Estimating global value chain impacts associated with UK consumption patterns

Anne Owen and John Barrett

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1. Introduction and aims

In an increasingly globalised world, UK consumers are purchasing products that are produced either wholly or partially in non-domestic factories. The supply chain of UK products is becoming increasingly complex and reliant on production processes outside of its borders, whilst the economies of many developing nations are increasingly reliant on the consumption patterns of UK consumers.

Tracing the full global supply chain of products bought in the UK is a complex task and has only recently become possible due to improvements in the collection and compilation of complex global trade models. This project uses the GTAP Multi-Regional Input-Output (MRIO) model for the year 2007 to explore global supply chains. This study offers a comprehensive study into trade dependences associated with UK consumption. The outcomes from this study give a complete picture of the economic value generated by UK consumption in 127 other world regions and countries to assess country level vulnerabilities associated with UK consumers' demand for products. For example, future extreme weather events and the implications of a change in climate might affect production in specific UK trade partner regions. This study can help to identify the risk to UK consumption resulting from such events due to the global nature of UK supply chains.

2. Data

In the last three years a number of MRIO models[1] have been developed, each slightly different in terms of country coverage, number of sectors and time scales covered (see table 1).

Table 1 MRIO models and their features

	EXIOPOL	GTAP	Eora	WIOD
No of sectors	130 (Tukker et al., 2009)	57 (yr '07, '04, '01)	Varies by country – high resolution ~15,000 rows and cols. Also 26 sector harmonised table available	35 industries,
No of regions	44 (EU27, 16 others + ROW)	129[2] (yr '07,'04) 113 (yr '04) 87 (yr '01)	186	41 (27 EU, 13 others + RoW)
Years of data	2000	2001, 2004, 2007	1990 – 2011	1995 – 2011
Updates?	Funding dependent	3 year intervals with a 4 year lag	Yearly with a 2 year lag	Funding dependent

This project, used the GTAP MRIO system based on the latest GTAP version 7.1 because of the sector classification's application to the project. GTAP covers 57 sectors and 129 regions and countries. This is greater sector coverage than WIOD and greater regional coverage than EXIOPOL. GTAP uses a homogenous sector classification system – i.e. the same sectors are reported for each country, making calculations and comparisons straightforward. Eora has more regions than GTAP, but the sectors are heterogeneous. GTAP is currently available for the years 2004 and 2007 whereas WIOD

[1] Eora, GTAP, WIOD, EXIOPOL

[2] Data for 2004 is available for both 129 and 113 regions

covers 1995-2011 and Eora 1990-2011. However, since this work considers a snap shot of UK consumption patterns, it was agreed that a single year, 2007, was sufficient for this analysis.

3. Methodology

3.1. Input Output methods

Input-output models have been adopted by environmental economists due to their ability to make the link between the environmental impacts associated with production techniques and the consumers of products. The Leontief Input-Output model is constructed from observed economic data and shows the interrelationships between industries that both produce goods (outputs) and consume goods (inputs) from other industries in the process of making their own product (Miller & Blair, 2009).

Consider the transaction matrix Z; reading across a row reveals which industries a single industry sells to and reading down a column reveals who a single industry buys from. A single element, z_{ij}, within Z, represents the contributions from the i^{th} sector to the j^{th} industry or sector in an economy. For example, Z_{aa} represents the ferrous metal contribution in making ferrous metal products, Z_{ab}, the Ferrous metal contribution to car products and Z_{bb} the car production used in making cars. Final demand is the spend on finished goods. For example y_{ac} is the spend on ferrous metal products by households as final consumers whereas y_{bd} is the spend on car products by government as final consumers.

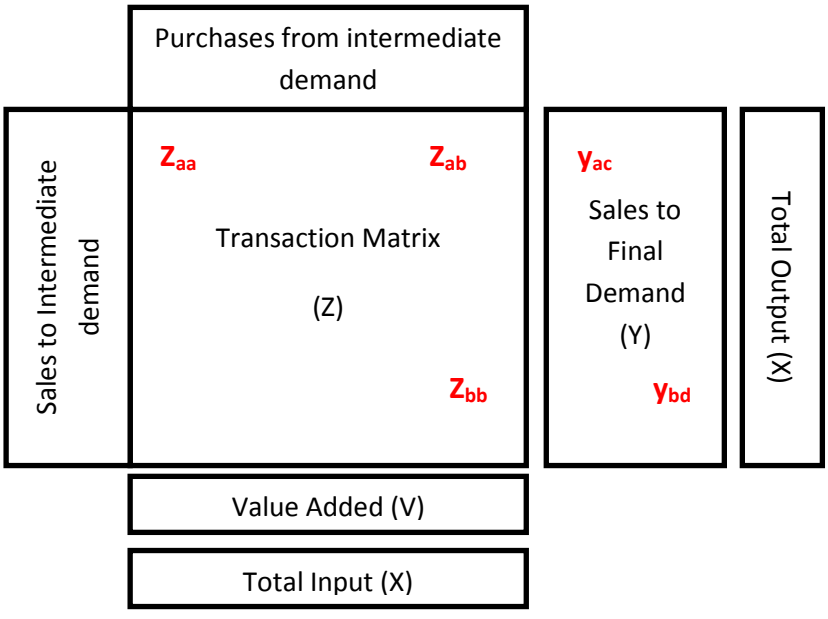


Figure 1: Basic structure of a Leontief Input-Output Model

This system can be expanded to the global scale by considering trade flows between every industry in the world rather than within a single country. This type of system is a multi-regional input-output (MRIO) table.

The total output (X_i) of a particular sector can be expressed as:

$$X_{i=}z_{i1} + z_{i2} + \cdots + z_{ij} + y_i \qquad (1)$$

where y_i is the final demand for that product produced by the particular sector. If each element, z_{ij}, along row i is divided by the output X_i , associated with the corresponding column j it is found in, then each element in Z can be replaced with:

$$a_{ij} = \frac{z_{ij}}{X_j} \qquad (2)$$

to form a new matrix *A*.

Substituting for (2) in equation (1) forms:

$$X_{i=}a_{i1}X_1 + a_{i2}X_2 + \cdots + a_{ij}X_i + y_i \qquad (3)$$

Which, if written in matrix notation is $X=AX + Y$.

Solving for X gives:

$$X = (I - A)^{-1}Y \qquad (4)$$

where X and Y are vectors of total output and final demand, respectively, I is the identity matrix, and A is the technical coefficient matrix, which shows the inter-industry requirements. $(I-A)^{-1}$ is known as the Leontief inverse (further identified as L). It indicates the inter-industry requirements of the i^{th} sector to deliver a unit of output to final demand.

The equation

$$X = LY \qquad (5)$$

shows that total output can be expressed by the product of the Leontief inverse matrix and the final demand vector.

If total final demand is replaced with $\widehat{Y_{uk}}$, a vector which places the elements of Y_{uk} on the principle diagonal, the result matrix LY_{uk} can be used to show the induced output, including intermediate and final demand, in all regions and sectors as a result of UK final demand.

Consider the vector of value added V, associated with each industrial sector. V_x is the value added per unit of output and multiplying both sides of (4) by V_x gives

$$V_xX = V_xLY \qquad (6)$$

which simplifies to

$$V = V_xLY \qquad (7)$$

This shows total GVA is equivalent to pre-multiplying the Leontief inverse by value added per unit of output and post-multiplying by final demand. This calculation can be used to show how a unit change in final demand Y, increases the value added by all industries to satisfy this change. Similarly, using the diagonalised vector of UK final demand allows the total GVA that is induced as a result of UK demand to be identified in each source sector and region.

3.2.Structural Path Analysis

In mathematics for certain types of functions, we can rewrite them as the sum of an infinite set of terms. For example,

$$(1-x)^{-1} = 1 + x + x^2 + x^3 + \cdots + x^n \qquad (8)$$

This is known as the Taylors expansion. From (4) and (8),

$$L = I + A + A^2 + A^3 + \ldots + A^n \qquad (9)$$

And substituting for (9) in (7) gives

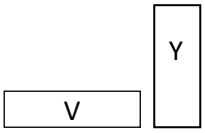
$$V = V_x \,.\, \left(I + A + A^2 + A^3 + \ldots + A^n\right).Y$$

This expansion approach to calculating the Leontief inverse means that we can examine the size of impacts at stages along a product's supply chain and also consider the size and character of individual paths in make-up of a products full supply chain impact.

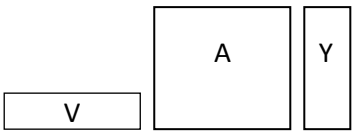
For example, direct GVA associated with an item of clothing product bought by UK consumers, would be any value added generated by the UK clothing industry or another clothing industry elsewhere in the world in making clothing products. This is known as a stage zero impact. Stage zero impacts are calculated by $V_x.Y_{uk}$. A stage one impact would be the GVA associated with making textiles that are then bought as intermediate demand by the clothing factory and are made into clothes bought by UK consumers. And the general equation for stage one impacts is $V_x \,.A.\, Y_{uk}$. Stage two might be the GVA associated with making the electricity that is bought by the textiles factory to make textiles bought by the clothing factory to make clothes bought by UK consumers and so on.

This project considers impacts from stages zero to five and in general nearly all of the total GVA is captured in the first five stages.

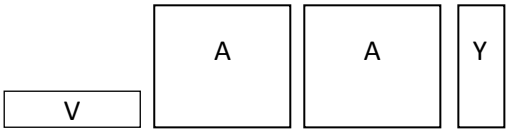
- Direct (stage 0) impacts = $V_x \,.\, Y_{uk}$



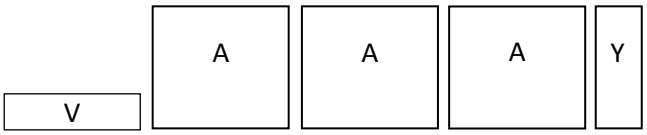
- Stage 1 impacts = $V_x \,.\, A \,.\, Y_{uk}$



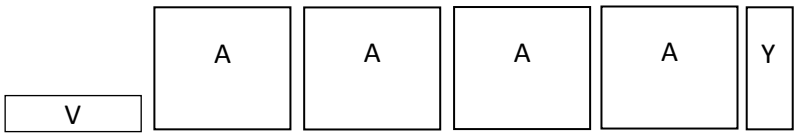
- Stage 2 impacts = $V_x \,.\, A.\, A.\, Y_{uk}$



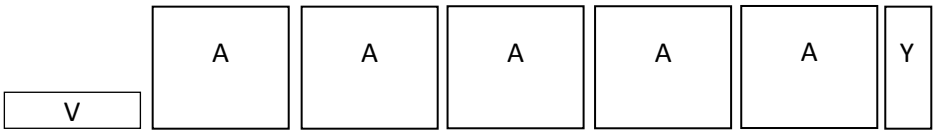
- Stage 3 impacts = $V_x \,.\, A.\, A.\, A.\, Y_{uk}$



- Stage 4 impacts = $V_x \,.\, A.\, A.\, A.\, A.\, Y_{uk}$



- Stage 5 impacts = $V_x \,.\, A.\, A.\, A.\, A.\, A.\, Y_{uk}$



We can calculate, for each product, the size of the GVA associated with each stage. The product stage impacts can also be broken down by source region. This allows analysis of the dependencies of other world region on UK consumption and how many stages apart they appear in the supply chain. For example, we can consider the impact of a clothing product bought in the UK and see the GVA in India that is directly (a stage 0 impact) due to UK consumption and compare this to the GVA that is indirect (i.e. stages 1 and above where there has been an intermediate transaction via another region or industry).

At an even greater level of detail, individual paths can be identified using structural path analysis. The path is constructed by multiplying together elements from each matrix that form a chain. In practice, this means that an element's row position is determined by the column position of the preceding matrix and its column position is the row position of the next one.

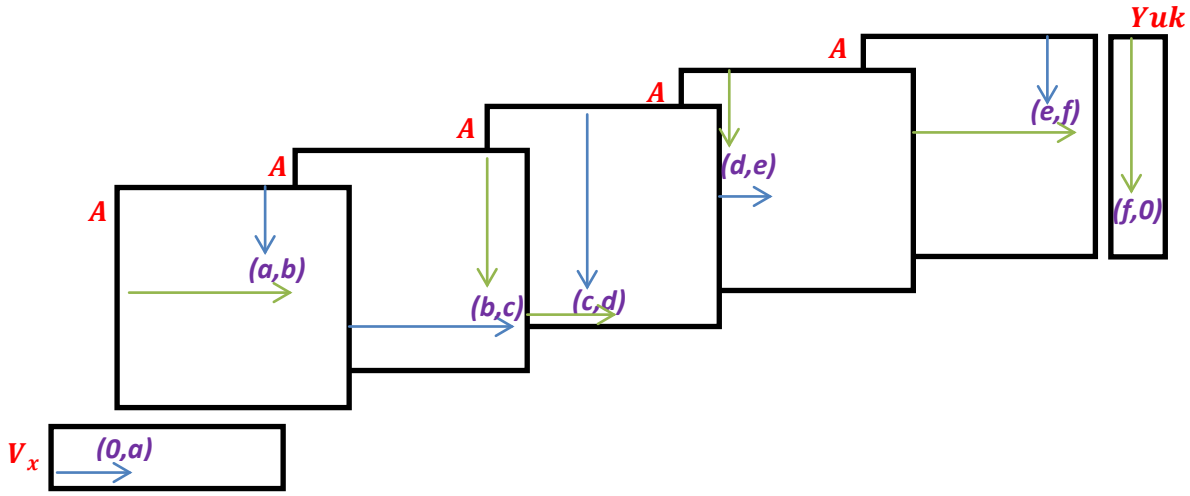


Figure 2: An example of a structural path construction

For example, the equation

$$V_{xa} \,.\, A_{ab}.\, A_{bc}.\, A_{cd}.\, A_{de}.\, A_{ef}.\, Yuk_f$$

can give information on the size of the GVA associated with industry 'a' as a result of consumption of product 'f' bought by UK consumers but only that portion of a's GVA that travel via industries b, c, d and e.

4. Results

4.1.Overview

The UK's GVA in 2007 calculated by the GTAP MRIO framework was 2,732 billion US dollars. The ONS reports GVA for 2007 as 1,274 billion GDP which, based on the average 2007 currency exchange rate, is 2,551 billion US dollars. The reason for the difference in these values is because the ONS GVA is GVA from domestic consumption plus exports, where-as the GTAP GVA is a measure of GVA from all UK consumption and covers domestic consumption and imports. The total GVA can be broken down in a number of ways. Firstly, we can consider a breakdown by products consumed by UK consumers as final demand. Here, 20% of GVA was generated by the consumption of services products and 24% in the consumption of Public Administration, Education and Defence products. The breakdown is different when we consider the source industries. For example, the GVA generated by the agricultural industry is three times higher than that of an agricultural product since much of agriculture is used to make food or other manufactured goods. Similarly the GVA associated with the vehicle industry is half that of the GVA of a vehicle product. For industries, Public Administration, Education and Defence accounts for 17% and Services 29%.

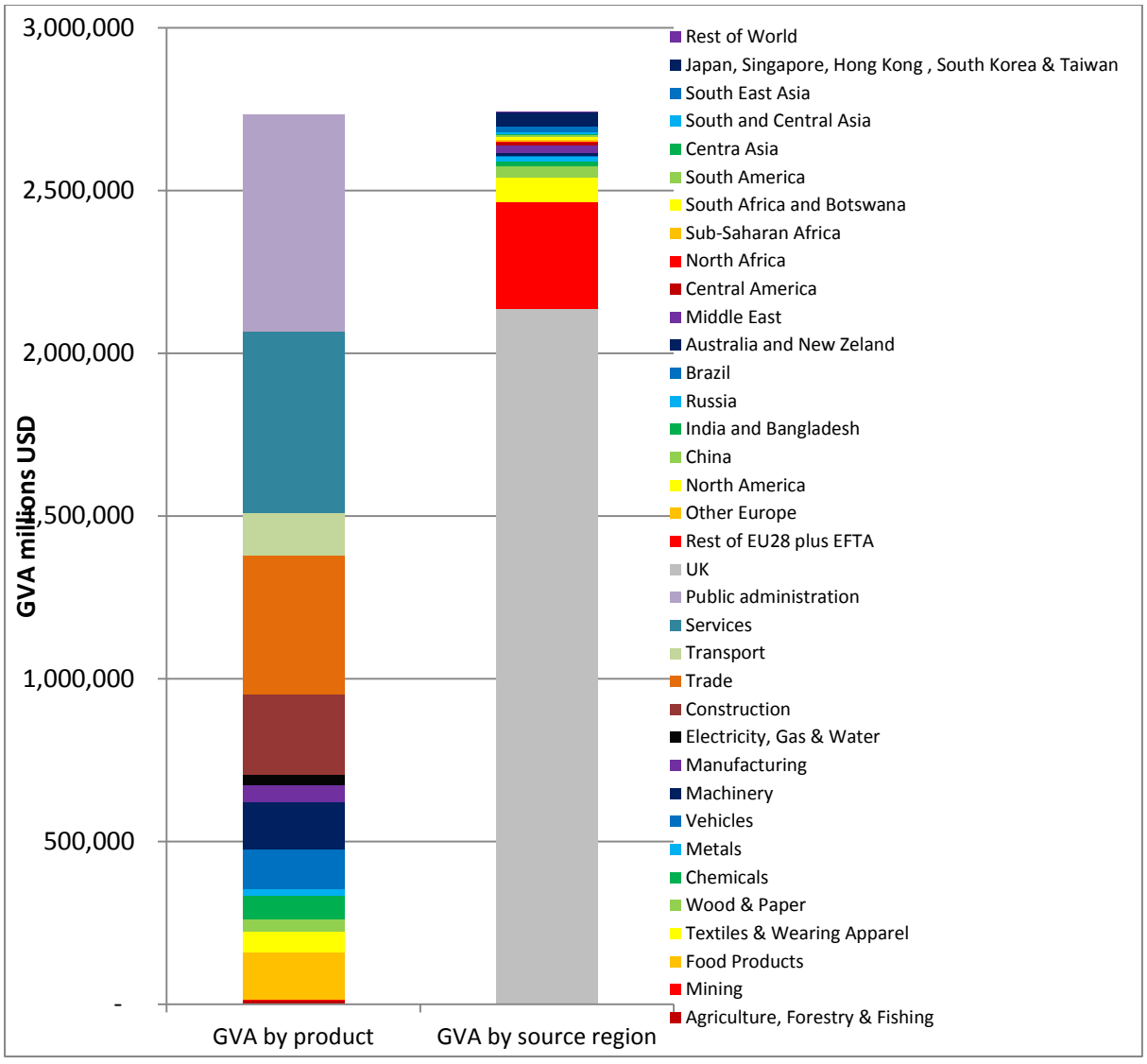


Figure 3: GVA broken down by product, source industry and source region

Alternatively, GVA can be broken down by source region. Here we find 78% of GVA stays in the UK with 12% in other EU28 nations, 3% North America, 1% in China, 1% in the Middle East, 1% in South East Asia and 1% in Japan, Singapore, Hong Kong and South Korea.

Product level breakdowns

We can perform a similar analysis at the product level, breaking down the GVA by source industry and region. In this section we concentrate on three products where the UK is reliant on production processes outside of its borders and other countries are therefore reliant on UK consumption. The three products chosen are Wearing Apparel, Motor Vehicles and Parts, and Electronic Equipment.

4.1.1. Wearing Apparel

Wearing Apparel products account for 1.1% of total GVA generated by UK consumption. The most significant portion of the GVA goes to Wearing apparel industries based in the UK (31%), followed by much smaller quantities going to UK Business services, Chinese Wearing apparel and Chinese textiles. Overall, 55% of GVA generated by UK consumption of wearing apparel products goes abroad with Germany, France, China and Spain being the largest regional partners.

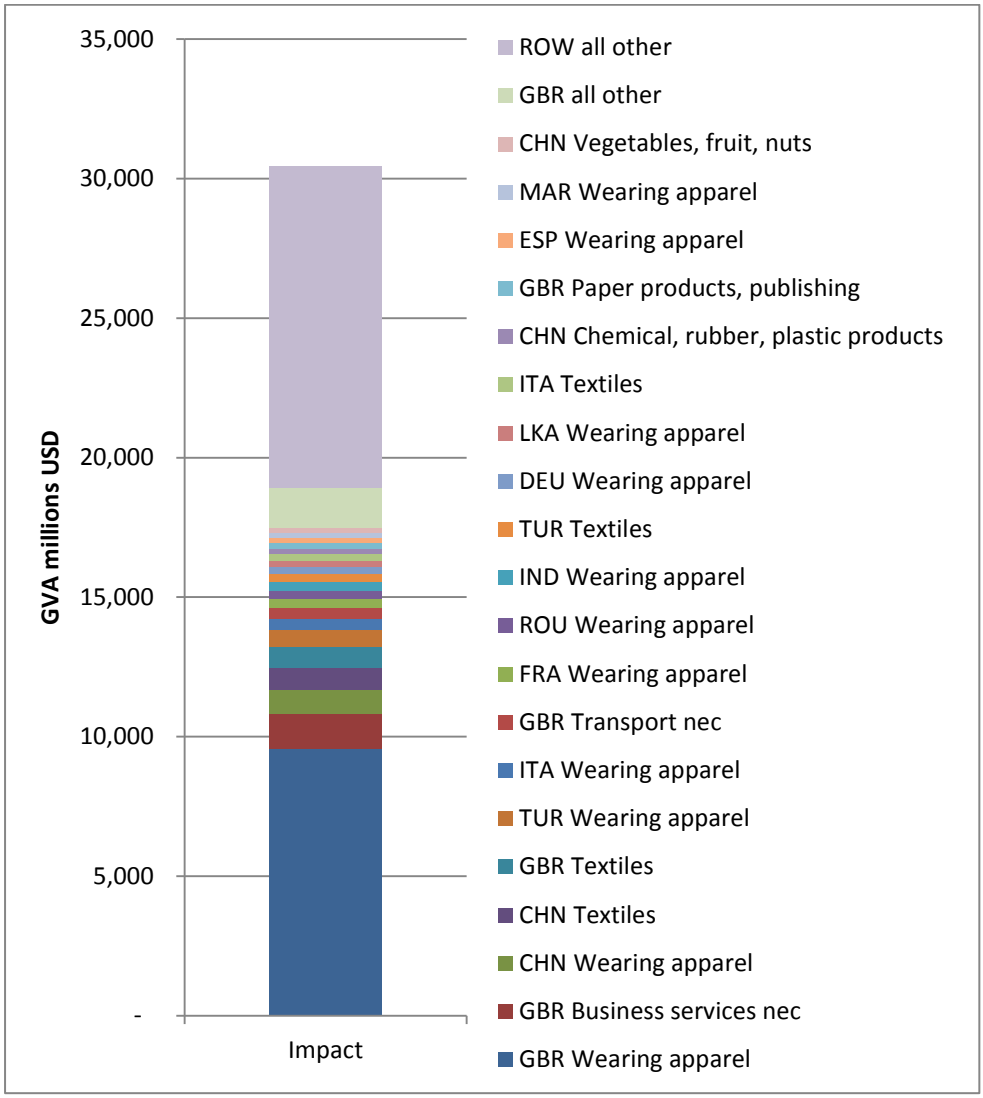


Figure 4: Breakdown of the GVA of Wearing Apparel products

4.1.2. Motor vehicles and parts

Products of motor vehicles and parts account for 3.7% of total GVA generated by UK consumption. The most significant portion of the GVA goes to motor vehicles and parts industries based in the UK (16%), followed by much smaller quantities going to German motor vehicles and parts industries, UK Business services, and German Business services. Overall, 69% of GVA generated by UK consumption of motor vehicles and parts goes abroad with Germany, Japan, France, Sweden and the USA being the largest regional partners.

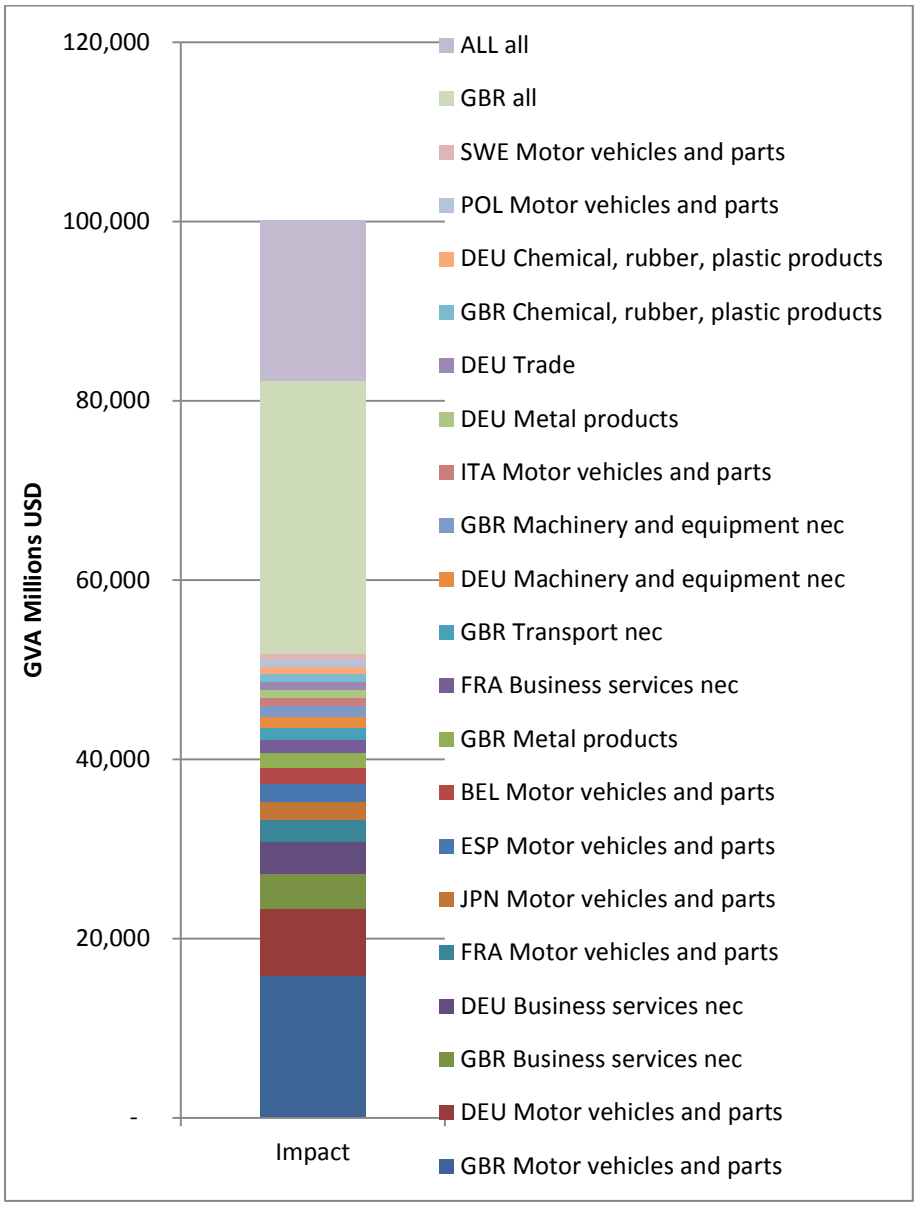


Figure 5: Breakdown of the GVA of Motor vehicles and parts

4.1.3. Electronic equipment

Products of electronic equipment account for 1.6% of total GVA generated by UK consumption. The most significant portion of the GVA goes to electronic equipment industries based in the UK (14%), followed by much smaller quantities going to Chinese electronic equipment, German electronic equipment, and UK Business services. Overall, 77% of GVA generated by UK consumption of electronic equipment products goes abroad with China, Germany and the USA being the largest regional partners.

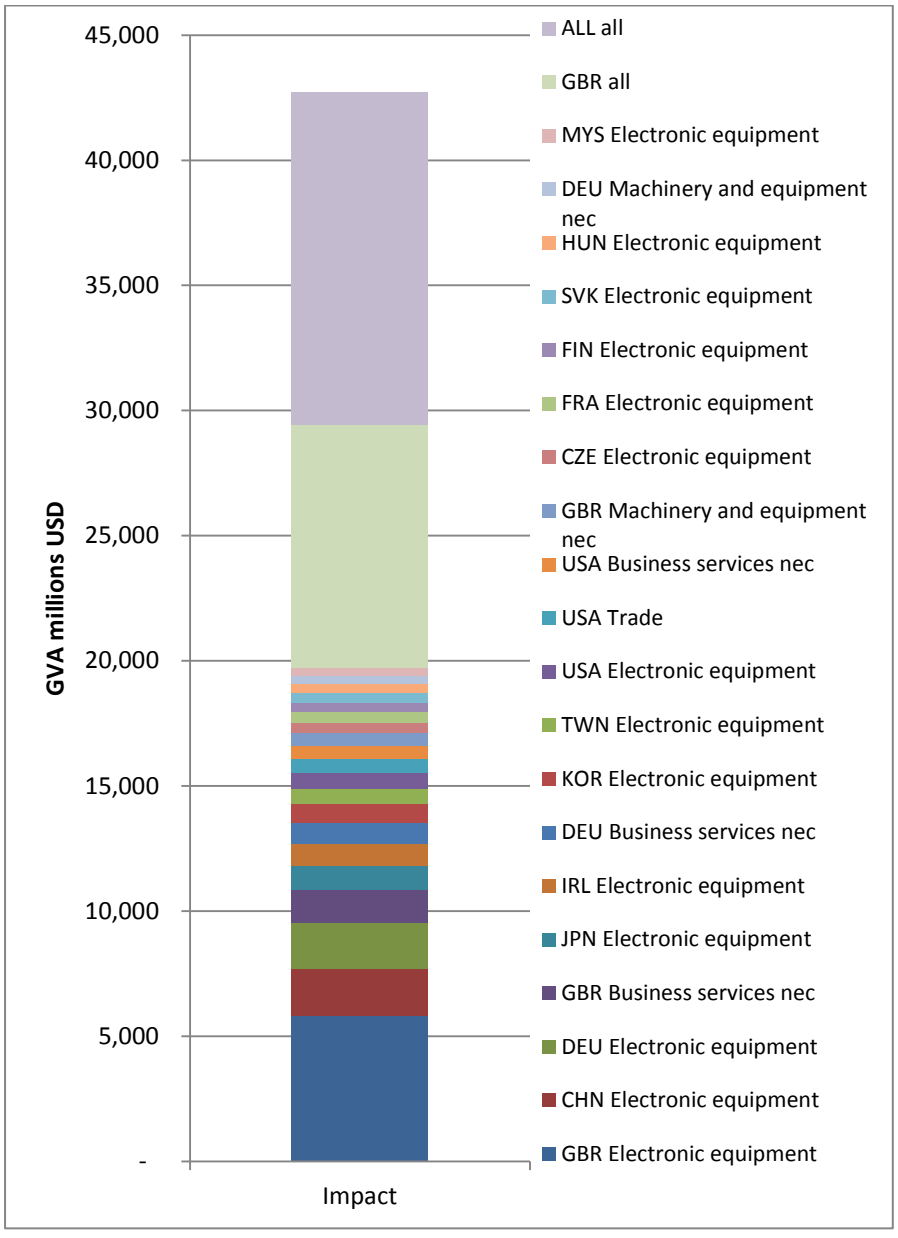


Figure 6: Breakdown of the GVA of Electronic Equipment

4.2.Supply Chain impacts

4.2.1. Wearing Apparel

Most GVA is generated at stage 0 of the supply chain (Figure 7). This is the value added in the finished wearing apparel products itself. The GVA drops off rapidly after stage 0 implying that most of the value is generated at the point of sale. The majority of value is generated in the UK at stages 0 and 1 of the supply chain – the stages closest to the finished article.

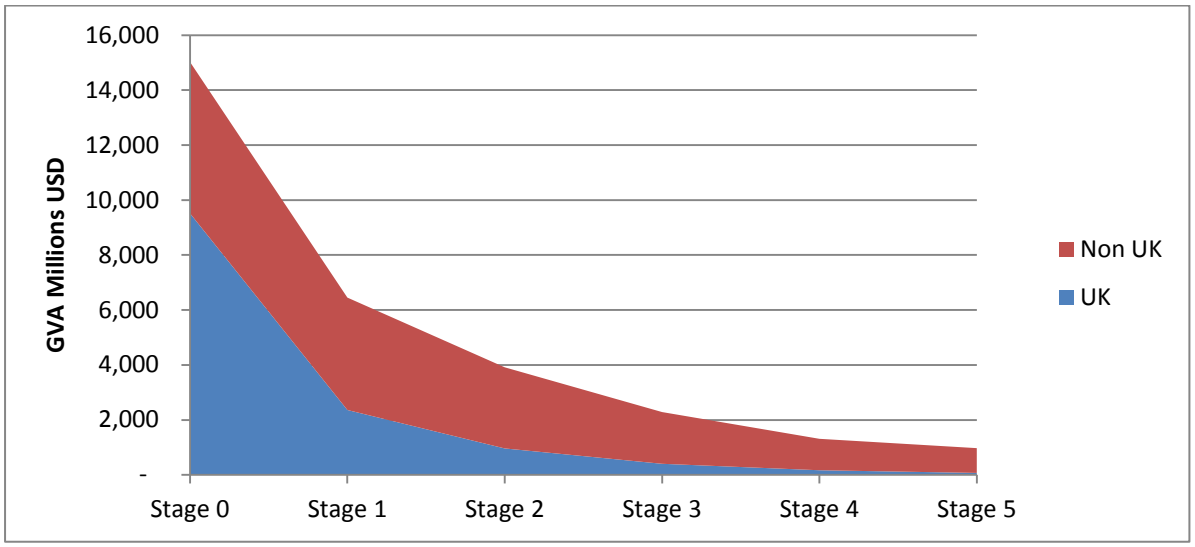


Figure 7: GVA in the supply chain for wearing apparel

Figure 8 breaks down the GVA from the UK's consumption of wearing apparel that is generated outside of the UK at each stage of the supply chain. We see that the regional share is reasonably even throughout the supply chain but with China accounting for an increasing proportion for higher stages due to these stages being closer to the raw material processing.

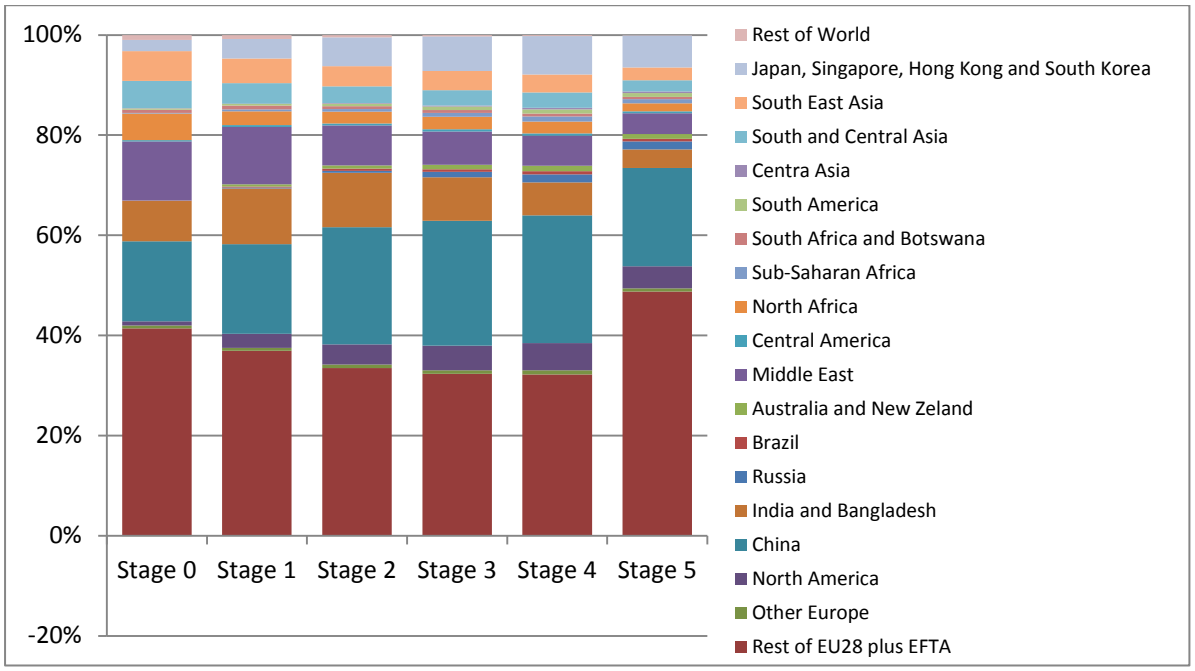


Figure 8: Breakdown of region activity at stages in the supply chain of wearing apparel

4.2.2. Motor vehicles and parts

The pattern observed for motor vehicles and parts is quite different to wearing apparel. Wearing apparel has high GVA in stage 0 and a rapid drop off whereas for motor vehicles and parts, stages 0 and 1 are both high. This implies that there is a large amount of GVA generated in the final production stages.

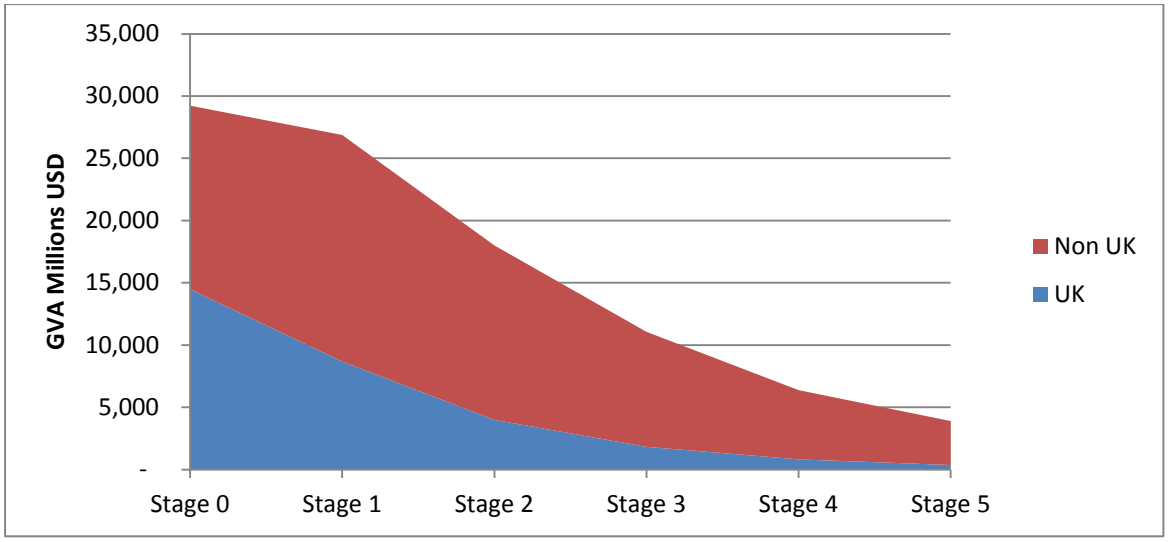


Figure 9: GVA in the supply chain of motor vehicles and parts

Figure 10 breaks down the GVA from the UK's consumption of motor vehicles and parts that is generated outside of the UK. We see the EU dominates the supply chain of motor vehicles consumed by the UK but that developing nations seem to have a greater role in stages 4 and 5 of the chain. These are the stages closest to the raw materials and furthest from the finished product where the greatest value is generated.

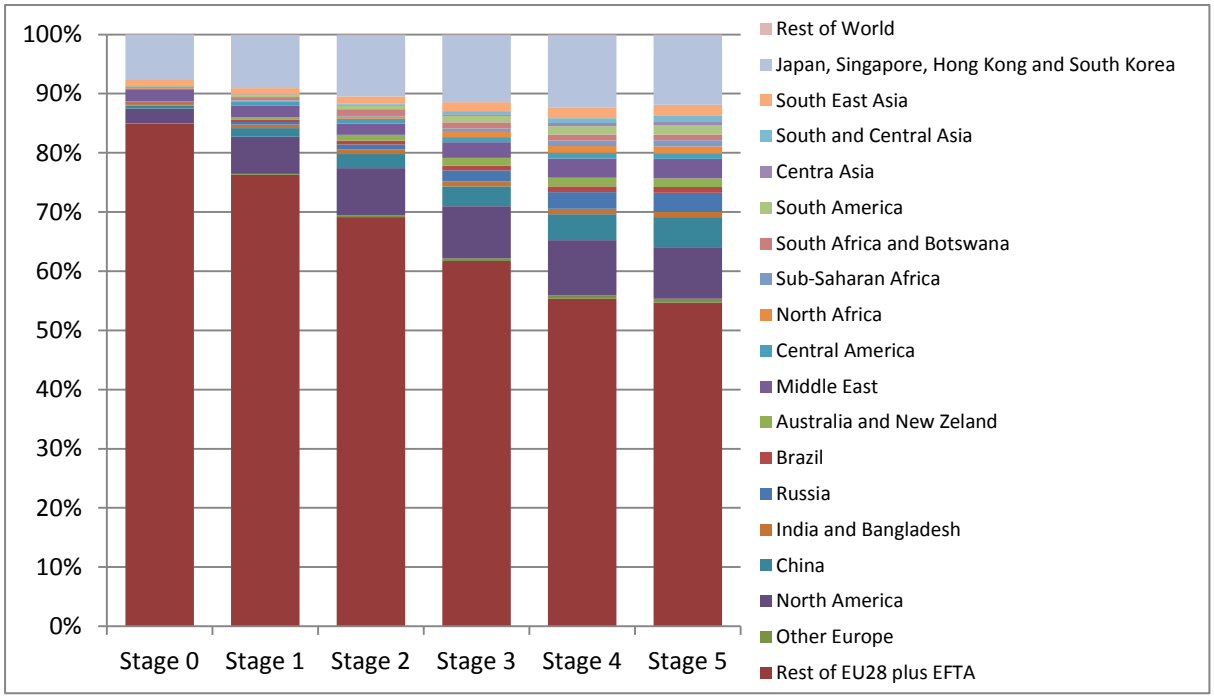


Figure 10: Breakdown of region activity at stages in the supply chain of motor vehicles and parts

4.2.3. Electronic equipment

Electronic equipment shows a steady decline in GVA along the supply chain (Figure 11).

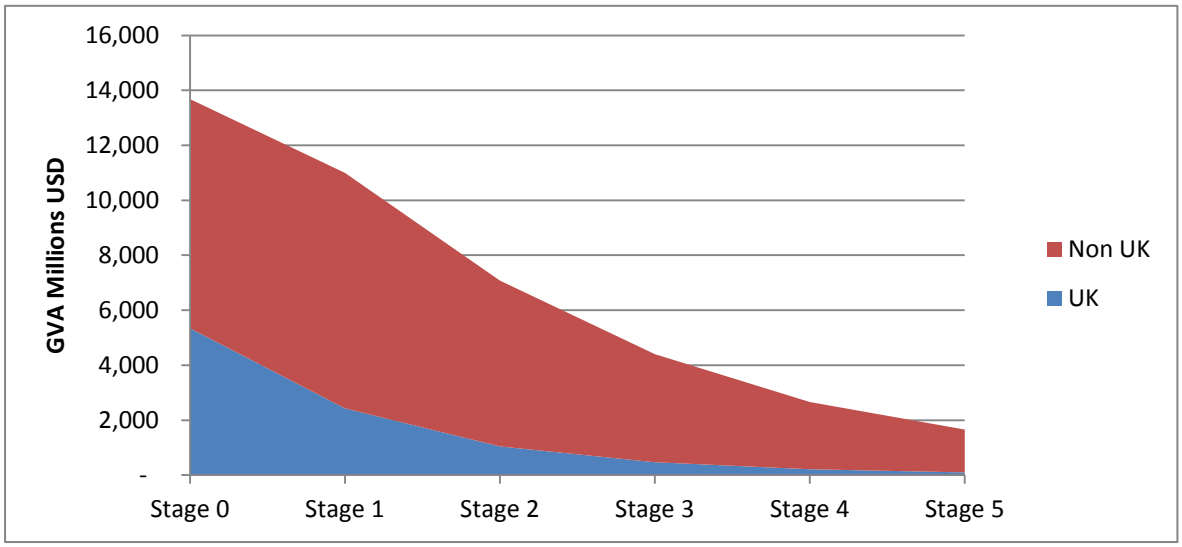


Figure 11: GVA in the supply chain for electronic equipment

Figure 12 breaks down the GVA from the UK's consumption of electronic equipment that is generated outside of the UK. We see that developing countries seem to have a greater role the in stages 4 and 5 of the chain. These are the stages closest to the raw materials and furthest from the finished product where the greatest value is generated.

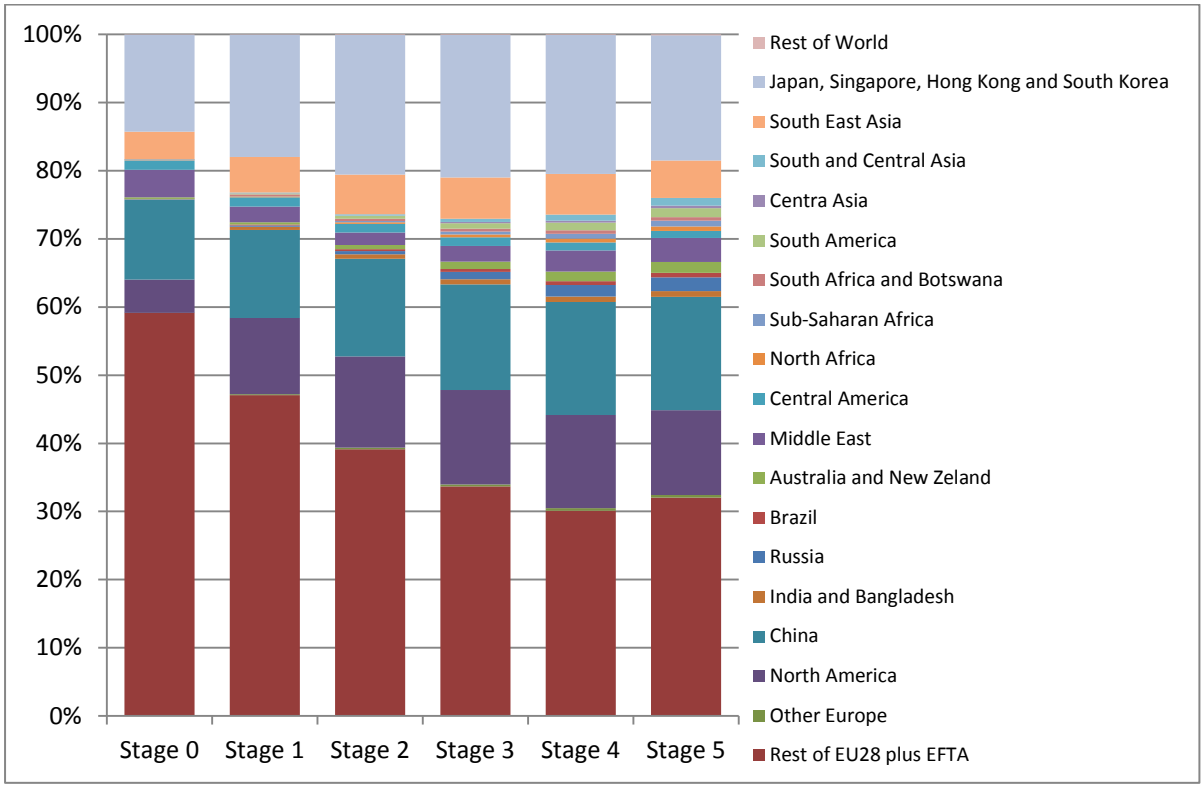


Figure 12: Breakdown of region activity at stages in the supply chain of electronic equipment

4.3.Largest paths

Finally we calculate the size of the very largest paths in a products' production.

4.3.1. Wearing Apparel

The largest path observed in the production of wearing apparel product is the path from the UK wearing apparel industry direct to the consumer. The third and fourth largest paths are stage 1 type paths which quantify the GVA associated with the business services and textiles bought by the wearing apparel industry. Path 20 is a stage 2 path but it represents less than half a percent of the total wearing apparel GVA.

	Source Region	Source Sector		to			to				
1	GBR	Wearing apparel	>	0	0	>	0	0	>	9,514.29	31%
2	CHN	Wearing apparel	>	0	0	>	0	0	>	846.51	3%
3	GBR	Business services nec	>	GBR	Wearing apparel	>	0	0	>	654.80	2%
4	GBR	Textiles	>	GBR	Wearing apparel	>	0	0	>	624.98	2%
5	TUR	Wearing apparel	>	0	0	>	0	0	>	589.00	2%
6	ITA	Wearing apparel	>	0	0	>	0	0	>	336.68	1%
7	CHN	Textiles	>	CHN	Wearing apparel	>	0	0	>	327.81	1%
8	ROU	Wearing apparel	>	0	0	>	0	0	>	304.25	1%
9	FRA	Wearing apparel	>	0	0	>	0	0	>	297.73	1%
10	IND	Wearing apparel	>	0	0	>	0	0	>	287.90	1%
11	DEU	Wearing apparel	>	0	0	>	0	0	>	257.11	1%
12	GBR	Transport nec	>	GBR	Wearing apparel	>	0	0	>	225.67	1%
13	LKA	Wearing apparel	>	0	0	>	0	0	>	220.15	1%
14	ESP	Wearing apparel	>	0	0	>	0	0	>	183.46	1%
15	MAR	Wearing apparel	>	0	0	>	0	0	>	169.44	1%
16	TUR	Textiles	>	TUR	Wearing apparel	>	0	0	>	147.52	0%
17	BEL	Wearing apparel	>	0	0	>	0	0	>	145.46	0%
18	BGD	Wearing apparel	>	0	0	>	0	0	>	142.70	0%
19	GBR	Paper products, publishing	>	GBR	Wearing apparel	>	0	0	>	120.82	0%
20	GBR	Business services nec	>	GBR	Business services nec	>	GBR	Wearing apparel	>	115.59	0%
	All									14,937.51	49%
	Total									30,449.38	100%

4.3.2. Motor vehicles and parts

The largest path observed in the production of motor vehicles and parts products is the path from the UK motor vehicles and parts industry direct to the consumer followed by the direct path from German motor vehicles and parts to the consumer.

	Source Region	Source Sector		to			
1	GBR	Motor vehicles and parts	>	0	0	14,490.75	14%
2	DEU	Motor vehicles and parts	>	0	0	4,992.61	5%
3	GBR	Business services nec	>	GBR	Motor vehicles and parts	1,707.28	2%
4	FRA	Motor vehicles and parts	>	0	0	1,577.54	2%
5	BEL	Motor vehicles and parts	>	0	0	1,533.96	2%
6	GBR	Metal products	>	GBR	Motor vehicles and parts	1,322.90	1%
7	ESP	Motor vehicles and parts	>	0	0	1,321.96	1%
8	DEU	Business services nec	>	DEU	Motor vehicles and parts	1,220.01	1%
9	DEU	Motor vehicles and parts	>	DEU	Motor vehicles and parts	979.38	1%
10	JPN	Motor vehicles and parts	>	0	0	941.56	1%
11	GBR	Motor vehicles and parts	>	GBR	Motor vehicles and parts	926.64	1%
12	GBR	Machinery and equipment nec	>	GBR	Motor vehicles and parts	877.34	1%
13	GBR	Transport nec	>	GBR	Motor vehicles and parts	660.55	1%
14	ITA	Motor vehicles and parts	>	0	0	633.56	1%
15	GBR	Chemical, rubber, plastic products	>	GBR	Motor vehicles and parts	497.94	0%
16	POL	Motor vehicles and parts	>	0	0	457.97	0%
17	SWE	Motor vehicles and parts	>	0	0	445.53	0%
18	JPN	Motor vehicles and parts	>	JPN	Motor vehicles and parts	414.20	0%
19	DEU	Machinery and equipment nec	>	DEU	Motor vehicles and parts	384.32	0%
20	FRA	Business services nec	>	FRA	Motor vehicles and parts	361.46	0%
	All					64,423.17	64%
	total					100,170.62	100%

4.3.3. Electronic equipment

The largest path observed in the production of electronic equipment product is the path from the UK electronic equipment industry direct to the consumer.

	Source Region	Source Sector		to			
1	GBR	Electronic equipment	>	0	0	5,341.82	12%
2	DEU	Electronic equipment	>	0	0	1,407.48	3%
3	CHN	Electronic equipment	>	0	0	982.26	2%
4	IRL	Electronic equipment	>	0	0	703.52	2%
5	GBR	Business services nec	>	GBR	Electronic equipment	635.92	1%
6	KOR	Electronic equipment	>	0	0	437.52	1%
7	JPN	Electronic equipment	>	0	0	404.25	1%
8	GBR	Machinery and equipment nec	>	GBR	Electronic equipment	360.73	1%
9	DEU	Business services nec	>	DEU	Electronic equipment	326.68	1%
10	SVK	Electronic equipment	>	0	0	320.57	1%
11	CZE	Electronic equipment	>	0	0	315.50	1%
12	USA	Electronic equipment	>	0	0	304.92	1%
13	FRA	Electronic equipment	>	0	0	299.53	1%
14	GBR	Electronic equipment	>	GBR	Electronic equipment	299.31	1%
15	CHN	Electronic equipment	>	CHN	Electronic equipment	271.21	1%
16	FIN	Electronic equipment	>	0	0	268.16	1%
17	ESP	Electronic equipment	>	0	0	268.10	1%
18	TUR	Electronic equipment	>	0	0	243.36	1%
19	HUN	Electronic equipment	>	0	0	239.21	1%
20	USA	Trade	>	USA	Electronic equipment	221.98	1%
	All					29,083.10	68%
	total					42,735.15	100%

5. Discussion

This study used the GTAP MRIO model to understand the globalised nature of UK consumption for the year 2007. By tracing the GVA through the supply chain of products purchased by UK consumers we are able to quantify the GVA generated in 127 other world regions. The study focuses in detail on the consumption of three products: wearing apparel; motor vehicles and parts; and electronic equipment. These particular products have much of their supply chain abroad and the analysis reveals the GVA that is generated at difference stages in the supply chain in non-domestic countries as a result of UK consumption of these products.

This type of analysis could be used together with additional data that ranks countries in terms of their vulnerability or resilience to climate change. This combination of data on the dependence on UK trade and a countries' vulnerability to extreme weather events could help to indicate future risks to UK consumption.

The construction of MRIO tables involves the collection and manipulation of large databases. The final MRIO table is inevitably the result of a combination of choices and compromises made by the agency responsible for its construction. These choices include the source data; the choice of sector classification or regions; and how to overcome missing information, alignment of the data with a common currency, and how to balance tables. National IO tables are submitted to GTAP by GTAP consortium members. This data then has to be matched to the 57 GTAP sectors. Often, to disaggregate a country's non-agricultural sectors, the structure from other IO tables within regional groupings is used. For agricultural sectors, yield data from the Food and Agriculture Organization (FAO) is used to disaggregate the agriculture sector. These types of sectoral level uncertainties mean that results need to be viewed with some caution. Confidence is highest at the country total level and reduces when considering sectoral totals. Data showing the breakdown of sectoral totals – i.e. into supply chain impacts will be subject to further uncertainty.

Studies using MRIO models to consider global distribution of GVA are cutting edge since it is only recently that we have had the data available and the computing power to handle it. As this field of research grows and becomes more established, models will become more detailed and there will be more studies into their accuracy and usefulness.