxembourg, the investment fund industry (*a.k.a.* Organismes de Placements Collectifs (OPC)) and particularly mutual funds (*a.k.a.* Organismes de Placements Collectifs en Valeurs Mobilières (OPCVM)) contribute to the major part of trade in financial services.

Bley (2015) argues that financial services exports by the Luxembourg's fund industry include the assignment to non-resident investors of all expenses incurred by investment funds regarding their assets holding. Such expenses cover the running costs of investment funds inherent to their assets holding activity and comprise management and advisory expenses, administrative fees, audit and accounting costs, marketing and legal expenses, custodian banks' commissions, distributors' costs, *etc*.). The expenses are actually paid by Luxembourg's investment funds to resident companies, but are assigned to non-resident shareholders of mutual funds. The latter expenses take part of the 23% of domestic value added exported by Luxembourg in the finance and insurance industry (Chart 12).

On the other hand, financial services imported by the Luxembourg's fund industry reflect the expenses paid by Luxembourg's management companies to their non-resident counterparts. The major part of these expenses relates to advisory commissions, trading fees and distribution costs paid to non-resident companies, either directly or indirectly through a resident management company. According to Bley (2015), the latter commissions represent about three-quarters of the total expenses incurred by Luxembourg's investment funds. The latter expenses are included in the 36% of foreign value added exported by Luxembourg in the finance and insurance industry (Chart 12).

[28] See EFAMA (2017), Table 2 "Total net assets excluding funds of funds by the type of funds", millions of euro, end of quarter, 2017Q2, *in* International Statistical Release, 2017, Worldwide Regulated Open-ended Fund Assets and Flows Trends in the Second Quarter of 2017, p. 10.

From a historical perspective, the geographical fragmentation of the finance and insurance industry is not a new phenomenon. Indeed, most finance and insurance companies have globalized their activities to seek new customers and new markets abroad. This process can be explained by the considerable reduction of transport costs and the improvement of communications, stimulated by technological development like internet (Capelle-Blancard and Tadjeddine (2009), OECD (2012)). Notwithstanding this, what becomes more acute since the 1990s is the vertical fragmentation of the finance and insurance industry (Capelle-Blancard and Tadjeddine (2009), Mudambi and Venzin (2010), OECD (2012)). According to Mudambi and Venzin (2010), financial services firms are increasingly offshoring and outsourcing parts of their value adding activities in countries where they can find specific factor endowments (*i.e.* skilled labor force, processing capabilities, *etc*.) and reduce their costs (*i.e.* lower labor cost, tax benefit, *etc*.).

Revealed comparative advantage across sectors

Trade in value added statistics allow refining the sectoral analysis by unveiling whether Luxembourg possesses a comparative advantage in the above considered sectors within the global value network. To this aim, the paper relies on the revealed comparative advantage (RCA) proposed by Balassa (1965)[29]. The latter indicator computes the ratio of domestic value added exported within GVC by sector *i* in country *c* to the total domestic value added exported within GVC by country *c* ($X_{c,i,t}/X_{c,t}$) divided by the ratio of domestic value added exported within GVC by sector *i* at the world level to the total domestic value added exported within GVC at the world

[29] A similar analysis is implemented in Timmer *et al.* (2013) and van der Marel (2015). According to Timmer *et al.* (2013), the revealed comparative advantage (RCA) index should be based on domestic value added exports rather than gross exports with which the index was originally developed. Indeed, domestic value added exports bear more importance concerning the total income captured by a country in the global value chains. van der Marel (2015) computes a "*GVC-related RCA index*" based on the domestic value added content of gross exports (see van der Marel (2015), Table 3 p. 13). However, this paper believes that the latter measure - based on domestic value added - is an accurate measure of the external comparative advantage of a country (compared to the use of gross exports) but not truly an accurate measure of a country's comparative advantage in GVC. Indeed, the components of the domestic value added implying GVC trade are the indirect domestic value added content of exports (*EXGR_IDC*) and re-imports (*EXGR_RIM*) *i.e.* the forward GVC participation (or equivalently, the total domestic value added minus the direct domestic value added). As a result, a more accurate measure of comparative advantage in GVC should be based on the forward GVC participation. Hence, this paper computes a GVC-related RCA index based on the forward GVC participation (see Table 1 in the core text). The paper also computes a RCA index based on the domestic value added to gauge the external revealed comparative advantage of a country (see Table D in Appendix D).

level ($X_{w,i,t}/X_{w,t}$). The domestic value added exported within GVC is equal to the forward GVC participation *i.e.* the sum of indirect domestic value added (*EXGR_IDC*) and re-imports (*EXGR_RIM*). Hence:

$$RCA_t = \frac{X_{c,i,t} / X_{c,t}}{X_{w,i,t} / X_{w,t}} = \frac{(EXGR\_IDC_{c,i,t} + EXGR\_RIM_{c,i,t}) / (EXGR\_IDC_{c,t} + EXGR\_RIM_{c,t})}{(EXGR\_IDC_{w,i,t} + EXGR\_RIM_{w,i,t}) / (EXGR\_IDC_{w,t} + EXGR\_RIM_{w,t})}$$

According to Balassa (1965) and Balassa and Nolan (1989), a RCA index above (below) unity indicates that a country has a revealed comparative advantage (disadvantage). This paper believes that identifying any comparative advantage of a country based on a single ratio bears some limits. A more relevant approach would require a thorough analysis. This task goes however beyond the scope of this paper. As a result, we consider that a particular sector has a revealed comparative advantage in GVC if two conditions are fulfilled: first, the related RCA is above unity and second, the related RCA is the highest in the set of countries[30]. Table 1 presents the GVC-related RCA index for Luxembourg. When the index is higher than unity, the table specifies the rank of Luxembourg in the sample of 50 advanced and emerging market economies.

[30] An additional criteria could be the implementation of a one-sided right-tailed Student t-test to check whether the value of the RCA is significantly higher than one (H_0: *RCA*=1 *versus* H_1: *RCA*>1). However, the paper ruled out this possibility given the low number of observations (12 data points between 2000 and 2011).

Table 1: GVC-related Revealed Comparative Advantage for Luxembourg

	1995		2000		2005		2010		Average 2000-2011	
Sectors	RCA	Rank	RCA	Rank	RCA	Rank	RCA	Rank	RCA	Rank
Agriculture & forestry	0.28		0.21		0.20		0.22		0.17	
Mining & quarrying	0.07		0.01		0.01		0.01		0.01	
Food, beverages & tobacco	0.44		0.33		0.29		0.19		0.25	
Textiles & apparel	0.38		0.27		0.32		0.20		0.26	
Wood, paper & publishing	0.43		0.37		0.57		0.40		0.44	
Chemicals & non-metallic products	0.24		0.16		0.10		0.08		0.11	
Basic & fabricated metals	1.18	18th	0.81		0.28		0.35		0.50	
Machinery & equipment	0.30		0.29		0.15		0.12		0.18	
Electrical & optical equipment	0.07		0.04		0.14		0.07		0.07	
Transport equipment	0.01		0.01		0.01		0.01		0.01	
Other manufactures & recycling	0.18		0.08		0.04		0.08		0.06	
Electricity, gas & water	0.29		0.20		0.16		0.37		0.48	
Construction	0.72		0.85		1.27	30th	1.09	34th	1.10	37th
Wholesale & retail	0.58		0.34		0.45		0.96		0.58	
Transport & telecom	0.78		0.74		0.56		1.53	20th	0.93	
Finance & insurance	39.27	**1rst**	37.67	**1rst**	36.99	**1rst**	31.34	**1rst**	33.47	**1rst**
Business & real estate services	0.96		0.50		1.38	18th	1.39	15th	1.04	26th
Personal & cultural services	4.29	3rd	1.77	21rst	1.54	15th	1.29	18th	1.45	20th

Source: Author's calculations based on OECD-TiVA database (December 2016). The GVC-related RCA index is calculated based on the forward GVC participation (*EXGR_IDC+EXGR_RIM*) of each sector.

Table 1 shows that a lot of heterogeneity prevails across sectors regarding the value of the GVC-related RCA index. Over the period of analysis, the index passes below unity for the basic and fabricated metals industry while other sectors evidence the reverse (*e.g.* construction, business and real estate services). Some sectors present a GVC-related RCA higher than one but remain far from the first positions in term of ranking (*e.g.* construction, transport and telecom, business and real estate services, personal and cultural services[31]). One sector presents a revealed comparative advantage in GVC that persists over time: the finance and insurance industry, where Luxembourg is ranked first throughout the considered period. Although not shown in Table 1, the main countries ranked behind Luxembourg in the finance and insurance industry are Cyprus (with a GVC-related RCA equal to 6.59 on average over the period 2000-2011), the United Kingdom (6.10), Switzerland (4.24), Hong Kong (2.97), Singapore (2.56), Ireland (2.32), Malta

[31] In the sector of personal and cultural services, the most important component stems from "other community, social and personal services". On average over the period 2000-2011, this component accounts for 87.49% of the domestic value added in gross exports by the sector of personal and cultural services and 95.95% of the foreign value added in gross exports by the sector of personal and cultural services. According to the OECD-TiVA database and the United Nations' ISIC Revision 3 industry classification, "other community, social and personal services" cover activities pertaining to sewage and refuse disposal, sanitation; activities of membership organizations n.e.c.; recreational, cultural and sporting activities (including the production of radio and television programmes). For more details, see Appendix F.

(2.25) and the United States (1.72)[32]. With an average GVC-related RCA equal to 33.47 over the period 2000-2011, Luxembourg holds a stronger GVC-related RCA in the finance and insurance industry compared to the latter countries.

4.6 Link between global value chain participation and foreign direct investment

According to UNCTAD (2013) and OECD (2015), the participation of countries in GVC along with its development is largely driven by multinational companies through Foreign Direct Investment (FDI). In the literature, the inward FDI stock[33] is often used as a proxy to outline GVC-oriented FDI. Several studies highlight a positive correlation between inward FDI and GVC participation (UNCTAD (2013), OECD-WTO-WB (2014), OECD (2015), Kowalski *et al.* (2015), Buelens and Tirpak (2017)).

Across selected OECD economies, Luxembourg presents the largest stock of inward FDI excluding SPEs[34] relative to GDP (Chart 13). The stock of inward FDI averages 308% of GDP over the period 2013-2015 (based on available data). In addition, over the latter period, the stock trends upward. In line with the importance of GVC participation in the finance and insurance industry (Chart 12), inward FDI is primarily directed to the finance and insurance sector in Luxembourg (representing on average 138% of GDP over the period 2013-2015), followed by the wholesale and retail industry (respectively, 80% of GDP) and the business and real estate services (respectively, 68% of GDP)[35]. This result is in line with the fact that Luxembourg is mainly a buyer of foreign value added (Chart 9). Indeed, according to Taglioni and Winkler (2016), buyers of foreign value added are likely to observe FDI inflows and high inward FDI stocks in sectors and products of GVC specialization (*i.e.* the finance and insurance industry in the case of Luxembourg).

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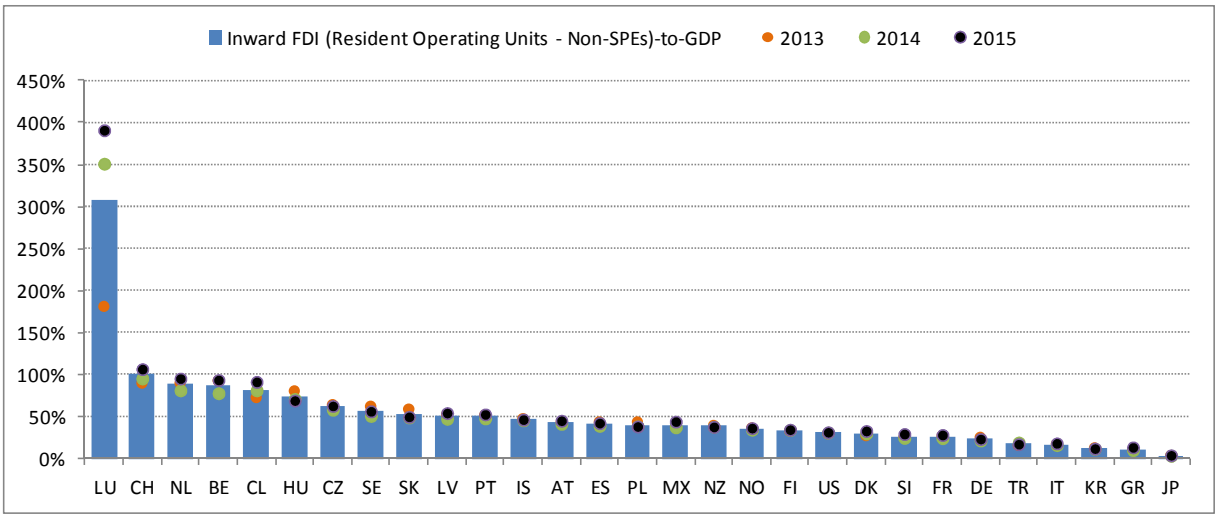
[32] Table D in Appendix D computes the RCA index based on total domestic value added (*EXGR_DVA*, where *EXGR_DVA*= *EXGR_DDC*+*EXGR_IDC*+*EXGR_RIM*). Results do not differ substantially compared to Table 1.

[33] The inward FDI stock is defined as the value of foreign investors' equity in and net loans to enterprises resident in the reporting economy.

[34] According to OECD (2015), Special Purpose Entities (SPEs) are entities whose role is to facilitate the internal financing of a multinational enterprise but that have little or no physical presence in an economy. By excluding such entities from their FDI statistics, countries presumably have a better measure of the FDI into their country that is having a real impact on their economy.

[35] Source: OECD (http://stats.oecd.org/index.aspx?lang=en), Globalisation\FDI statistics according to Benchmark Definition 4th Edition (BMD4)\FDI positions\FDI positions by industry BMD4\Inward and outward FDI by industry.

Chart 13: Inward FDI stock excluding Special Purpose Entities (SPEs) across selected OECD countries



Source: OECD, average 2013-2015, based on available data. Globalisation\FDI statistics according to Benchmark Definition 4th Edition (BMD4)\FDI positions\FDI positions, main aggregates BDM4\FDI positions, main aggregates BDM4. Inward FDI stocks are measured as a share of GDP.

4.7 Length of the sourcing chain *versus* length of the selling chain

While the GVC participation index points to the involvement degree of a given country within a vertical production network, it does not inform about the production length, *i.e.* the number of production stages a given country is involved in within the value chain. Indeed, a high backward GVC participation may not necessarily reflect a long value chain as it could correspond to the use of expensive intermediate products (*e.g.* costly raw materials, high technology inputs, *etc*.) in a very short (or simple) value chain. Similarly, a high forward GVC participation may not necessarily reflect a long value chain as the value could be added all at once in the final stage of the production process in a very short (or simple) value chain. This is why the GVC length can be a useful and complementary indicator to the GVC participation (De Backer and Miroudot (2014)). To this aim, the literature set out two main indicators: the length of the sourcing chain and the length of the selling chain[36]. These indicators reflect the complexity

[36] To measure the sourcing chain length, Dietzenbacher and Romero (2007) use the average propagation length (APL) indicator. Fally (2012) and Antràs *et al*. (2012) propose an index of the number of production stages often labeled in the literature as the "*GVC length index*". According to De Backer and Miroudot (2014), this measure is equivalent to total backward linkages. To measure the selling chain length, Fally (2012) and Antràs *et al*. (2012) introduce the "*distance to final demand*". Starting from one industry in a given country, the latter indicator measures how many stages of production are left before the product reaches the final consumer. According to De Backer and Miroudot (2014), this measure is equivalent to total forward linkages. For further information, see Escaith (2017),

of the production process (Wang *et al*. (2017)) and the level of opportunities a country can exploit within GVC to ultimately export value added (van der Marel (2015), Taglioni and Winkler (2016)).

Length of the sourcing chain

From the perspective of value added buyers, the sourcing chain length addresses the degree of interconnections of a particular country/sector with those upstream countries/sectors from which it purchases intermediate products (Rasmussen (1957), Miller and Blair (2009)). According to De Backer and Miroudot (2014), the sourcing chain length is equivalent to total backward linkages and provides a measure of downstreamness (Miller and Blair (2009), Wang *et al*. (2017)). The sourcing chain length can be decomposed into domestic and international parts (OECD (2012)). The domestic part measures the length of production processes when the intermediate products for the realization of a final product are domestically sourced. Conversely, the international part measures the length of production processes when the intermediate products for the realization of a final product are sourced from foreign countries[37]. The minimum value of the sourcing chain length is unity if there is only a single production stage in the final industry *i.e.* when no intermediate products (whether domestic or foreign) are used to make a product. In the latter case, the product is directly purchased by final customers. Conversely, the value of the sourcing chain length increases when intermediate products from the same industry or other industries in the domestic country or abroad are used in the production process of a given product[38]. According to Taglioni and Winkler (2016), the sourcing chain length can inform about the potential benefits a country can exploit within GVC, assuming that longer value chains

"Annex 4.2: Measuring the length of global value chains and the number of border crossings", p. 114, and De Backer and Miroudot (2014), "Annex 1: Indicators on Global Value Chains". See also Appendix C.

[37] Source: https://stats.oecd.org/; Industry and Services\Structural Analysis (STAN) Databases\STAN Archives\OECD Global Value Chains indicators - May 2013\Indices of the number of production stages.

[38] Industries with a sourcing chain length close to unity would typically be the case of local production directed to domestic final consumers (*e.g.* real estate activities, education activities). This does not mean that local production is less developed, but rather that there is limited geographical and vertical fragmentation in these activities. Conversely, industries where the sourcing chain length gets higher than unity typically represent global productions characterised by a large geographical and vertical fragmentation of the value chain (*e.g.* communication equipments, motor vehicles). See for example, OECD (2012) and Taglioni and Winkler (2016), "Figure 4.17, Length of Sourcing Chains, by Industry, 2008", p. 84.

(*i.e.* more fragmented or more complex value chains) provide more opportunities to countries as they offer a greater number of participation possibilities.

Chart 14 presents the sourcing chain length across countries[39]. On average over the period 2000-2011, the index varies between 1.7 and 2.9 for the considered countries. China features the longest sourcing chain, reflecting its specialization in sourcing intermediate products to produce manufacturing products given its status of world factory (Mees (2016)). Luxembourg presents a rather long sourcing chain, holding the sixth longest sourcing chain across countries. In addition, Luxembourg features the second longest international sourcing chain across countries, behind China.

This result is in line with the fact that Luxembourg is deeply integrated in GVC and presents a strong backward participation (Chart 9). The fact that an important part of the production stages is located abroad agrees with the small size of the country and the importance of global or more accurately regional partition of production chains in which Luxembourg is involved (Chart 11.1). Indeed, larger countries feature a relatively shorter international sourcing chain length (hence a longer domestic sourcing chain length) as they utilize intermediate products from their domestic value chains to a greater extent (see for example, Japan, Brazil, the United States, Australia, India and Russia, in Chart 14).

Moreover, Chart 14 shows that for the majority of economies (including Luxembourg) the sourcing chain length has increased over time. This suggests that, over the period, the value added network has become more fragmented or more complex, with production stages implemented in more countries. For Luxembourg, the increase in the sourcing chain length is in line with the increase in backward GVC participation over the period of analysis (Chart 10).

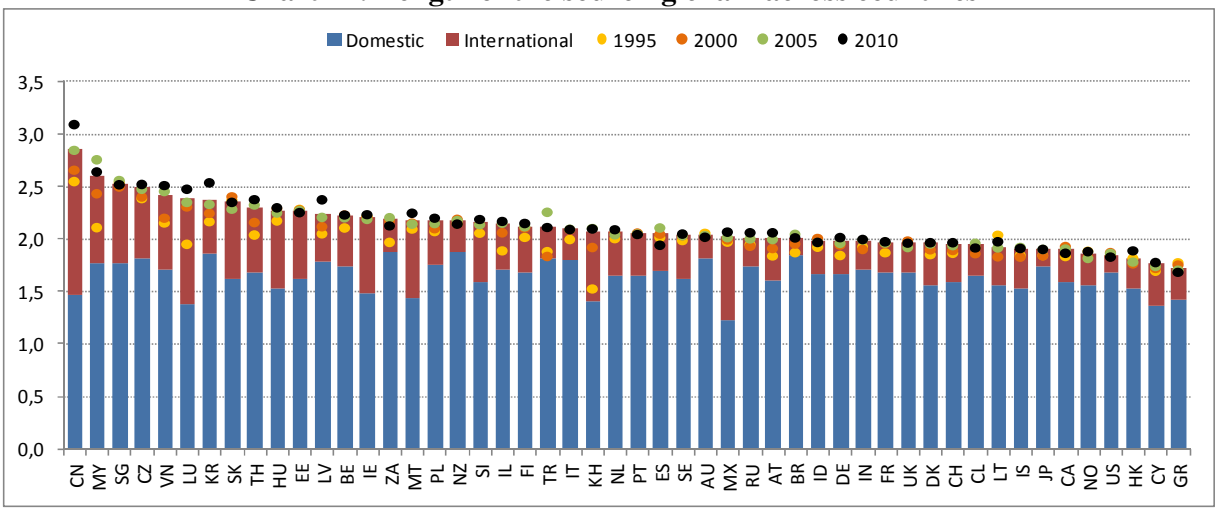
The fact that Luxembourg features a long, increasing and internationally-oriented sourcing chain bears advantages and limits. On the one hand, long sourcing chains are often associated with complex GVC where countries can exploit a lot of opportunities in terms of technology transfers for example (van der Marel (2015), Taglioni and Winkler (2016)[40]). In Luxembourg, these opportunities can be illustrated by the strong and increasing inward FDI

[39] The calculation of the sourcing chain length follows De Backer and Miroudot (2014) and is equivalent to total backward linkages (see Appendix C). Literally, the sourcing chain length informs about the level of influence by a given country/sector on the output of all countries/sectors through its purchases or its input demand (Marx *et al.* (2014)).

[40] See Taglioni and Winkler (2016), p. 85.

stock (Chart 13) or by the contribution of GVC trade to economic activity and domestic employment (section 2). On the other hand, long sourcing chains and in particular internationally-oriented sourcing chains could imply a higher exposure to foreign shocks, including GVC disruptions. The latter result concurs with the large trade dependence of Luxembourg evidenced in Chart 1. This means that external demand is a substantial driver of economic activity in Luxembourg but also that the country is substantially exposed to foreign shocks.

Chart 14: Length of the sourcing chain across countries

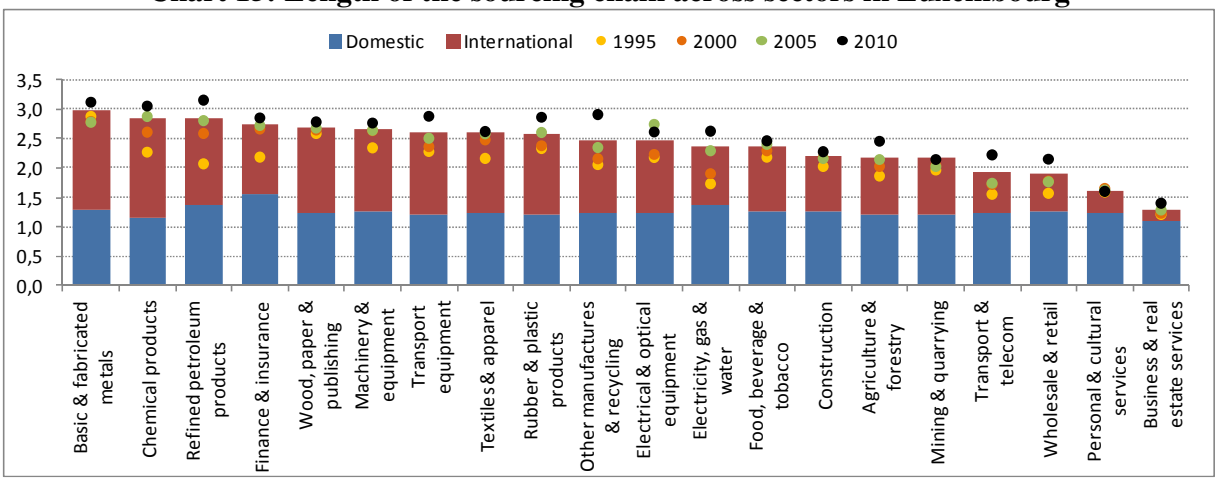


Source: Author's calculations based on OECD Inter-Country Input-Output (ICIO) tables, average 2000-2011, based on available data.

Chart 15 presents the sourcing chain length for Luxembourg at the sector level. The longest sourcing chains are found in the basic and fabricated metals industry, the chemicals products industry, the refined petroleum products industry and the finance and insurance sector. This result is in line with the productive structure of the economy and especially the presence of global manufacturers in Luxembourg relating to the former three industries (*e.g. Arcelor Mittal*, *Goodyear*, *DuPont de Nemour*, *Shell*, *Esso*, *etc.*) and the numerous financial entities in the finance and insurance sector that Luxembourg hosts as a global financial center (*e.g.* banks, investment funds, insurance companies and MNEs' affiliates mainly involved in financial intermediation). Regarding specifically the finance and insurance sector, a comparison across countries unveils that Luxembourg possesses the longest sourcing chain over the period of

analysis[41]. Thus, as a global financial center, Luxembourg is typically the type of competence centers where financial firms from other countries offshore some activities as evidenced by the important stock of inward FDI pertaining to finance and insurance activities (section 4.5) and by the important participation of this sector in GVC (Chart 12).

Chart 15: Length of the sourcing chain across sectors in Luxembourg



Source: Author's calculations based on OECD Inter-Country Input-Output (ICIO) tables, average 2000-2011, based on available data. NB: In Chart 15, the sector "Chemicals & non-metallic products" has been decomposed into "Chemical products", "Refined petroleum products" and "Rubber & plastic products".

Length of the selling chain

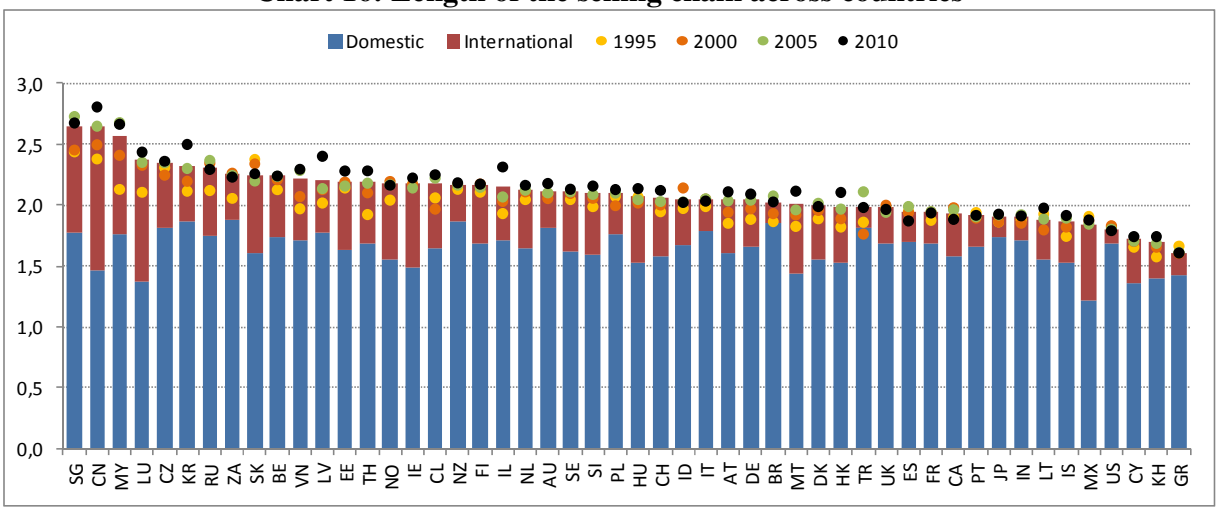
From the perspective of value added sellers, the length of the selling chain (or distance to final demand) indicates the degree of interconnections of a particular country/sector with those downstream countries/sectors to which it sells its output (Rasmussen (1957), Miller and Blair (2009)). In other terms, the selling chain length measures how many stages of production are left before the goods and services produced by an industry or by a country reach final consumers (Fally (2011, 2012), Antràs *et al.* (2012)). It can be interpreted as the number of stages that intermediate products cross borders before reaching final consumers. According to De Backer and Miroudot (2014), the selling chain length is equivalent to total forward linkages and provides a measure of upstreamness (Miller and Blair (2009), Wang *et al.* (2017)). The selling chain length can also be decomposed into domestic and international parts. Basically, a country presents a short selling chain if the length is close to unity. This country is then positioned more

[41] Author's calculations based on OECD Inter-Country Input-Output (ICIO) tables. Results are available from the author upon request.

downstream and tends to serve relatively more the final producers or the final consumers at the end of the value chain. This is typically the case of countries that regroup a high share of customer-oriented activities that are close to final demand (*e.g.* tourism, customer services, education, *etc.*). Conversely, a country presents a longer selling chain as the length becomes higher than unity. This country is positioned more upstream in the value chain, closer to its beginning, and thus far from final producers or final consumers. Countries entering this category generally specialize in activities such as innovation, research and development, design, production of raw materials, *etc*. Such activities are often pre-requisites before the conception and then the selling of a product to final consumers (OECD (2012)).

Chart 16 reports the length of the selling chain across countries[42]. On average, over the period 2000-2011, the selling chain length varies between 1.6 and 2.7 across countries. The longest selling chains are found for Singapore, China and Malaysia. Luxembourg comes fourth and features the third longest international selling chain, behind Singapore and China.

Chart 16: Length of the selling chain across countries



Source: Author's calculations based on OECD Inter-Country Input-Output (ICIO) tables, average 2000-2011, based on available data.

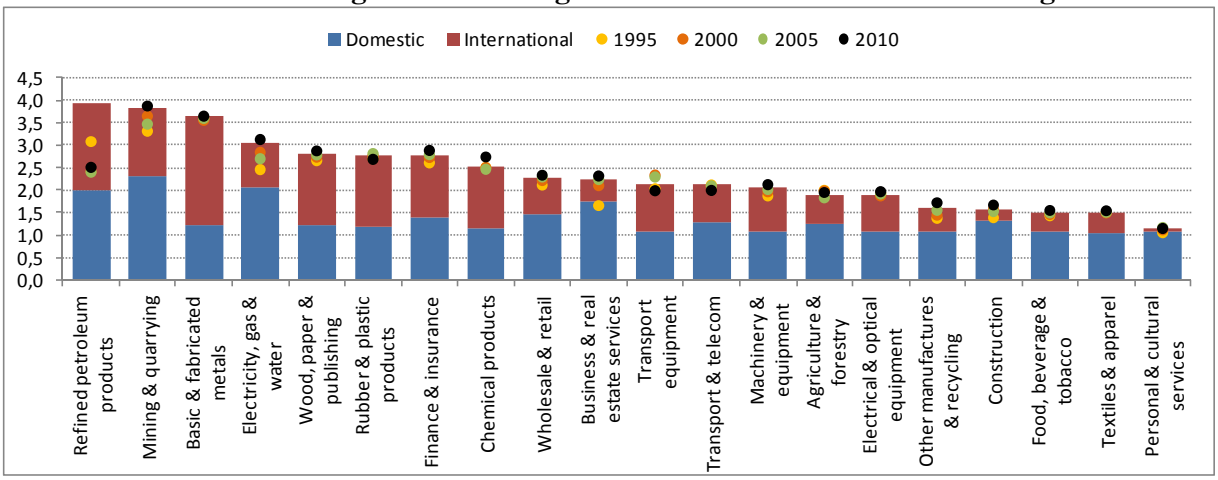
Over time and for the majority of countries (including Luxembourg), the selling chain length has increased. This suggests additional fragmentation in the global value chains and a

[42] The calculation of the selling chain length follows De Backer and Miroudot (2014) and is equivalent to total forward linkages (see Appendix C). Literally, the selling chain length informs about the level of influence by a given country/sector on the output of all countries/sectors through its sales or its output supplies (Marx *et al*. (2014)).

move for most countries towards upstream activities. De Backer and Miroudot (2014) found a similar result. They explain that the upstream move for most countries is consistent with the overall increase in the sourcing chain length (Chart 14) and the offshoring phenomenon (Chart 13). Indeed, when the production of some intermediate products is offshored, their value added is moved backward (or upstream) to the industries supplying intermediate products, leading to an increase in the length of the selling chain (Chart 16).

Chart 17 presents the sourcing chain length at the sector level in Luxembourg. The longest selling chains are found for the following industries: refined petroleum products; mining and quarrying products; basic and fabricated metals; utilities (electricity, gas and water); wood, paper and publishing; rubber and plastic products. The services industry (*e.g.* finance and insurance, business and real estate services, personal and cultural services) feature shorter selling chains - due to the nature of their customer-oriented activities - and are thus located relatively closer to final demand.

Chart 17: Length of the selling chain across sectors in Luxembourg



Source: Author's calculations based on OECD Inter-Country Input-Output (ICIO) tables, average 2000-2011, based on available data. NB: In Chart 17, the sector "Chemicals & non-metallic products" has been decomposed into "Chemical products", "Refined petroleum products" and "Rubber & plastic products".

Altogether, the long and internationally-oriented sourcing and selling chains point to an important degree of interconnections of Luxembourg with upstream and downstream countries in GVC. In other words, this suggests that Luxembourg acts an important chain-link in the global value network.

Merging GVC length with GVC participation: the GVC smile curve indicator

Merging the GVC length with the GVC participation informs about the evolution of Luxembourg's GVC participation along the GVC chain length. As we need more than one sector to be able to draw a curve and examine its shape, we consider the sector where Luxembourg holds a GVC-related revealed comparative advantage *i.e.* the finance and insurance industry (Table 1) along with the sectors that feature a GVC-related RCA (Table 1) or a domestic value added-based RCA (Table D, Appendix D) higher than one. The latter sectors pertain to business and real estate services, construction, transport and telecom, personal and cultural services. Following these lines, Chart 18 depicts the figures for Luxembourg by considering the aforementioned five sectors. The upper (lower) charts show the GVC participation (forward GVC participation). The left-hand (right-hand) charts present the sourcing chain length (selling chain length).

A few observations are worth noting. First, the relationship between GVC participation and GVC length is a U-shaped curve, resembling a smile. This confirms the results found in the literature advocating that most of the value added is created at the extreme sides of the global value chains *i.e.* whether in upstream activities or in downstream activities while typically only limited value added is created in activities located in the middle of the value chain, pertaining to pure manufacturing and assembly stages (WTO (2014), OECD (2012, 2016a), Ye *et al*. (2015), Degain *et al*. (2017)). Second, the sectors hold different positions along the smile curve. Third, the evolution of this position differs over time and across sectors.

Across the considered sectors, one sector is located at the right-hand extremity of the GVC smile curve: the finance and insurance industry. The other considered sectors are located at the bottom of the GVC smile curve. The finance and insurance industry is hence the sector where most of the value added is captured from Luxembourg's GVC participation over the considered period. In turn, this contributes to explain why this specific sector acts as an important catalyst of economic activity and employment in Luxembourg. As a matter of fact, the contribution of the finance and insurance sector to the value added created in Luxembourg in 2016 amounts to

almost 30%[43]. In addition, employment in the finance and insurance industry along with business and real estate services accounts for almost 30% of total employment in Luxembourg in 2017Q2[44]. Over time, the finance and insurance industry has moved to the right of the *x*-axis. This suggests that the sourcing chain length (Charts 18.1 and 18.3) and the selling chain length (Charts 18.2 and 18.4) have increased.

[43] Source: STATEC, http://www.statistiques.public.lu/en/index.html: Home\Economy and finance\National accounts\Annual accounts - Aggregates by branch\Production by activity (NaceR2)(at current prices) (in millions EUR) 1995 – 2016.

[44] Source: STATEC, http://www.statistiques.public.lu/en/index.html: Home\Economy and finance\National accounts\Quarterly accounts - Aggregates by branch\Total employment by activity (NaceR2) (in 1 000 persons) 1995 - 2017.

Chart 18: Merging GVC participation and GVC chain length: the GVC smile curves in Luxembourg

Caption for time: Average 2000-2011 · 1995 · 2000 · 2005 · 2010 · Smile curve 1995 · Smile curve 2000 · Smile curve 2005 · Smile curve 2010

Caption for sectors: business & real estate services: *diamond* ; construction: *cross*; finance & insurance: *triangle*; transport & telecom: *square*; personal & cultural services: *circle*

Chart 18.1: GVC participation & sourcing chain length

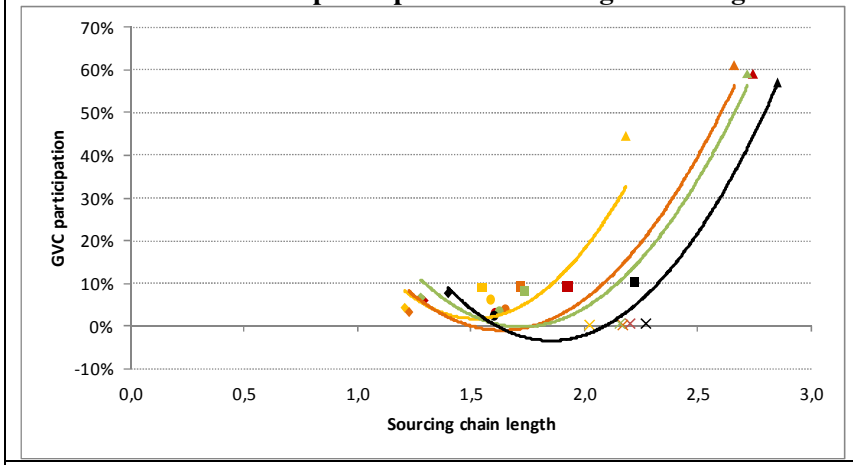


Chart 18.2: GVC participation & selling chain length

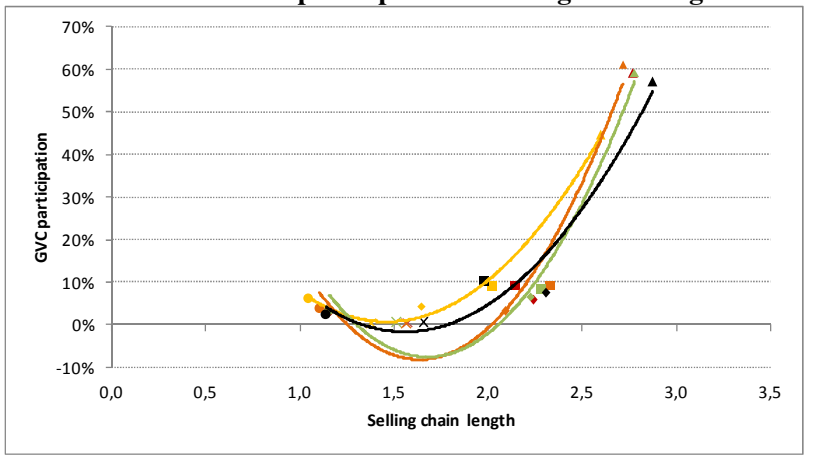


Chart 18.3: Forward GVC participation & sourcing chain length

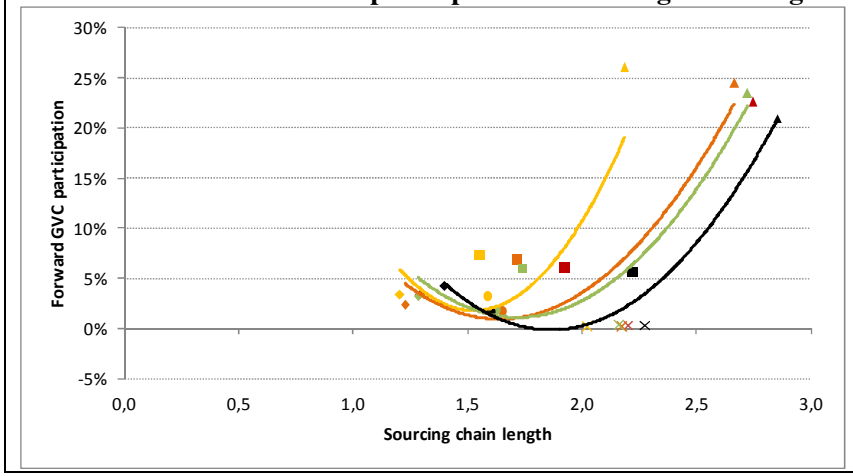
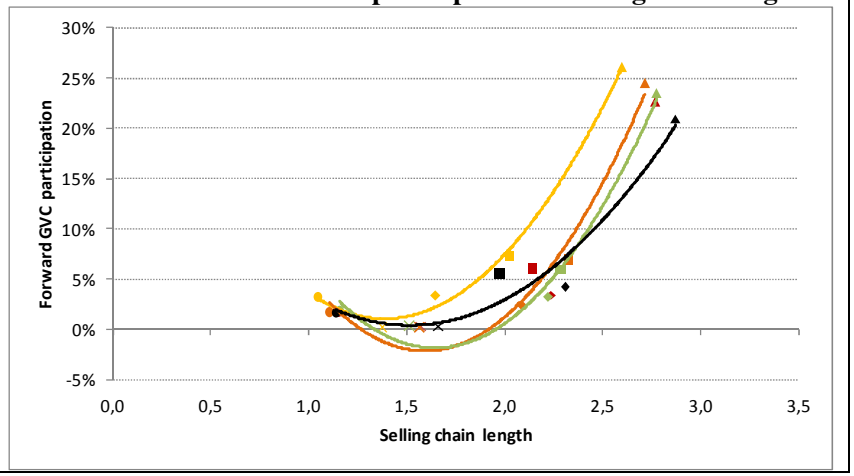


Chart 18.4: Forward GVC participation & selling chain length



Source: Author's calculations based on OECD Inter-Country Input-Output (ICIO) tables, based on available data. The smile curve is drawn based on a polynomial trend line of order 2. NB: The smile curves should in principle always be located in the positive areas of the charts. Note that it is sometimes not the case in the charts, due to the approximation of the smile curve with a polynomial trend of order 2.

5. Global value chains: the final consumers' side

5.1 Who are the ultimate consumers of Luxembourg's value added?

The previous section focused on the direct links between a country and its value added trade partners within GVC. Trade in value added statistics provide also an understanding of the final consumers of a country's value added. Final consumers gather economic agents that absorb final value added – or final products – at the end of the value chain, as consumption (*e.g.* households, non-profit institutions serving households and government) or as investments.

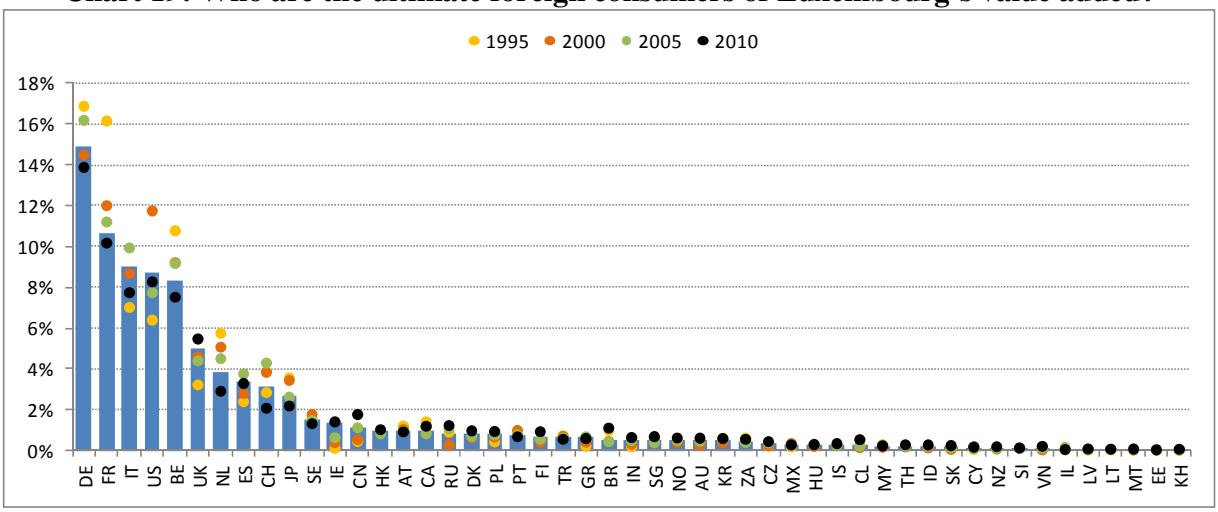
Chart 19 presents the ultimate foreign consumers of Luxembourg's value added. It computes the share of domestic value added produced in Luxembourg and embodied in a foreign country's final demand divided by the total domestic value added embodied in foreign final demand by Luxembourg. The domestic value added embodied in foreign final demand captures the value added that domestic industries export both directly through exports of final goods or services, and indirectly *via* exports of intermediate products that reach foreign final consumers. In Chart 19, figures are averaged over the period 2000-2011. The chart also presents the evolution of the latter share for the years 1995, 2000, 2005 and 2010 (given available data).

From a geographical perspective, the main ultimate consumers of Luxembourg's value added are located in Germany (14.92%), France (10.63%), Italy (9.02%), the United States (8.69%), Belgium (8.33%), the United Kingdom (4.98%) and the Netherlands (3.86%). Between 1995 and 2011, the geographical partition has evolved. The average share of advanced economies lost ground while the share of East Asian and Eastern European emerging economies gained some importance in relative terms[45]. A similar observation prevails at the sector level and notably in the finance and insurance industry. For the latter sector, although advanced economies remain the main ultimate consumers of Luxembourg's value added[46], their share declined in relative terms compared to EMEs[47].

[45] For instance, over the period 2000-2011, the average share declined for France (-3.06%), the Netherlands (-2.95%), Belgium (-2.23%), Japan (-2.04%), Germany (-0.96%) and Switzerland (-0.57%). On the other hand, the share increased for Italy (0.74%), the United States (1.63%) and the United Kingdom (3.65%) but the increase remains relatively weak compared to the increase of East Asian and Eastern European emerging economies (*e.g.* Estonia (18.68%), Slovakia (17.73%), Lithuania (17.62%), India (12.62%), China (10.24%) and Russia (8.58%)).

[46] By order of importance and on average, over the period 2000-2011, the main ultimate consumers of Luxembourg's value added in the finance and insurance sector (as a percentage of Luxembourg's total domestic value added embodied in foreign final demand in this sector) are Germany (13.81%), Italy (13.02%), the United

Chart 19: Who are the ultimate foreign consumers of Luxembourg's value added?



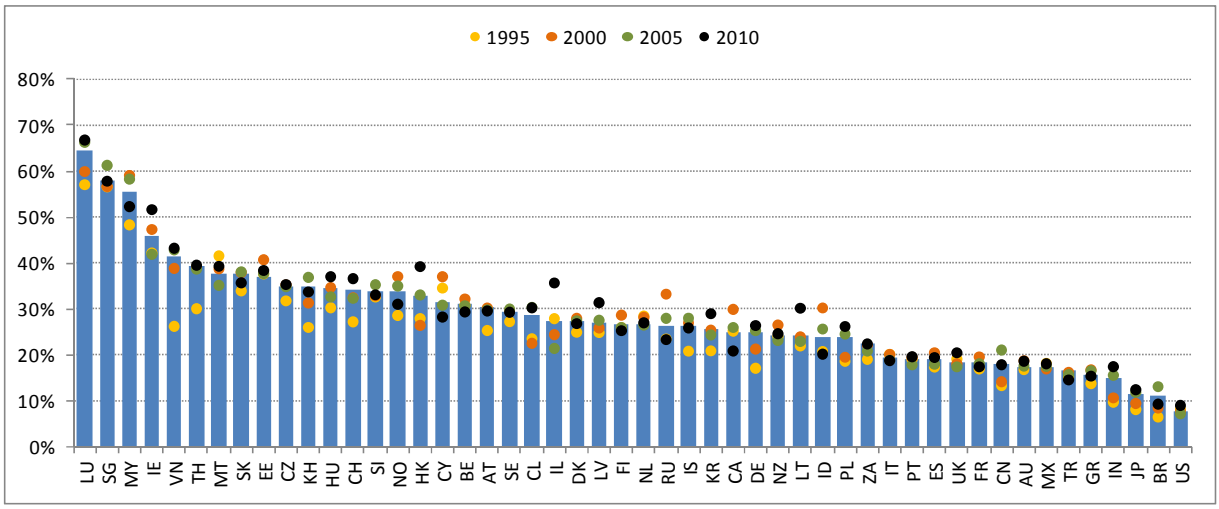
Source: OECD-TiVA database (December 2016), average 2000-2011, based on available data. Ratio: Share of domestic value added embodied in foreign final demand-to-total domestic value added embodied in foreign final demand.

When reported to GDP, the domestic value added embodied in foreign final demand informs about the contribution of external final demand to domestic GDP. On average, over the period 2000-2011, foreign final demand contributed to 64.52% of Luxembourg's GDP (Chart 20). This means that over this period, 64.52% of Luxembourg GDP depends on foreign demand while 35.48% relies on domestic demand. Across the considered countries, Luxembourg features the most important contribution of foreign final demand to GDP; a contribution that increases all over the period 1995-2011 (Chart 20).

States (9.06%), France (7.95%), Japan (4.23%), Spain (4.03%), the United Kingdom (3.13%) and Belgium (2.98%). See Chart E.1 in Appendix E.

[47] For example, over the period 2000-2011, the average share declined for the Netherlands (-11.37%), Japan (-2.13%) and Belgium (-0.86%). On the other hand, the share increased for Germany (1.75%), Italy (1.80%), the United States (2.59%), France (2.67%) and the United Kingdom (11.36%) but the increase remains relatively weak compared to East Asian and Eastern European emerging economies (*e.g.* Slovenia (28.36%), Vietnam (27.13%), Russia (23.19%), India (17.22%) and China (11.68%)). See Chart E.1 in Appendix E.

Chart 20: Contribution of external final demand to GDP across countries

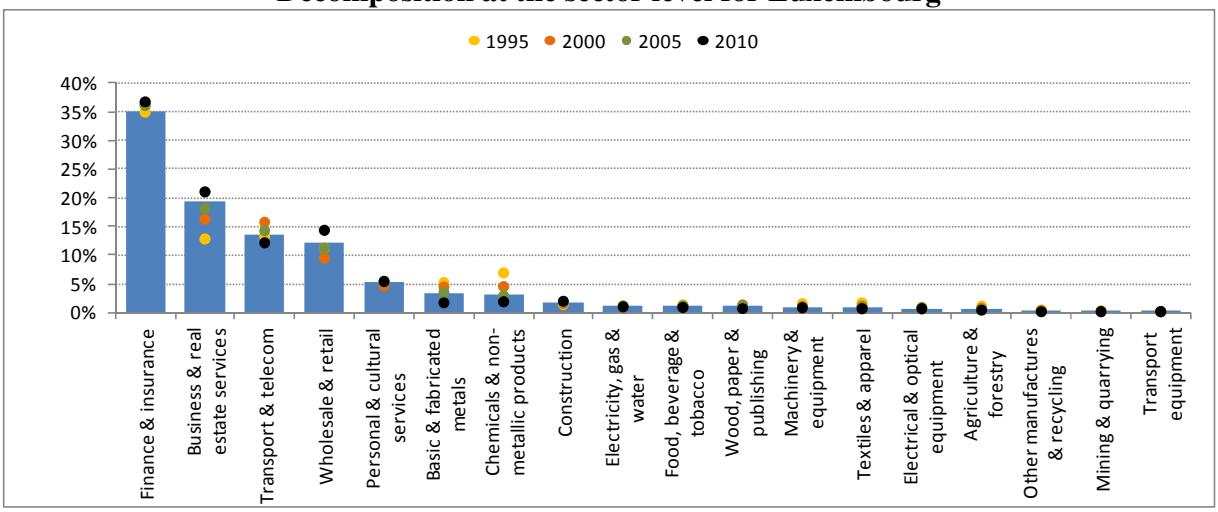


Source: OECD-TiVA database (December 2016), average 2000-2011, based on available data for domestic value added embodied in foreign final demand; IMF for GDP. Ratio: Share of domestic value added embodied in foreign final demand-to-GDP.

At the sector level (Chart 21), the foreign sector that accounts the most for Luxembourg GDP is the finance and insurance industry (representing 34.91% of total domestic value added produced in Luxembourg and embodied in foreign final demand) followed by business and real estate services (19.30%)[48], the transport and telecom industry (13.63%)[49] and the wholesale and retail industry (12.06%)[50].

[48] Business services cover real estate activities, renting of machinery and equipment, computer and related activities, research and development and other business activities (source: https://stats.oecd.org/). See Appendix F.
[49] The transport and telecom industry includes transport and storage, post and telecommunications (source: https://stats.oecd.org/). See Appendix F.
[50] The wholesale and retail industry regroups wholesale and retail trade, repairs, hotels and restaurants (source: https://stats.oecd.org/). See Appendix F.

Chart 21: Who are the ultimate foreign consumers of Luxembourg's value added? Decomposition at the sector level for Luxembourg



Source: OECD-TiVA database (December 2016), average 2000-2011, based on available data. Ratio: Share of domestic value added embodied in foreign final demand by sector-to-total domestic value added embodied in foreign final demand.

5.2 Where does foreign value added embodied in Luxembourg's final demand come from?

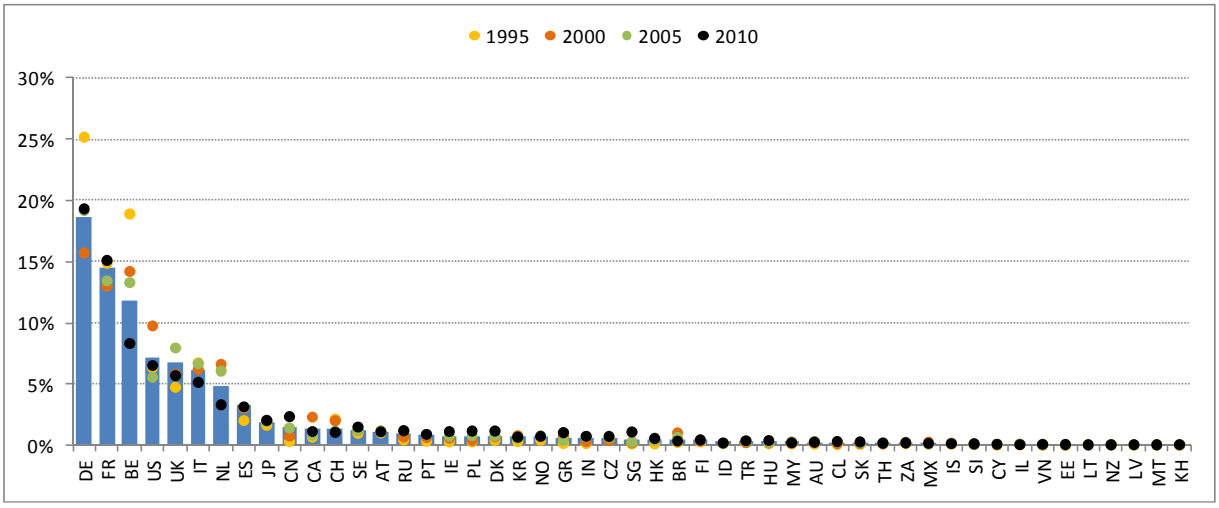
While the domestic value added embodied in foreign final demand looks at the sales side, on the buying side a mirroring measure is provided by the foreign value added embodied in domestic final demand. The latter reveals the amount of foreign value added present in final products purchased by households, non-profit institutions serving households, government or as investments in Luxembourg. This measure shows how industries abroad are connected to final domestic consumers.

Chart 22 presents the main providers of foreign value added embodied in Luxembourg's final demand. It computes the share of foreign value added produced abroad by a foreign country and embodied in Luxembourg's final demand divided by the total foreign value added produced abroad and embodied in Luxembourg's final demand. Figures are averaged over the period 2000-2011. The chart also presents the evolution of the latter share for the years 1995, 2000, 2005 and 2010 (given available data).

From a geographical perspective, the most important providers of foreign value added to Luxembourg's final demand are Germany (18.64%), France (14.45%), Belgium (11.87%), the

United States (7.16%), the United Kingdom (6.78%), Italy (6.11%) and the Netherlands (4.79%). Between 1995 and 2011, the geographical breakdown has changed. The share of advanced economies lost ground to the benefit of East Asian and Eastern European emerging economies[51]. A similar observation prevails at the sector level and notably for the finance and insurance industry. For the latter sector, although advanced economies remain the main ultimate providers of foreign value added to Luxembourg's final demand[52], their share declined in relative terms compared to EMEs[53].

Chart 22: Who are the main providers of foreign value added embodied in Luxembourg's final demand?



Source: OECD-TiVA database (December 2016), average 2000-2011, based on available data. Ratio: Share of foreign value added embodied in domestic final demand-to-total foreign value added embodied in domestic final demand.

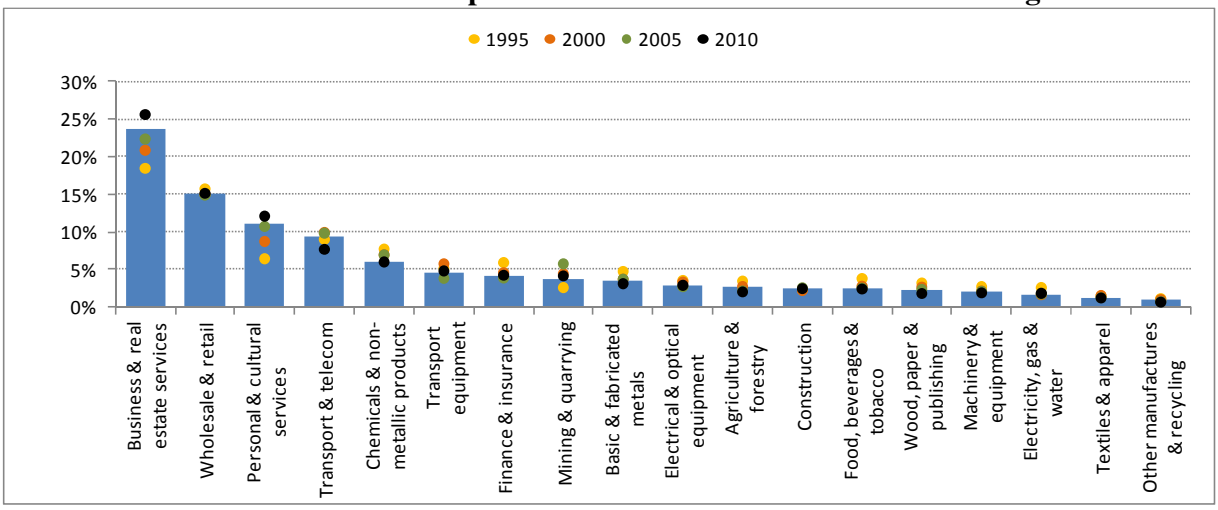
[51] For instance, over the period 2000-2011, the average share declined for Belgium (-5.49%), the Netherlands (-3.41%), Switzerland (-1.40%) and Germany (-1.03%). On the other hand, the share increased for France (0.10%), the United Kingdom (1.44%), Japan (1.86%) and the United States (4.70%) but the increase remains relatively weak compared to East Asian and Eastern European emerging economies (*e.g.* Slovakia (31.69%), Brazil (31.28%), Estonia (29.21%), Latvia (21.35%), Lithuania (21.29%), China (15.32%), India (15.05%), Poland (12.04%) and Russia (10.95%)).

[52] By order of importance and on average, over the period 2000-2011, the main providers of foreign value added to Luxembourg's final demand in the finance and insurance sector (as a percentage of total foreign value added embodied in Luxembourg's final demand in this sector) are France (13.44%), the United States (12.44%), Germany (12.33%), Belgium (11.46%), Switzerland (7.21%), the United Kingdom (6.41%), Italy (5.88%) and the Netherlands (4.94%). See Chart E.2 in Appendix E.

[53] For example, over the period 2000-2011, the average share declined for Belgium (-5.14%), Switzerland (-2.62%), Italy (-1.76%), Germany (-1.54%). On the other hand, the share increased for France (1.15%), Japan (2.33%), the United States (3.72%) and the United Kingdom (4.23%) but the increase remains relatively weak compared to East Asian and Eastern European emerging economies (*e.g.* Russia (24.85%), Estonia (24.51%), China (19.92%), India (17.06%) and Poland (15.89%)). See Chart E.2 in Appendix E.

At the sector level (Chart 23), the main industries providing foreign value added embodied in Luxembourg's final demand are by order of importance, business and real estate services (representing 23.57% of total foreign value added embodied in domestic final demand), wholesale and retail (15.08%), personal and cultural services (11.06%), transport and telecom (9.42%), chemicals and non-metallic products (6.05%), transport equipment (4.53%) and finance and insurance (4.06%). It is not surprising to find the finance and insurance sector far from the first positions given that Luxembourg already gathers a large number of finance and insurance intermediaries able to satisfy foreign needs but also domestic ones.

Chart 23: Who are the main providers of foreign value added embodied in Luxembourg's final demand? Decomposition at the sector level for Luxembourg



Source: OECD-TiVA database (December 2016), average 2000-2011, based on available data. Ratio: Share of foreign value added embodied in domestic final demand by sector-to-total foreign value added embodied in domestic final demand.

6. Conclusion

The paper analyses the place held by Luxembourg - a small open economy - in the global value network *vis-à-vis* other advanced and emerging market economies. The paper relies on trade in value added statistics retrieved from OECD inter-country input-output tables, available over the period 1995-2011. The analysis is multifaceted as implemented within a sample of 50 advanced and emerging market economies, at the country level, at the sector level and over time.

The paper highlights the following results. Across OECD countries, Luxembourg features the highest dependence to trade. Foreign trade contributes strongly to economic activity and domestic employment. Trade in intermediate products represents the majority of foreign trade in Luxembourg. In this regard, the country appears to be deeply integrated in GVC as it features the highest GVC participation across the considered countries. Luxembourg's GVC participation is characterized by a strong backward participation and a relatively low forward participation. This means that Luxembourg trades a larger amount of intermediate products imported from abroad while it exports a lower amount of domestically produced intermediate products. In other words, Luxembourg is primarily a buyer of foreign value added and less a seller of domestic value added. This is generally the case of small open economies. The latter usually source more intermediate products from abroad in GVC than larger economies where, given their size, a longer part of the value chain is domestic and hence a higher share of intermediate products is produced domestically. Moreover, Luxembourg's GVC participation is characterized by an involvement in long, increasing and internationally-oriented production chains, whether on the sourcing side or on the selling side. The country thus features strong upstream and downstream interconnections in GVC with other partner countries. This suggests that Luxembourg acts as an important chain-link in the global value network.

The major part of Luxembourg's GVC trading partners is located in Western Europe (by order of importance, Germany, Belgium, Switzerland, France, the United Kingdom and Italy) implying that the supply chain network is not global for Luxembourg but rather regional. Notwithstanding this, the share of East Asian and Eastern European emerging countries - albeit relatively low compared to advanced economies - is increasing over the period of analysis.

At the sector level, Luxembourg's GVC participation is concentrated in the finance and insurance industry. It is from this specific sector that the country retrieves the most important share of value added from GVC. This is notably evidenced by the position of this sector at the extremity of the GVC smile curve. The latter observation concurs with the fact that Luxembourg is able to capture large benefits from GVC participation in the finance and insurance industry in terms of inward FDI, employment and economic activity.

In addition, the analysis shows that across the considered countries, Luxembourg possesses a revealed comparative advantage in GVC in the finance and insurance industry. This comparative advantage is maintained over time in the sample of countries.

Eventually, the main ultimate foreign consumers of Luxembourg's value added are located in Western Europe. Outside Europe, the United States are an important final customer. Notwithstanding this, the share of East Asian and Eastern European emerging countries, albeit relatively low compared to advanced economies, is increasing over the period of analysis. At the sector level, Luxembourg's ultimate consumers are primarily located in the finance and insurance industry, followed by business and real estate services and the transport and telecom industry. On the other side of the chain, the providers of foreign value added to Luxembourg's final demand share similar geographical characteristics. However, at the sector level, the main providers of foreign value added to Luxembourg's final demand originate primarily from business and real estate services and less from the finance and insurance sector. This suggests that the Luxembourg's finance and insurance industry is able to satisfy domestic needs, in addition to foreign ones.

Moving forward, as soon as the OECD releases their inter-country input-output tables after 2011, the analysis will be updated. Moreover, to improve the understanding of Luxembourg's position in GVC, future work could resort to network analysis (Cerina *et al*. (2015), Zhu *et al*. (2015), Amador and Cabral (2016), Xiao *et al*. (2017)). The latter tool contributes to reveal interesting stylized facts on the value added network structure that are useful to guide both research and policy analysis (Gereffi *et al*. (2005), Santoni and Taglioni (2015)). In particular, by characterizing the place held by a given country within GVC, the network analysis allows understanding how shocks transmit within the global value network (Frohm and Gunnella (2017)). Furthermore, while the paper provides a better understanding of

the place held by Luxembourg in the global value network, it does not investigate thoroughly the underlying factors that determine such a place but only hints at them (*e.g.* distance to trade partners, country's size, natural resource endowments, tax benefits, skilled workforce, quality of infrastructure, political stability and better living standards). Testing which factors contribute to explain the involvement of Luxembourg in GVC together with its evolution over time could constitute a potential sequel of this paper. Finally, an important question revolves around the implications for Luxembourg regarding its deep integration in GVC. Here again, the paper makes allusion to several potential consequences (*i.e.* strong dependence on foreign demand, strong exposure to GVC disruption) but a refined analysis is required to address properly the exposure to shock propagation *via* GVC or the implications of strong GVC participation in terms of current account imbalances (Haltmaier (2015), Nagengast and Stehrer (2015), ECB (2017)). An in-depth analysis is a pre-requisite to answer these questions and could again constitute a potential sequel of this paper.

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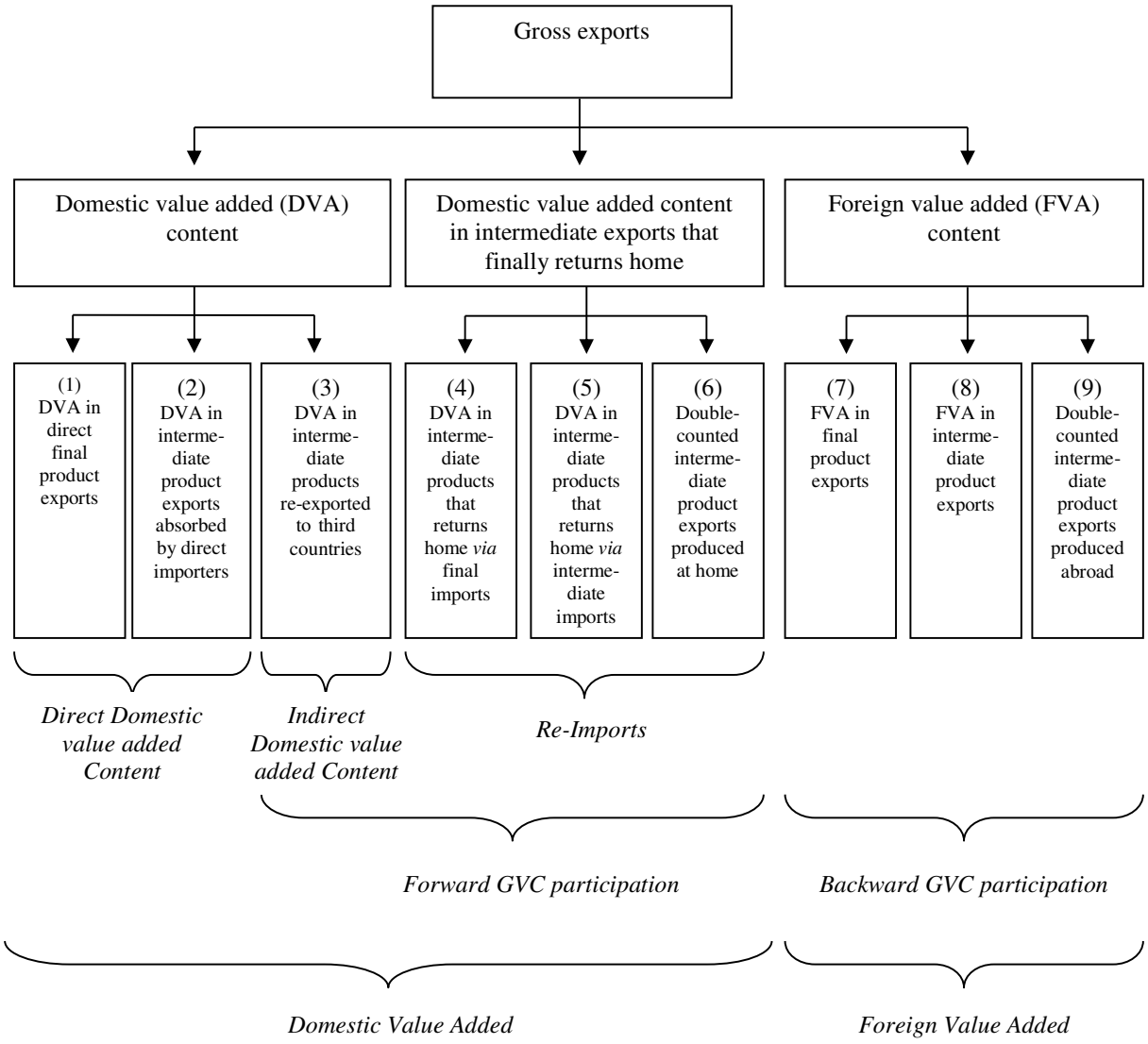
Appendix

A. Decomposition of gross exports

Koopman *et al*. (2014) put forward a decomposition of gross exports into nine components (Chart A.1). This decomposition encompasses previous attempts proposed in the literature, notably Hummels *et al*. (2001) and Johnson and Noguera (2012a,b).

Chart A.1: Decomposition of gross exports by Koopman *et al*. (2014)



Source: adapted from Koopman *et al*. (2014)

(1) Domestic value added in direct final product exports include final goods and services entirely produced in the domestic country without the requirement of any intermediate products imported from abroad and that are exported and entirely consumed in a foreign country.

(2) Domestic value added in intermediate product exports absorbed by direct importers cover intermediate goods and services entirely produced in the domestic country without the requirement of any intermediate imports. These intermediate products are exported to a foreign country and are used by the direct (or initial) importer to produce final goods and services to be subsequently consumed in this foreign country.

The sum (1) + (2) is labeled absorption or domestic value added sent to consumer economy. It corresponds to the domestic value added embodied either in final or intermediate goods or services that is directly consumed by the importing (*i.e.* foreign) economy. The terms (1) + (2) represent also the direct domestic value added content of gross exports (*DDC* or *EXGR_DDC*). According to Rahman and Zhao (2013), the sum (1) + (2) tells us "*how much of a country's exports is created as stand-alone exports, i.e. outside any supply chain*".

(3) Domestic value added in intermediate products re-exported to third countries include intermediate goods and services that the direct (or initial) importer embodies into other goods and services (final or intermediate), which are then exported to third countries. According to Cappariello and Felettigh (2014, 2015), this component is labeled redirection to indicate domestic value added that is absorbed abroad by countries other than the direct (or initial) importer. This corresponds to the indirect domestic value added content of gross exports (*IDC* or *EXGR_IDC*).

The sum (1) + (2) + (3) corresponds to the direct and indirect domestic value added content of gross exports. When dividing the sum (1) + (2) + (3) by gross exports, one gets the *VAX* ratio by Johnson and Noguera (2012a,b). The sum (1) + (2) + (3) is also labeled *FFD_DVA* in the OECD-TiVA database (Aslam *et al*. (2017)).

(4) Domestic value added in intermediate products that returns home *via* final imports include intermediate goods and services produced in the domestic country exported abroad for further processing and then embodied in imports of final goods and services by the domestic country where they are ultimately absorbed.

(5) Domestic value added in intermediate products that returns home *via* intermediate imports include intermediate goods and services produced in the domestic country exported abroad for further processing and then embodied in imports of intermediate goods and services by the domestic country where they are used to produce final goods and services for domestic consumption.

(6) Double-counted intermediate product exports produced at home include intermediate goods and services produced by the domestic economy exported in the foreign economy and exported by the foreign economy to a third economy that eventually returns in the domestic country.

The sum (4) + (5) + (6) is labeled reflection, to indicate domestic value added that is exported and ultimately absorbed at home. Another label would be "export content of imports". This component measures the contribution of a country's internal demand to the activation of its own exports. It corresponds also to the re-imported domestic value added content of gross exports (*RIM* or *EXGR_RIM*). It is also labeled *VS1** in Daudin *et al*. (2011) or *RDV* in Wang *et al*. (2017). The latter term stands for Returned Domestic Value, or the portion of domestic value added that is initially exported and returned home, embedded in imports.

The sum (1) + (2) + (3) + (4) + (5) + (6) represents the domestic value added content of gross exports. This sum is labeled *DVA* or *EXGR_DVA*. Within this sum, traded products regroup final products traded outside GVC since directly consumed in the foreign country (components (1) + (2)) as well as intermediate products traded within GVC (components (3) + (4) + (5) + (6)). Thus, the domestic value added content of gross exports includes the value added generated by the exporting domestic country during its production process as well as any value added coming from upstream domestic suppliers that is embodied in exports. In this

regard, the domestic value added content of gross exports is the part of gross exports created in-country, *i.e.* the share of gross exports that contributes to GDP.

Hummels *et al.* (2001) call the sum (3) + (4) + (5) + (6) "*the value of exports that are embodied in a second country's export products*" and label it as *VS1*. Other authors (Koopman *et al*. (2014), Aslam *et al*. (2017)) designate the latter sum as the "*domestic value added in intermediate products further re-exported by the partner country*" or the "*indirect value added exports via third countries*" and label it as *DVX*. The latter sum corresponds to the forward GVC participation and represents the multiple value added exchanges of intermediate products taking place within the global value network. The forward GVC participation captures the domestic value added contained in intermediate products processed in domestic production chains and sent to third economies for further processing *via* the global value chains. The forward GVC participation represents the sellers' perspective or supply (or selling) side of value added trade flows.

Aslam *et al*. (2017) note that the *VAX* ((1) + (2) + (3)) is considered as a better measure of the domestic value added content of gross exports than the *DVA* ((1) + (2) + (3) + (4) + (5) + (6)). Indeed, the *DVA* accounts for the domestic content in intermediate exports that finally returns home *via* the terms (4) + (5) + (6). The latter terms include a double-counting item (term (6)), as well as intermediate products that return to the origin country *via* imports (terms (4) + (5)).

(7) Foreign value added in final product exports gather final goods and services produced in the domestic country with the requirement of intermediate products imported from abroad and that are exported to a foreign country where they are entirely consumed.

(8) Foreign value added in intermediate product exports include intermediate products produced in the domestic country with the requirement of intermediate products imported from abroad and that are then exported to a foreign country where they are used to produce final goods and services for consumption in this foreign country.

(9) Double-counted intermediate product exports produced abroad include intermediate goods and services produced by the foreign economy exported in the domestic economy and then exported by the domestic economy to a third economy.

The sum (7) + (8) + (9) represents the foreign value added content of gross exports. This sum is labeled *FVA* or *EXGR_FVA* or *VS* (Koopman *et al*. (2014)) in the literature. The foreign value added content of gross exports is also referred to as vertical specialization. It corresponds to the value added of intermediate products that were produced in other countries and imported in order to produce intermediate or final products to be exported. As such, the foreign value added content of gross exports is the share of a country's gross exports that is not adding to its GDP. The foreign value added content of gross exports represents the backward GVC participation. The latter corresponds to the buyers' perspective or demand (or sourcing) side of value added trade flows.

The sum of the backward and forward GVC participations defines the GVC participation index (Koopman *et al*. (2014)). Basically, this index suggests that individual economies participate in global value chains by importing foreign intermediate products to produce the goods and services they export (backward GVC participation) and also by exporting domestically processed intermediate products to partners in charge of downstream production stages (forward GVC participation). Chart A.2 below illustrates the value added components of gross exports in GVC trade flows. Altogether, the sum (3) + (4) + (5) + (6) + (7) + (8) + (9) measures exports generated by the participation of a country in GVC.

Note that the literature often decomposes gross exports between domestic value added without multiple-counting ((1) + (2)), foreign value added without multiple-counting and a pure multiple-counting term. Indeed, as components (3) through (9) involve trade in intermediate products within GVC, implying that products cross national borders at least twice before reaching final consumers, they are thus the source of multiple-counting in standard gross trade statistics. In other terms, indirect domestic value added exports, re-imports and foreign value added exports which involve intermediate trade flows within GVC embed a double or multiple-counting term in standard gross trade statistics. As a result, gross exports can also be

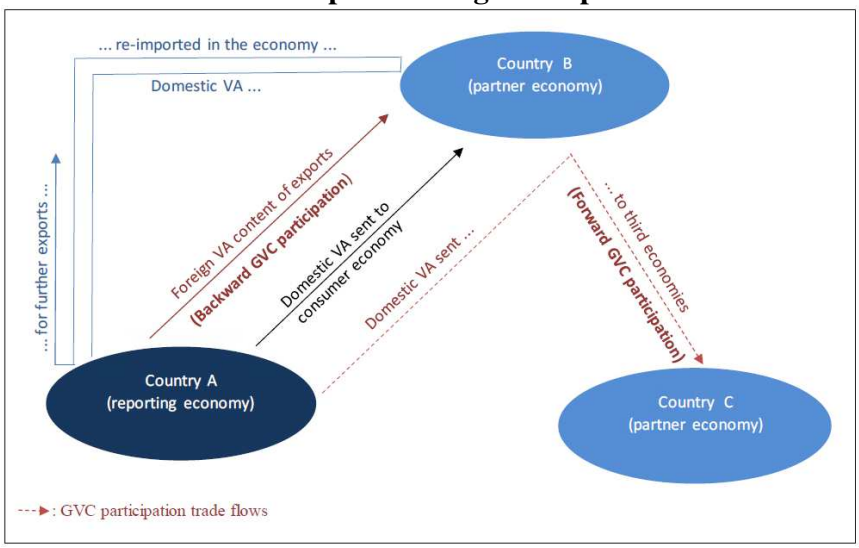
decomposed as domestic value added without multiple-counting, foreign value added without multiple-counting and a pure multiple-counting term. Hence:

Gross exports	=	*Domestic value added content without multiple-counting*	+	*Foreign value added content without multiple-counting*	+	*Pure multiple-counting term*

According to Cappariello and Felettigh (2014, 2015), the literature (Koopman *et al*. (2012) and Rahman and Zhao (2013)) entertains the notion that countries featuring a large share of forward GVC participation in gross exports tend to be specialized in upstream activities. Conversely, countries with a large share of backward GVC participation in gross exports tend to be specialized in downstream activities.

Cappariello and Felettigh (2014, 2015) add that the Koopman *et al*. (2014) decomposition focuses on GDP and hence does not consider the case of a firm offshoring its entire production (and sales). In the latter case, no exports are recorded by the home economy and even profit repatriation would not contribute to its GDP (though it would contribute to GNP through the income account, in the balance of payments).

Chart A.2: Value added components of gross exports in GVC trade flows

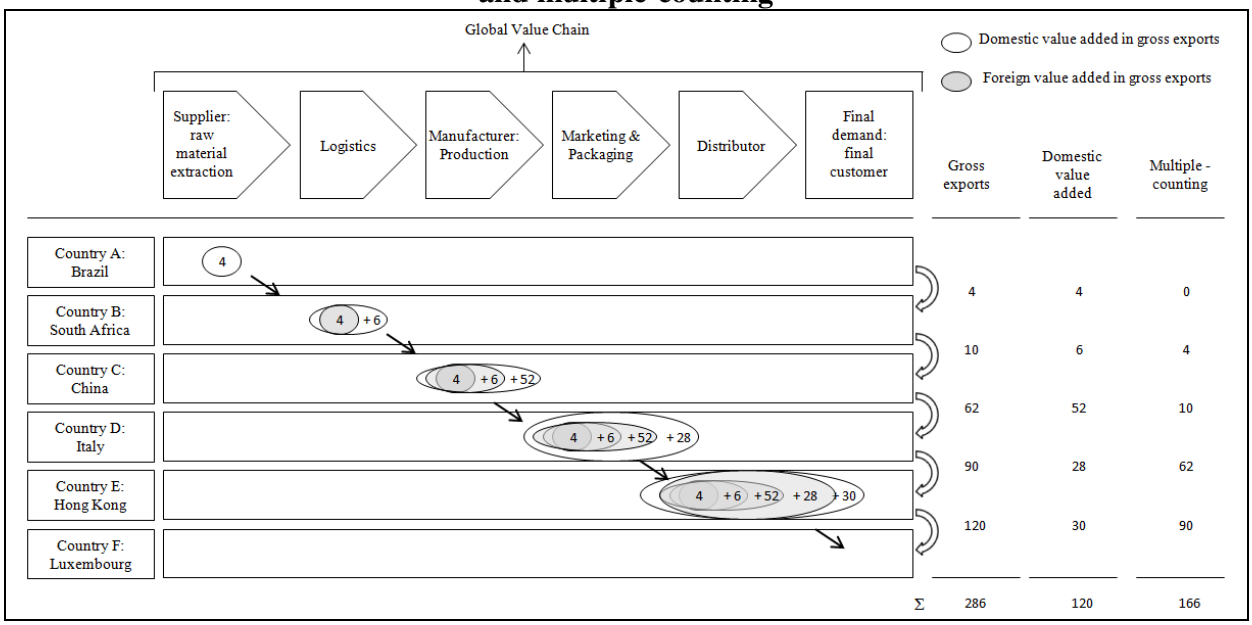


Source: OECD-WTO (2016), https://www.wto.org/english/res_e/statis_e/miwi_e/Explanatory_Notes_e.pdf

B. The measurement issue of double or multiple-counting in gross trade figures

To understand the issue of double or multiple-counting in gross trade figures, consider the hypothetical example of the production of a device (*e.g.* an electronic device) imported and finally consumed in Luxembourg.

Chart B.1: Hypothetical example of a GVC to understand gross trade, trade in value added and multiple-counting



Based on the example provided in Chart B.1, Hong Kong exports a device to Luxembourg. From the Luxembourg's perspective, the device is recorded by national authorities in the Luxembourg's trade account as an import from Hong Kong (and will probably require a tag "Made in Hong Kong"). However, some of the intermediate products used for the production of the device might have been produced in and imported from different countries, for example Italy, China, South Africa or Brazil (Chart B.1). The value of these intermediate products has been recorded as Hong Kong imports from Italy, China, South Africa and Brazil but not linked with the exportable final product. As a consequence, the country of the final producer (Hong Kong in Chart B.1) appears as capturing most of the value of products traded, while the role of countries providing intermediate products upstream (Italy, China, South Africa and Brazil) can be overlooked.

At present, official trade statistics (*i.e.* gross trade statistics) do not differentiate whether the intermediate products in the production of the device were produced in Hong Kong or not; thus possibly inflating the role of exports for Hong Kong. Furthermore, this official recording of trade creates double, triple or multiple-counting in international trade. Indeed, the total value of the device was counted as a final export of Hong Kong, but so were the intermediate products exported from the other countries (Italy, China, South Africa and Brazil), which also had imported intermediate products which in turn were recorded as exports by countries where those originated (this is the case of Italy, China and South Africa). Hence, the total gross exports are overestimated at the global level and measures of ratios of gross exports-to-GDP can be misleading. At the extreme, in economies where re-exports are significant (*e.g.* Singapore, Hong Kong), gross exports could exceed the total value of GDP (see Chart 1 in the core text). The trade in value added approach avoids this multiple-counting issue by accounting for the net trade flow of value added between countries. The trade in value added approach allows to differentiate between the domestic value added in gross exports and the foreign value added in gross exports; the latter being a source of multiple-counting in gross exports (166 in Chart B.1). Chart B.1 clearly shows that gross trade statistics overestimate total exports (286 in Chart B.1) compared to trade in value added statistics (120 in Chart B.1).

Empirically, differences between exported domestic value added and gross exports can become somewhat important depending on the country (see Charts B.2 and B.3 below). UNCTAD (2013) estimates that in 2010, five trillion USD of trade flows was multiple-counted; representing more than 25% of global gross exports. Regarding the case of Luxembourg more specifically, the ratio of gross exports-to-GDP is larger than the ratio of exported domestic value added-to-GDP, whether at the country level (Chart B.2) or when considering the finance and insurance industry (Chart B.3). This largely reflects the large amounts of foreign intermediate products included in Luxembourg's gross exports.

Chart B.2: Gross trade figures *versus* value added trade figures (all sectors considered)

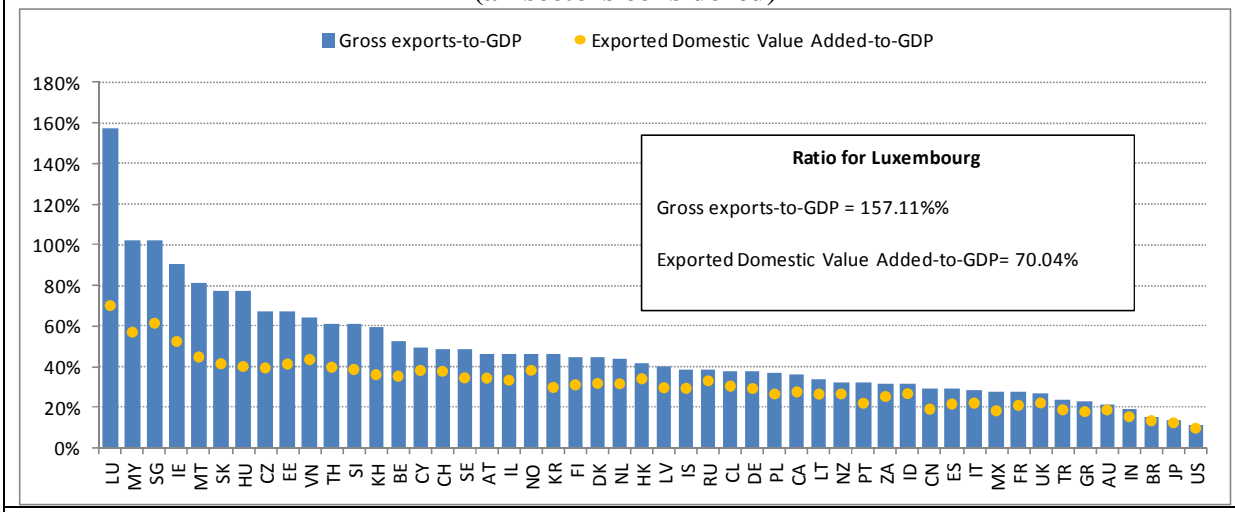
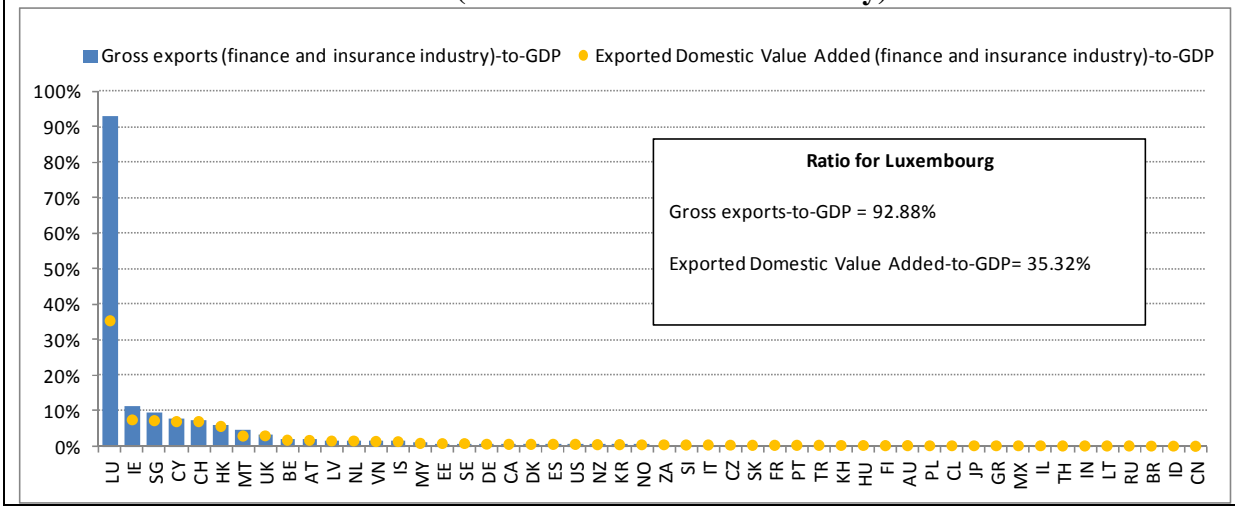


Chart B.3: Gross trade figures *versus* value added trade figures (finance and insurance industry)



Source: OECD-TiVA database (December 2016), average 2000-2011, based on available data.

C. Measuring trade in value added from inter-country input-output tables

This appendix clarifies *via* a step-by-step approach how trade in value added metrics are derived from inter-country input-output tables[54].

The appendix starts by presenting an input-output table for a single country with two industries (Table C.1). When reading across rows, Industry 1 delivers 100 to itself, 600 to Industry 2 and 800 to final demand. Similarly, Industry 2 delivers 400 to Industry 1, 200 to itself and 1000 to final demand. In this example, final demand comprises only household consumption. In other databases, final demand can be decomposed as household and non-profit institutions serving households final consumption, government final consumption, gross fixed capital formation, changes in inventories and acquisitions less disposals of valuables (Aslam *et al*. (2017)). When reading down columns, Industry 1 uses 100 from itself, 400 from Industry 2 and 1000 from primary factors (*i.e.* labor, land and capital). Industry 2 uses 600 from Industry 1, 200 from itself and 800 from primary factors. Gross domestic product (GDP) is equal to the sum of value added (line "*Value added*": 1000+800=1800) and also to the sum of final sales (column "*Final demand*": 800+1000=1800). Gross output measures total economic activity in the production of new goods and services. It is a much broader measure of economic activity than GDP and is equal to 3100[55].

Table C.1: Input-Output table for one country

		OUTPUT (use or demand)			
		Intermediate demand		Final demand	Gross output
	Industries	1	2		
INPUT (supply)	1	100	600	800	1500
	2	400	200	1000	1600
	Value added	1000	800	1800	
	Gross input	1500	1600		3100

NB: Figures are expressed in monetary units

[54] For additional information, see Stehrer (2012), Powers (2012), Johnson and Noguera (2012a,b), Koopman *et al*. (2014), Aslam *et al*. (2017). See also UNCTAD (2013), "Annex: Technical note on the UNCTAD-Eora GVC Database", p. 26-30 *in* "Global Value Chains: Investment and Trade for Development", World Investment Report 2013, United Nations, New York and Geneva.

[55] Gross output measures the sum of a country's gross value added (*i.e.* the value of final products) and intermediate consumption (*i.e.* the value of intermediate products used to produce final products), in a given period of time. Gross domestic product (*a.k.a.* net output or gross value added) is equal to the sum of value added *i.e.* the difference between gross output and intermediate consumption, in a given period of time.

Table C.2 presents an inter-country input-output (ICIO) table for two countries with two industries each. This table is a combination of national input-output tables and trade data that breaks down the use of goods and services according to the country of their origin (Powers (2012)). When reading across rows, Industry 1 (Country A) delivers 100 to itself, 600 to Industry 2 (Country A), 0 to Industry 3 (Country B), 300 to Industry 4 (Country B), 800 to final consumers in Country A and 200 to final consumers in Country B. For a given country, gross exports are defined as the difference between gross output and domestic demand (whether intermediate or final) of the considered country. When reading down columns, Industry 4 (Country B) uses 300 from Industry 1 (Country A), 700 from Industry 2 (Country A), 0 from Industry 3 (Country B), 25 from itself and 215 from its own primary factors as payment to its factors (*i.e.* labor, land and capital).

Table C.2: Inter-Country Input-Output table for two countries

		OUTPUT (use or demand)								
			Intermediate demand				Final demand		Gross output	Gross exports
			Country A		Country B					
		Industries	1	2	3	4	Country A	Country B		
INPUT (supply)	Country A	1	100	600	0	300	800	200	2000	500
		2	400	200	0	700	1000	700	3000	1400
	Country B	3	50	350	50	0	10	1300	1760	410
		4	250	150	0	25	5	810	1240	405
		Value added	1200	1700	1710	215				
		Gross input	2000	3000	1760	1240			8000	

NB: Figures are expressed in monetary units

Table C.3 is derived from Table C.2. In Table C.3, the GDP is equal to the sum of the value added of each country or equivalently to the sum of factor incomes. Indeed, value added represents payments to primary factors (labor, capital, land) or equivalently, the income of factors (wages, profits, rents). The final demand expenditures sum the final demand of each country. Final demand relates to household and non-profit institutions serving households final consumption, government final consumption, gross fixed capital formation, changes in inventories and acquisitions less disposals of valuables (Aslam *et al*. (2017)). The sum of final demands is also equal to GDP. The net saving is the difference between the income (GDP) and the final demand. Gross exports sum the supply of intermediate and final products to the rest of the world. Gross imports sum intermediate and final products used from the rest of the world. Net exports are equal to the difference between gross exports and gross imports.

Table C.3: Macroeconomic accounts

	Country A	Country B	World
Value added (GDP)	2900	1925	4825
Final demand expenditures	1815	3010	4825
Net saving	1085	-1085	0
Gross exports	1900	815	2715
Gross imports	815	1900	2715
Net exports (gross value)	1085	-1085	0

NB: Figures are expressed in monetary units

Based on the inter-country input-output Table C.2, one can define two models: the Leontief model (Leontief (1936, 1941)) and the Ghosh model (Ghosh (1958)).

From a demand-side perspective, when reading Table C.2 across rows, one gets the Leontief model. This model is based on a basic supply-demand (or resources-uses) relationship stating that gross output X must be used as either intermediate products T or final products F:

$$X=TI+F \tag{1}$$

With X, the gross output vector; T, the transactions matrix (or input-output matrix of intermediate products), whose element t_{ij} (i refers to rows, j refers to columns) describes the value of output from a given sector in source country i used in the production of another sector's output by destination country j; I, an identity vector; F, the final demand vector that sums the rows of the matrix of products used for final demand.

Based on Table C.2, one gets:

$$X=TI+F \iff \begin{bmatrix}2000\\3000\\1760\\1240\end{bmatrix}=\begin{bmatrix}100&600&0&300\\400&200&0&700\\50&350&50&0\\250&150&0&25\end{bmatrix}\begin{bmatrix}1\\1\\1\\1\end{bmatrix}+\begin{bmatrix}800+200\\1000+700\\10+1300\\5+810\end{bmatrix} \tag{2}$$

Equivalently, the above expression can be expressed in a block matrix language as:

$$X=TI+F \iff \begin{bmatrix}X_A\\X_B\end{bmatrix}=\begin{bmatrix}T_A\\T_B\end{bmatrix}\begin{bmatrix}I\\I\end{bmatrix}+\begin{bmatrix}F_A\\F_B\end{bmatrix} \tag{3}$$

With $X_A = \begin{bmatrix} 2000 \\ 3000 \end{bmatrix}$ $X_B = \begin{bmatrix} 1760 \\ 1240 \end{bmatrix}$ $F_A = \begin{bmatrix} 1000 \\ 1700 \end{bmatrix}$ $F_B = \begin{bmatrix} 1310 \\ 815 \end{bmatrix}$ $I = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$

$$T_A = \begin{bmatrix} 100 & 600 & 0 & 300 \\ 400 & 200 & 0 & 700 \end{bmatrix} \text{ and } T_B = \begin{bmatrix} 50 & 350 & 50 & 0 \\ 250 & 150 & 0 & 25 \end{bmatrix}$$

The above expression (3) can also be expressed at the country level, by aggregating across sectors:

$$\begin{bmatrix} 5000 \\ 3000 \end{bmatrix} = \begin{bmatrix} 100+600+400+200 & 300+700 \\ 50+350+250+150 & 50+25 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \end{bmatrix} + \begin{bmatrix} 800+200+1000+700 \\ 10+1300+5+810 \end{bmatrix} \quad (4)$$

From a supply-side perspective, when reading Table C.2 down columns, one gets the Ghosh model. This model starts with a basic relationship that shows the inter-sectoral allocation of gross output *X* between intermediate products *T* and primary inputs (or value added) *W*:

$$X' = I'T + W' \quad (5)$$

With *X*, the gross output vector; *T*, the transactions matrix; *I*, an identity vector; *W*, the value added vector. The prime symbol (') denotes matrix/vector transposition. The vector *W* gives value added (or factor income) in the accounting sense. This normally includes six items: compensation of employees, taxes on production, subsidies on production, net operating surplus, net mixed income and consumption of fixed capital (Aslam *et al*. (2017)). In Table C.2, these six components are all aggregated in a single category labeled "value added"[56].

Based on Table C.2, one gets: $X' = I'T + W'$ <=>

$$\begin{bmatrix} 2000 & 3000 & 1760 & 1240 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} 100 & 600 & 0 & 300 \\ 400 & 200 & 0 & 700 \\ 50 & 350 & 50 & 0 \\ 250 & 150 & 0 & 25 \end{bmatrix} + \begin{bmatrix} 1200 & 1700 & 1710 & 215 \end{bmatrix} \quad (6)$$

[56] Note that it is important not to confuse the value added vector *W* with the Domestic Value Added vector that relates to trade in value added flows (see *infra*).

Or equivalently, at the country level:

$$\begin{bmatrix}5000 & 3000\end{bmatrix} = \begin{bmatrix}1 & 1\end{bmatrix}\begin{bmatrix}1300 & 1000\\ 800 & 75\end{bmatrix} + \begin{bmatrix}2900 & 1925\end{bmatrix} \quad (7)$$

We will come back later to the Ghosh model and proceed with the Leontief model. Based on the Leontief model, one can retrieve the matrix of technical (or input or technological) coefficients *A*. To this aim, implement the element-wise division of matrix *T* by the gross output vector *X* or equivalently *A=T./X* (the sign "./" denotes element-wise division). Hence:

$$A = \begin{bmatrix}0.05 & 0.20 & 0 & 0.24\\ 0.20 & 0.07 & 0 & 0.56\\ 0.03 & 0.12 & 0.03 & 0\\ 0.13 & 0.05 & 0 & 0.02\end{bmatrix} \quad (8)$$

The element a_{ij} in matrix A is equal to $a_{ij}=T_{ij}/X_j$. This element indicates the proportion of input from industry *i* used to produce one unit of output by industry *j*. Matrix A thus provides the inputs consumed per unit of sector output. In other words, it tells us that in order to produce one monetary unit of product 1 in Country A, the following inputs are required: 0.05 monetary unit of intermediate product 1 from domestic Industry 1 (Country A), 0.2 monetary unit of intermediate product 2 from domestic Industry 2 (Country A), 0.03 monetary unit of imported intermediate product 3 from foreign Industry 3 (Country B) and 0.13 monetary unit of imported intermediate product 4 from foreign Industry 4 (Country B).

If *A=T./X*, then *T=AX*. From relation (1), one gets: *X=TI+F* <=> *X=AX+F*. By rearranging, we get: *X-AX=F* <=> *(I-A)X=F* <=> $X=(I-A)^{-1}F$ <=> *X=LF*. The matrix *L* is called the international Leontief inverse matrix (or input inverse matrix or total requirements matrix; Miller and Blair (2009), p. 544). Hence:

$$L = (I - A)^{-1} = \begin{bmatrix}1.17 & 0.27 & 0 & 0.45\\ 0.35 & 1.19 & 0 & 0.77\\ 0.07 & 0.15 & 1.03 & 0.10\\ 0.17 & 0.10 & 0 & 1.12\end{bmatrix} \quad (9)$$

The element l_{ij} of the Leontief inverse matrix L reflects the total requirements from sector i to provide a unit of the final demand for the products of sector j. Equivalently, l_{ij} provides the complete required quantities (direct and indirect inputs) of product i to satisfy one unit of demand of product j. In other words, the international Leontief inverse matrix tells us how much gross output from each industry and each country is required to produce a given vector of final products. Hence, in order to produce one monetary unit of final product 2, the following units of gross output are required: 0.27 monetary unit of gross output 1 produced by domestic Industry 1 (Country A), 1.19 monetary units of gross output 2 produced by domestic Industry 2 (Country A), 0.15 monetary unit of imported gross output 3 produced by foreign Industry 3 (Country B) and 0.10 monetary unit of imported gross output 4 produced by foreign Industry 4 (Country B).

Using the Leontief inverse matrix, one can analyze how value added distributes across countries and sectors. To this aim, define a direct value added coefficient matrix $\hat{V}$ (or direct matrix of value added shares). From the Ghosh model, gross output X sums up to intermediate products T and value added W: $X' = \imath'T + W'$. As $T=AX$, we get $X'=AX+W'$. Dividing by X leads to: $1=A+v$ (where $v = W'./X$, *i.e.* the value added divided by gross output). By rearranging, we get: $v=1-A$. We thus define v, the matrix of value added in global production as:

$$v = W'./X = \begin{bmatrix} 0.60 \\ 0.57 \\ 0.97 \\ 0.17 \end{bmatrix} \tag{10}$$

Considering the diagonal of v leads to the direct value added coefficient matrix $\hat{V}$:

$$\hat{V} = \text{diag}(v) = \begin{bmatrix} 0.60 & 0 & 0 & 0 \\ 0 & 0.57 & 0 & 0 \\ 0 & 0 & 0.97 & 0 \\ 0 & 0 & 0 & 0.17 \end{bmatrix} \tag{11}$$

Note that as $v=1-A$, another way to get the matrix $\hat{V}$ is by summing the elements of each column of the technical coefficients matrix A, putting these elements on the diagonal of a square matrix and subtracting it from an identity matrix I of the same size:

$$\hat{V} = I_{4\times4} - \begin{bmatrix} 0.05+0.20+0.03+0.13 & 0 & 0 & 0 \\ 0 & 0.20+0.07+0.12+0.05 & 0 & 0 \\ 0 & 0 & 0.03 & 0 \\ 0 & 0 & 0 & 0.24+0.56+0.02 \end{bmatrix} \quad (12)$$

We get the same direct value added coefficient matrix $\hat{V}$ as in (11):

$$\hat{V} = \begin{bmatrix} 0.60 & 0 & 0 & 0 \\ 0 & 0.57 & 0 & 0 \\ 0 & 0 & 0.97 & 0 \\ 0 & 0 & 0 & 0.17 \end{bmatrix} \quad (13)$$

Finally, when multiplying the matrix $\hat{V}$ with the L matrix and the diagonal matrix of gross exports $\hat{E}$, we get the trade in value added matrix T_v: $T_v = \hat{V} \times L \times \hat{E}$. $\hat{E}$ is the diagonal matrix of gross exports where each element on the diagonal gives the gross exports for the corresponding country-sector. Hence:

$$T_v = \begin{bmatrix} 0.60 & 0 & 0 & 0 \\ 0 & 0.57 & 0 & 0 \\ 0 & 0 & 0.97 & 0 \\ 0 & 0 & 0 & 0.17 \end{bmatrix} \times \begin{bmatrix} 1.17 & 0.27 & 0 & 0.45 \\ 0.35 & 1.19 & 0 & 0.77 \\ 0.07 & 0.15 & 1.03 & 0.10 \\ 0.17 & 0.10 & 0 & 1.12 \end{bmatrix} \times \begin{bmatrix} 500 & 0 & 0 & 0 \\ 0 & 1400 & 0 & 0 \\ 0 & 0 & 410 & 0 \\ 0 & 0 & 0 & 405 \end{bmatrix}$$

$$<=> \qquad T_v = \begin{bmatrix} 350.76 & 230.57 & 0 & 108.58 \\ 99.62 & 942.56 & 0 & 177.02 \\ 35.13 & 203.66 & 410.00 & 40.97 \\ 14.49 & 23.22 & 0 & 78.43 \end{bmatrix} \quad (14)$$

The matrix T_v essentially describes how the value added contained in gross exports of each country (and industry) is generated (by column) and distributed (by row) across countries/sectors. Based on the T_v matrix, one can calculate trade in value added metrics such as the domestic value added (*DVA*), the indirect value added (*IDC* or *DVX*) and the foreign value added (*FVA*). For ease of readability, matrix T_v is replicated in Table C.4.

Table C.4: Trade in value added matrix

		Country A		Country B	
		Industry 1	Industry 2	Industry 3	Industry 4
Country A	Industry 1	350.76	230.57	0.00	108.58
	Industry 2	99.62	942.56	0.00	177.02
Country B	Industry 3	35.13	203.66	410.00	40.97
	Industry 4	14.49	23.22	0.00	78.43

NB: Figures are expressed in monetary units

The first two columns of the matrix T_v (or equivalently, of Table C.4) describe the value added contained in the export of Country A (by Industry 1 and Industry 2, respectively). This is composed of two parts: the domestic value added content of gross exports by Country A and the foreign value added content of gross exports by Country A.

The domestic value added (*DVA*) content of gross exports by Country A can be decomposed at the sector level: 450.38 for Industry 1 (350.76+99.62) and 1173.13 for Industry 2 (230.57+942.56). The *DVA* is larger for Industry 2 than for Industry 1, given that Industry 2 exports more intermediate products to Country B than Industry 1 (respectively, 700 for Industry 2 and 300 for Industry 1, Table C.2). Hence, the total domestic value added content of gross exports for Country A amounts to 1623.51 (450.38+1173.13).

The foreign value added (*FVA*) content of gross exports by Country A can also be decomposed at the sector level: 49.62 for Industry 1 (35.13+14.49) and 226.88 for Industry 2 (203.66+23.22). The total foreign value added content of gross exports amounts to 276.50 for Country A (49.62+226.88). Recall that the production of output by Country A (part of which is exported) requires intermediate products from Country B. In producing these intermediate products, Country B also generates value added. Hence, the *FVA* represents the share of value added that has been generated in Country B and imported by Country A in order to produce its exports. The *FVA* represents the source of multiple-counting in gross exports by Country A. The *FVA* is larger for Industry 2 than for Industry 1 as Industry 2 uses more inputs (*i.e.* source more intermediate products) from Country B (350+150, Table C.2) than Industry 1 (50+250, Table C.2).

By construction, the (column) sum of *DVA* and *FVA* yields the total gross exports of Country A. Thus, for Industry 1, *DVA* + *FVA* = 450.38 + 49.62 = 500 *i.e.* the total gross exports of Industry 1 in Country A (Table C.2). For Industry 2, *DVA* + *FVA* = 1173.13 + 226.88 = 1400 *i.e.* the total gross exports of Industry 2 in Country A (Table C.2). At the country level, the sum of gross exports across Industry 1 and Industry 2 leads to total gross exports by Country A: 500+1400=1900 (see Table C.3).

In a matrix language, by aggregating across sectors for each country in the matrix T_v, the domestic value added of gross exports (*DVA*) for each country is given by the diagonal elements of the T_v matrix:

$$T_v=\begin{bmatrix} 350.76+99.62+230.57+942.56 & 0+0+108.58+177.02 \\ 35.13+14.49+203.66+23.22 & 410.00+0+40.97+78.43 \end{bmatrix}=\begin{bmatrix} 1623.51 & 285.60 \\ 276.50 & 529.40 \end{bmatrix} \quad (15)$$

$$DVA = \text{diag}(T_v) = \begin{bmatrix} 1623.51 \\ 529.40 \end{bmatrix} \quad (16)$$

Thus, the domestic value added content of gross exports in Country B amounts to 529.40. As Country B exports less intermediate and final demand products than Country A (see Table C.3), its *DVA* is lower than the *DVA* of Country A.

The foreign value added (*FVA*) of exports for each country can be calculated by summing up all the blocks in the corresponding column of matrix T_v and subtracting the diagonal block matrix of matrix T_v. Hence:

$$FVA = \sum_{j=1}^{n} T_{v,ij} \text{-diag}(T_v) \quad (17)$$

FVA=

$$\begin{bmatrix} 350.76+99.62+35.13+14.49+230.57+942.56+203.66+23.22 \\ 0+0+410.00+0+108.58+177.02+40.97+78.43 \end{bmatrix}-\begin{bmatrix} 1623.51 \\ 529.40 \end{bmatrix}=\begin{bmatrix} 276.50 \\ 285.60 \end{bmatrix}$$

Thus, the foreign value added content of gross exports in Country B (and produced in Country A) amounts to 285.60. It is higher than that of Country A. Indeed, Country B imports more intermediate and final demand products from Country A (compared to Country A's imports from Country B, see Table C.3). As mentioned earlier, *DVA* and *FVA*, by construction, always

add up to gross exports (or to unity if expressed as ratios of gross exports). For Country B, the sum of *DVA* and *FVA* leads to its gross exports: 285.60+529.40=815 (see Table C.3).

By reading the matrix T_v across rows, rather than down columns (and excluding the diagonal term of matrix T_v), we would have an indication of how much of each country's domestic value added enters as an intermediate product in the value added exported by other countries. The latter terms is what Koopman *et al*. (2014) call "*indirect value added exports via third countries*" (*DVX*). *DVX* for each country/sector can be calculated by summing up all the blocks in the corresponding row and subtracting the diagonal block matrix of the matrix T_v. At the country level, one gets:

$$DVX = \sum_{i=1}^{n} T_{v,ij} - \text{diag}(T_v) \tag{18}$$

$$DVX = \begin{bmatrix} 350.76 + 230.57 + 108.58 + 99.62 + 942.56 + 177.02 \\ 35.13 + 203.66 + 410.00 + 40.97 + 14.49 + 23.22 + 78.43 \end{bmatrix} - \begin{bmatrix} 1623.51 \\ 529.40 \end{bmatrix} = \begin{bmatrix} 285.60 \\ 276.50 \end{bmatrix}$$

Clearly, by construction what each country contributes to all the others in terms of indirect value added exports *via* third countries has to be equal at the world level to what each country sources from all the others in terms of foreign value added. Hence, at the world level, the sum of *FVA* is equal to the sum of *DVX*. As a result, *DVX* can also provide a proxy of the multiple-counting embedded in the gross (official) trade figures.

The literature defines various indicators based on the above value added metrics (De Backer and Miroudot (2014), Taglioni and Winkler (2016)): the GVC participation index, the GVC position index and the length of the value chain.

The GVC participation index (Koopman *et al*. (2014)) sums the foreign value added embodied in gross exports (*a.k.a.* backward GVC participation) and the domestic value added embodied in third countries' gross exports (*a.k.a.* forward GVC participation). This index informs about the depth of GVC integration of a given country. The country's GVC integration is assessed both as a user of foreign intermediate products for its own exports and as a supplier of intermediate products processed domestically and used in other countries' exports. Koopman *et al*. (2014) define the GVC position index as the log of the domestic value added embodied in

third countries' gross exports (*a.k.a.* forward GVC participation) to the foreign value added embodied in gross exports (*a.k.a.* backward GVC participation). According to Koopman *et al*. (2014), the larger the GVC position index, the more upstream the country in the value chain. We thus get:

$$Forward\ GVC\ participation = \frac{DVX}{E} = \begin{bmatrix} 0.15 \\ 0.34 \end{bmatrix} \tag{19}$$

$$Backward\ GVC\ participation = \frac{FVA}{E} = \begin{bmatrix} 0.14 \\ 0.35 \end{bmatrix} \tag{20}$$

$$GVC\ participation = \frac{FVA}{E} + \frac{DVX}{E} = \begin{bmatrix} 0.29 \\ 0.69 \end{bmatrix} \tag{21}$$

$$GVC\ position = \ln(1 + \frac{DVX}{E}) - \ln(1 + \frac{FVA}{E}) = \begin{bmatrix} 4.17 \times 10^{-3} \\ -8.31 \times 10^{-3} \end{bmatrix} \tag{22}$$

Hence, Country B is relatively more integrated than Country A in GVC as its backward and forward GVC participations are larger than those of Country A. This means that given their respective amount of exports, Country B trades more than Country A in GVC. In addition, the GVC position index shows that Country B is located more downstream in the value chain than Country A; the latter being more upstream.

It is also possible to compute the above metrics at the sector level. When transposing the final vectors, we get:

$$Forward\ GVC\ participation = \begin{bmatrix} 0.22 & 0.13 & 0.58 & 0.09 \end{bmatrix}; \tag{23}$$

$$Backward\ GVC\ participation = \begin{bmatrix} 0.10 & 0.00 & 0.16 & 0.71 \end{bmatrix}; \tag{24}$$

$$GVC\ participation = \begin{bmatrix} 0.32 & 0.13 & 0.74 & 0.80 \end{bmatrix}; \tag{25}$$

$$GVC\ position = \begin{bmatrix} 0.10 & 0.12 & 0.31 & -0.44 \end{bmatrix}; \tag{26}$$

As a result, Industry 4 in Country B presents the most important GVC participation characterized by the strongest backward participation. It is thus located more downstream in the value chain as pointed by the GVC position. Conversely, Industry 3 in Country B features the

strongest forward GVC participation and is thus located more upstream in the value chain as evidenced by the GVC position.

While the GVC participation index informs about the involvement degree of a given country within a vertical production network, it does not inform about the length of value chains, *i.e.* the number of production stages a given country is involved in.

Indeed, a high backward GVC participation may not necessarily reflect a long value chain as it could correspond to the use of expensive intermediate products (*e.g.* raw materials, high technology inputs, *etc.*) in a very short (or simple) value chain. Similarly, a high forward GVC participation may not necessarily reflect a long value chain as the value could be added all at once in the final stage of the production process in a very short (or simple) value chain. This is why an indication on the GVC length can be useful and complementary to the GVC participation (De Backer and Miroudot (2014)). To this aim, the literature set out two main indicators: the length of the sourcing chain and the length of the selling chain.

From the perspective of value added buyers, the sourcing chain length addresses the degree of interconnections of a particular country/sector with those upstream countries/sectors from which it purchases inputs (Rasmussen (1957), Miller and Blair (2009)). Following De Backer and Miroudot (2014), the sourcing chain length is defined as::

Length of the sourcing chain: $N = \imath'.(I-A)^{-1} = \imath'.L$ (27)

With N, a column vector with the indexes for all countries c and industries k; $\imath$, a column unit vector (the prime symbol (') denotes vector transposition) and A, the matrix of technical coefficients. The term $(I-A)^{-1}$ is equal to the Leontief inverse matrix L.

The minimum value of the index N is unity if there is only a single production stage in the final industry *i.e.* when no intermediate products (whether domestic or foreign) are used to produce a product. In the latter case, the product is directly purchased by final consumers. Conversely, the value of the index increases when intermediate products from the same industry or other industries in the domestic country or abroad are used in the production process of a given product. In the inter-country input-output matrix, we have the values of all intermediate

products used by one industry in a given country. In such a matrix, one can distinguish between the use of domestic intermediate products and the use of foreign intermediate products by a given country or a given industry. As a result, the sourcing chain length can be decomposed according to domestic production stages and foreign (or international) production stages. The domestic part measures the sourcing chain length when intermediate products for the realization of a final product are sourced domestically. The international part measures the sourcing chain length when intermediate products for the realization of a final product are sourced from foreign countries.

According to De Backer and Miroudot (2014), the index *N* is equivalent to total (direct and indirect) backward linkages in the context of an inter-country input-output table and provides a measure of downstreamness (Miller and Blair (2009), Wang *et al*. (2017)). Indeed, the indicator of total backward linkages (*BL*) informs about the level of influence by sector *j* on the output of all sectors through its purchases or its input demand (Miller and Blair (2009) p. 545, Marx *et al.* (2014)). In other words, total backward linkages indicate the degree of interconnections of a particular country/sector with those upstream countries/sectors from which it purchases inputs (Rasmussen (1957), Miller and Blair (2009) p. 555). Hence:

Total backward linkages: $$BL_j = L_{*j} = \sum_{i=1}^{n} l_{ij} \quad (28)$$

Where L_{*j} is the associated column sum of the elements of the matrix *L*.

From the perspective of value added sellers, the length of the selling chain (or distance to final demand) indicates the degree of interconnections of a particular country/sector with those downstream countries/sectors to which it sells its output (Rasmussen (1957), Miller and Blair (2009)). The selling chain length measures how many production stages are left before the goods and services produced by an industry or by a country reach final consumers. It can be interpreted as the number of stages that intermediate products cross borders before reaching final consumers. A country presents a short selling chain if the length is close to unity. This country will be positioned more downstream in the value chain and tends to serve relatively more the final producers or the final consumers at the end of the value chain. Conversely, a country presents a longer selling chain as the length becomes higher than unity. This country is positioned more

upstream in the value chain and is thus located far from final producers or final consumers. The selling chain length can also be decomposed into domestic and international parts. Following De Backer and Miroudot (2014), the selling chain length is defined as:

Length of the selling chain: $D = (I-B)^{-1}.I = G.I$ (29)

With D, a column vector with the indexes for all countries c and industries k; I, a column unit vector and B, the allocation coefficients matrix (as opposed to the technical coefficient matrix A). The allocation coefficients matrix B gives the percentage of the output of industry i that is sold to industry j. In other words, b_{ij} indicates the proportion of industry i's total output that is used by industry j as input for production. Hence, $B_{ij}=T_{ij}/X_i$ or equivalently, $B = \hat{X}^{-1}T$. The term $(I-B)^{-1}$ is the output inverse (as opposed to the input inverse $(I-L)^{-1}$). The term $(I-B)^{-1}$ is also known as the Ghosh inverse or the Ghosh matrix G, hence $G=(I-B)^{-1}$. The latter is retrieved from the Ghosh model. From a formal perspective, if $B=\text{diag}(X)^{-1}T$, then $T=X'B$. From the Ghosh model (5), one gets: $X' = I'T + W' <=> X' = X'B + W'$. By rearranging: $X'-X'B=W' <=> X'(I-B)=W' <=> X'=W'(I-B)^{-1} <=> X'=W'G <=> G=(I-B)^{-1}$. The element g_{ij} of the Gosh matrix G reflects the total required outputs from sector j to absorb one unit of the primary factors of sector i (Rasmussen (1957), Miller and Blair (2009) p. 544).

According to De Backer and Miroudot (2014), the index D is similar to the calculation of total (direct and indirect) forward linkages in the context of an inter-country input-output table and provides a measure of upstreamness (Miller and Blair (2009), Wang *et al*. (2017)). Indeed, the indicator of total forward linkages (FL) informs about the level of influence by sector i on the output of all sectors through its sales or its output supplies and is interpreted as the total output required to absorb a unit of primary inputs (Miller and Blair (2009) p. 545, Marx *et al.* (2014)). In other words, total forward linkages indicate the degree of interconnections of a particular country/sector with those downstream countries/sectors to which it sells its output (Rasmussen (1957), Miller and Blair (2009) p. 555). Hence:

Total forward linkages: $FL_i = G_{i*} = \sum_{j=1}^{n} g_{ij}$ (30)

Where G_{i*} is the associated row sum of the elements of the matrix G.

Based on our simple example, we get:

$$N = \begin{bmatrix} 1.76 \\ 1.71 \\ 1.03 \\ 2.44 \end{bmatrix} \quad \text{and} \quad D = \begin{bmatrix} 1.86 \\ 1.74 \\ 1.44 \\ 1.62 \end{bmatrix} \tag{31}$$

$$\text{With } B = \begin{bmatrix} 0.05 & 0.30 & 0 & 0.15 \\ 0.13 & 0.07 & 0 & 0.23 \\ 0.03 & 0.20 & 0.03 & 0 \\ 0.20 & 0.12 & 0 & 0.02 \end{bmatrix} \text{ and } G = \begin{bmatrix} 1.17 & 0.41 & 0 & 0.28 \\ 0.23 & 1.19 & 0 & 0.32 \\ 0.08 & 0.26 & 1.03 & 0.07 \\ 0.27 & 0.23 & 0 & 1.12 \end{bmatrix} \tag{32}$$

Concerning the sourcing chain length (*N*), Industry 4 in Country B presents the longest chain and thus the largest degree of interconnections with the upstream sectors from which it purchases intermediate products. In other words, this suggests that Industry 4 in Country B has strong backward linkages and is thus located more downstream in the value chain. The reverse holds true for Industry 3 in Country B which shows the shortest sourcing chain. These results are in line with the ones from the GVC participation index computed above (see (23) to (26)).

Regarding the selling chain length (*D*), Industry 3 in Country B presents the shortest selling chain (or the shortest distance to final demand) and thus the lowest degree of interconnections with those downstream sectors from which it sells output. In other words, this suggests that Industry 3 (Country B) has weak forward linkages and is thus located less upstream in the value chain. Or, the GVC participation index computed above (see (23) to (26)) showed that Industry 3 in Country B featured the most important domestic value added export content and would have thus been positioned more upstream in the value chain. However, a high forward GVC participation share may not necessarily reflect a long selling chain as the value could be added all at once in the final stage of the production process in a very short (or simple) selling chain. Indeed, as evidenced in Table C.2, Industry 3 in Country B exports 10 to Country A and uses only its own inputs to produce its product 3; hence the shortness of its selling chain length. This latter case evidences the useful complementarities between the GVC length and the GVC participation index.

The Matlab codes to compute the above vectors/matrices from inter-country input-output tables are available from the author upon request. Note also that Aslam *et al*. (2017) provide a Matlab code (upon request) that retrieves trade in value added indicators from the UNCTAD's Eora Multi-Region Input-Output (MRIO) database (Lenzen *et al*. (2012, 2013)).

D. Revealed Comparative Advantage based on domestic value added

Table D presents the RCA index for Luxembourg calculated based on the domestic value added exported by each sector:

$$RCA_t = \frac{X_{c,i,t} / X_{c,t}}{X_{w,i,t} / X_{w,t}} = \frac{EXGR\_DVA_{c,i,t} / EXGR\_DVA_{c,t}}{EXGR\_DVA_{w,i,t} / EXGR\_DVA_{w,t}}$$

When the RCA is higher than unity, the table specifies the rank of Luxembourg in the sample of 50 advanced and emerging market economies. As for the GVC-related RCA index presented in Table 1 in the core text, we consider that a particular sector has a revealed comparative advantage if two conditions are fulfilled: first, the related RCA is above unity and second, the related RCA is the highest across the considered countries.

Table D: Domestic Value Added-based Revealed Comparative Advantage for Luxembourg

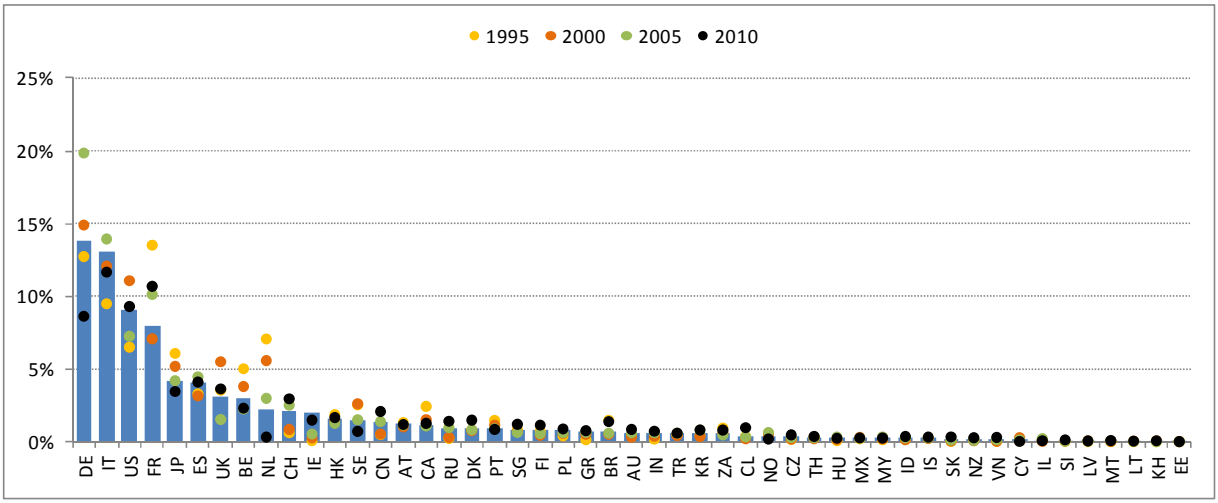
	1995		2000		2005		2010		Average 2000-2011	
Sectors	RCA	Rank	RCA	Rank	RCA	Rank	RCA	Rank	RCA	Rank
Agriculture & forestry	0.37		0.34		0.30		0.22		0.27	
Mining & quarrying	0.03		0.01		0.01		0.00		0.01	
Food, beverages & tobacco	0.38		0.38		0.38		0.27		0.35	
Textiles & apparel	0.49		0.37		0.38		0.27		0.33	
Wood, paper & publishing	0.32		0.39		0.53		0.35		0.43	
Chemicals & non-metallic products	0.71		0.47		0.28		0.17		0.30	
Basic & fabricated metals	1.06	23rd	0.99		0.62		0.34		0.68	
Machinery & equipment	0.26		0.26		0.21		0.17		0.21	
Electrical & optical equipment	0.07		0.06		0.12		0.08		0.09	
Transport equipment	0.01		0.01		0.02		0.02		0.02	
Other manufactures & recycling	0.27		0.18		0.10		0.07		0.11	
Electricity, gas & water	0.67		0.45		0.41		0.40		0.66	
Construction	0.65		0.85		1.49	20th	1.22	28th	1.22	27th
Wholesale & retail	0.53		0.43		0.59		0.91		0.68	
Transport & telecom	1.19	22nd	1.55	15th	1.38	18th	1.40	19th	1.44	18th
Finance & insurance	19.09	**1rst**	18.88	**1rst**	16.11	**1rst**	14.39	**1rst**	15.34	**1rst**
Business & real estate services	1.20	18th	0.90		1.12	18th	1.44	13th	1.19	17th
Personal & cultural services	2.96	3rd	1.94	10th	2.23	7th	1.98	8th	2.04	9th

Source: Author's calculations based on OECD-TiVA database (December 2016). The RCA index is calculated based on the domestic value added exported by each sector (*EXGR_DVA*).

Along these lines, Luxembourg possesses a revealed comparative advantage in the finance and insurance industry. Although not shown in Table D, the main countries ranked behind Luxembourg in the finance and insurance industry are: Switzerland (with a domestic value added based-RCA equal to 5.55 on average, over the period 2000-2011), Cyprus (5.54), Hong Kong (4.97), Ireland (4.29), the United Kingdom (3.99), Singapore (3.53), Malta (1.91) and the United States (1.75). With a domestic value added based-RCA equal to 15.34 on average over the period 2000-2011, Luxembourg holds a stronger domestic value added based-RCA in the finance and insurance industry compared to the latter countries.

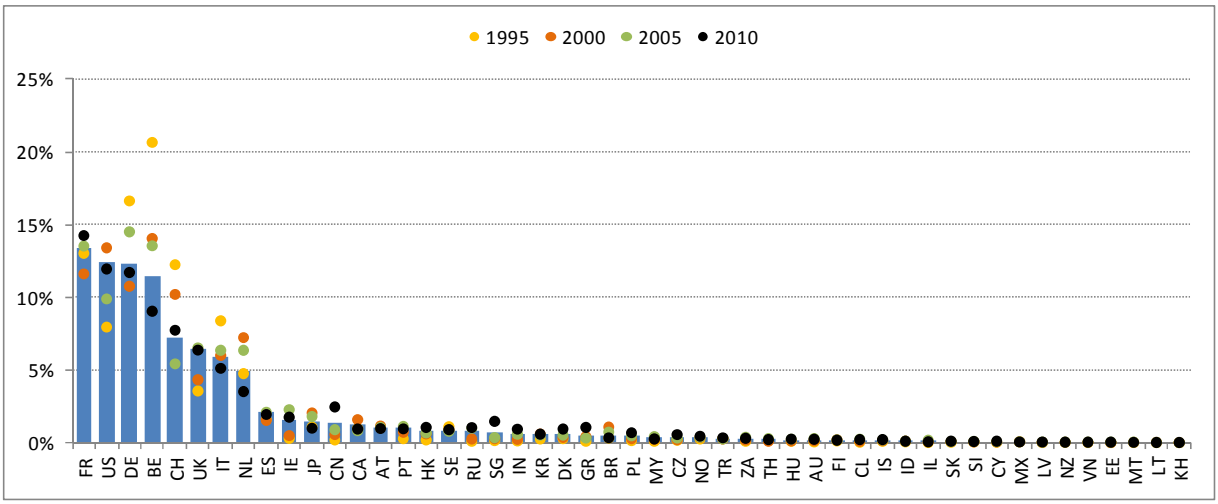
E. Ultimate consumers of Luxembourg's value added *versus* ultimate providers of foreign value added to Luxembourg's final demand (finance and insurance sector)

Chart E.1: Who are the ultimate consumers of Luxembourg's value added in the finance and insurance sector?



Source: OECD-TiVA (December 2016), average 2000-2011, based on available data. Ratio: Share of domestic value added embodied in foreign final demand (finance and insurance sector)-to-total domestic value added embodied in foreign final demand (finance and insurance sector).

Chart E.2: Who are the main providers of foreign value added for Luxembourg's final demand in the finance and insurance sector?



Source: OECD-TiVA (December 2016), average 2000-2011, based on available data. Ratio: Share of foreign value added embodied in domestic final demand (finance and insurance sector)-to-total foreign value added embodied in domestic final demand (finance and insurance sector).

F. Data description

Tables F.1 and F.2 describe the economic sectors considered in the paper according to the definition provided by the OECD-TiVA database. This database covers 34 industries whose structure relies on the United Nations' ISIC Revision 3 classification (ISIC stands for International Standard Industrial Classification of All Economic Activities)[57,58].

Table F.1: Description of economic sectors

Sector	Mnemonic	Description according to the United Nations' ISIC Revision 3 classification
Agriculture & forestry	C01T05	Agriculture, hunting, forestry and fishing
Mining & quarrying	C10T14	Mining and quarrying (*e.g.* quarrying of stone, sand and clay)
Food, beverages & tobacco	C15T16	Food products, beverages and tobacco
Textiles & apparel	C17T19	Textiles, textile products, leather and footwear
Wood, paper & publishing	C20T22	Wood, paper, paper products, printing and publishing
Chemicals & non-metallic products	C23T26	Chemicals and non-metallic mineral products (*e.g.* coke, refined petroleum products and nuclear fuel; chemicals and chemical products; rubber and plastics products; other non-metallic mineral products)
Basic & fabricated metals	C27T28	Basic metals and fabricated metal products
Machinery & equipment	C29	Machinery and equipment, not elsewhere classified (nec)
Electrical & optical equipment	C30T33	Electrical and optical equipment (*e.g.* computer, electronic and optical equipment, electrical machinery and apparatus not elsewhere classified (nec))
Transport equipment	C34T35	Transport equipment (*e.g.* motor vehicles, trailers, semi-trailers, other transport equipment)
Other manufactures & recycling	C36T37	Manufacturing not elsewhere classified (nec); recycling
Electricity, gas & water	C40T41	Electricity, gas and water supply
Construction	C45	Construction (*e.g.* site preparation, building of complete constructions or parts thereof, civil engineering, building installation, building completion, renting of construction or demolition equipment with operator)
Wholesale & retail	C50T55	Wholesale and retail trade; repairs; hotels and restaurants

[57] For more information, see http://www.oecd.org/sti/ind/tiva/tivasourcesandmethods.htm and OECD (2016), "Trade in Value Added (TiVA) - List of industries – 2016", available at: http://www.oecd.org/sti/ind/tiva/TiVA_2016_ISIC3_Industries.pdf

[58] The detailed structure and explanatory notes of the United Nations' ISIC Rev. 3 classification is available on the United Nations Statistics Division website (https://unstats.un.org), at: https://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=2.

Table F.2: Description of economic sectors (continued)

Sector	Mnemonic	Description according to the United Nations' ISIC Revision 3 classification
Transport & telecom	C60T64	Transport and storage (*e.g.* land transport, water transport, air transport, activities of travel agencies), post, courier and telecommunication activities (*e.g.* transmission of sound, images, data or other information *via* cables, broadcasting, relay or satellite; exclusion: production of radio and television programmes).
Finance & insurance	C65T67	Financial intermediation (finance and insurance activities)
Business & real estate services	C70T74	Real estate, renting and business activities: renting of machinery and equipment computer and related activities, R&D and other business activities (*e.g.* legal, accounting and auditing activities, tax consultancy, market research and public opinion polling; business and management consultancy, architectural, engineering and other technical activities, advertising)
Personal & cultural services	C75T95	Community, social and personal services: public administration and defence, compulsory social security; education; health and social work, private households with employed persons; other community, social and personal service activities (*e.g.* sewage and refuse disposal, sanitation and similar activities, activities of membership organizations not elsewhere classified (nec) (*e.g.* activities of business, employers and professional organizations; activities of trade unions; activities of other membership organizations), recreational, cultural and sporting activities (*e.g.* motion picture, radio, television and other entertainment activities; news agency activities; library, archives, museums and other cultural activities; sporting and other recreational activities) and other service activities (*e.g.* washing, and (dry-) cleaning of textile and fur products; hairdressing and other beauty treatment; funeral and related activities))