



# Slicing Up Global Value Chains

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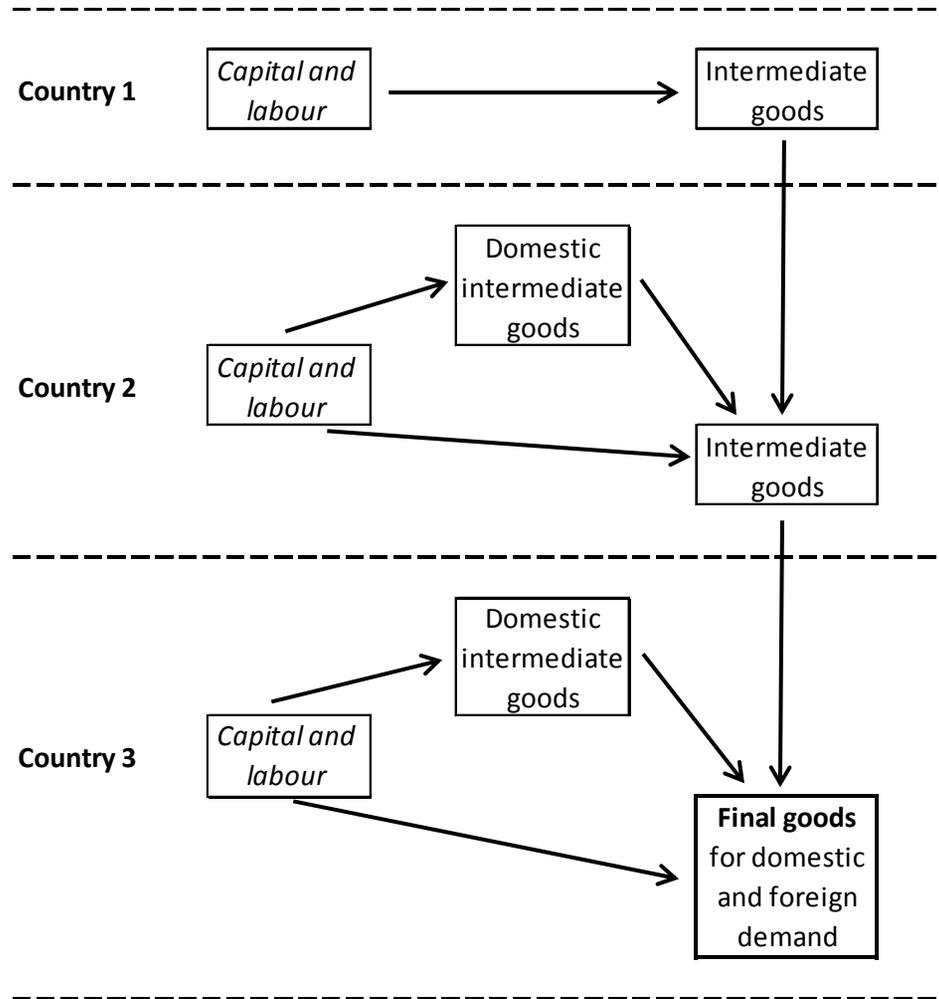
## Aims of this study

- International production fragmentation (IPF): unbundling of production processes into “tasks” which are carried out in different countries.
- IPF has a long history (Feenstra 1998), but accelerated since the mid 1990s with global labour supply shock due to opening up of China and India.
- Aim of this explorative study to measure :
  - the trends in IPF for global production of manufacturing goods
  - patterns of factor income distributions within vertically integrated production (denoted by “global value chains”)
- Macro-economic equivalent of the product case studies, like of iPod, Dedrick et al, (2010)

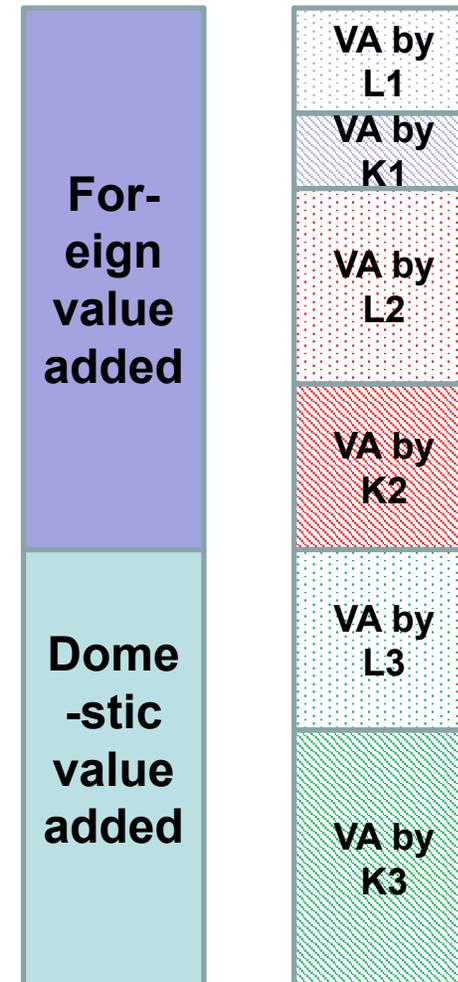


# Factor content of a global value chain: graphical representation

## Production process of a good



## Value of good





## Main findings

- Basically an accounting exercise to provide stylised facts that can serve as starting point for deeper analysis of causes and consequences of IPF.
  
- We find three trends in global production of manufactures since 1995:
  1. International production fragmentation has increased rapidly (but there is still a large share of domestic value added)
  2. Globally, increasing shares of value added by capital and high-skilled workers
  3. Similar shifts in factor content within countries and within sectors



## Related literature

- Our method is based on Leontief's (1936) input-output decomposition technique, applied to a new industry-level database of global input-output transactions: World Input-Output Database (WIOD)
  
- Variations of this approach are also used in literature on
  - *vertical specialisation in trade*: Johnson and Noguera (2012, JIE) who extended Hummels, Iishi and Yi (2001, JIE) multi-regional.
  - *Value added content of exports*: Koopman, Wei and Zhang (forthcoming AER) and Bems, Johnson and Yi (2011, AER)
  - *Factor content of trade*: Reimer (2006, JIE) and Trefler and Zhu (2010, JIE)
  
- Our analysis starts from vertical integrated production chain of final goods
  - *Length of production chains*: Dietzenbacher and Romero (2007, IRSR) and Antràs et al. (2012, AER) who compute the average number of 'transactions' a dollar will go through before final use.



## Prelims

Product  $i$ , = 1,...,I ; Country  $j$ , = 1,...,J; Production factor  $k$ , = 1,...,K

$Y(i,j)$  = final output of product  $i$  completed in country  $j$

$Z(h,i,j)$  = intermediate use by country  $h$  of product  $(i,j)$

$F(k,h)(i,j)$  = quantity of production factor  $k$  located in country  $h$ , used in production of product  $(i,j)$

### **Neo-classical gross output production function:**

$$Y(x,c) + \sum_j Z(j,x,c) = \mathcal{A} ( F(k,c)(x,c) ; Z(c,i,c); Z(c,i,\neq c) ) \quad (\text{in quantities})$$

Gross output = value added + domestic interm.+ imports (*in values*)



## Prelims: Vertically integrated production

**Vertically integrated production function**, as in Von Neumann / Leontief / Sraffa (1960) tradition:

$$Y(x,c) = \mathcal{B} ( F(k,c)(x,c) ; F(k,\neq c)(x,c) ) \quad (\text{in quantities})$$

Final output = value added in all activities *(in values)*

More formally, let  $P$  denote price, then one may write the *value added accounting identity for vertically integrated production* (Pasinetti, *MetE*1973):

$$P(x,c)Y(x,c) = \sum_j \sum_k P(k,j)F(k,j)(x,c) \quad (1)$$



## Prelims: Vertically integrated production

- Problem is that vertically integrated production is typically not observable due to joint production and multiple use of intermediates.
- Leontief's (1936) solution: model the production system in an economy by a set of linear equations, one for each product  $(x,c)$ , (the so-called Leontief production functions)
- Using this one can derive a decomposition method, given prices, for a set of  $F(k,h)(x,c)$  such that:
  1. the value added identity (1) holds for all products, and
  2. endowment identity:  $\sum_i \sum_j F(k,h)(i,j) = F^*(k,h)$ , holds for all  $(k,h)$ , with  $F^*$  the endowment of factor  $k$  in country  $h$



## Prelims decomposition method

This set of  $F(k,h)(x,c)$  can be found by:

$$\mathbf{F} = \mathbf{R}(\mathbf{I} - \mathbf{Z})^{-1}\mathbf{Y} \quad (2)$$

$\mathbf{Y}$  matrix of final output of all products (i,j);

$\mathbf{Z}$  the matrix of intermediate input use of all products per unit of output for each product;

$\mathbf{I}$  is identity matrix and  $(\mathbf{I} - \mathbf{Z})^{-1}$  is the Leontief inverse ( $= 1 + \mathbf{Z} + \mathbf{Z}^2 + \mathbf{Z}^3 + \dots$ );

$\mathbf{R}$  a matrix with direct factor requirements per unit of gross output of (x,c) with elements  $[P(k,c)F(k,c)(x,c)] / [P(x,c)(Y(x,c) + Z(x,c))]$

(NB All matrices of the appropriate dimensions with elements in values)



## Two new measures

1. The foreign value added share (FVAS) in a final product (x,c)

$$FVAS(x,c) = 1 - \sum_k P(k,c)F(k,c)(x,c) / P(x,c)Y(x,c) \quad (3)$$

This is an indicator of international production fragmentation

2. Factor  $k$  cost shares in vertical integrated production a final product (x,c)

$$FCS(k,x,c) = \sum_j P(k,j)F(k,j)(x,c) / P(x,c)Y(x,c) \quad (4)$$

These indicate the factor content of production of the product

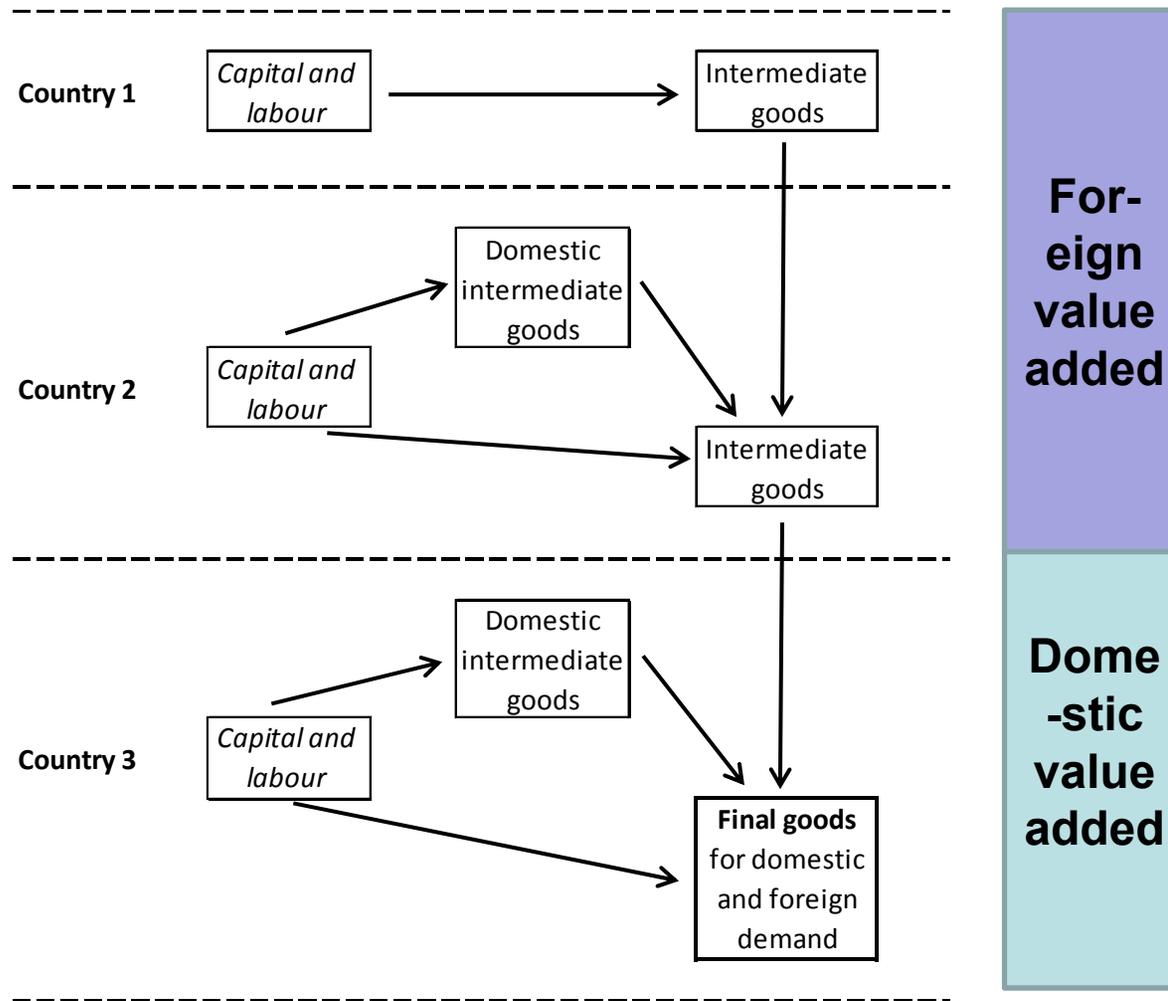


# DATA: World Input-Output Tables

- **World Input-Output Table (WIOT)** represents flows of goods and services across industries *and* countries (40 countries and rest-of-the-world region), 1995-2008. Two data challenges in construction:
  - 1. Times-series of input-output tables.**
    - Based on harmonised official benchmark national supply and use tables (34 industries and 59 product groups)
    - Adjusted to, and interpolated with, industry output and main final demand time series from the National Accounts (RAS-like method)
  - 2. Allocation of imports to three use categories**
    - using improved BEC-classification (based on COMTRADE HS 6-digit level) rather than standard proportionality assumption (Feenstra and Jensen, 2012)
    - Breakdown of imports by country of origin, using bilateral trade statistics on goods and services (export shares by mirroring imports)

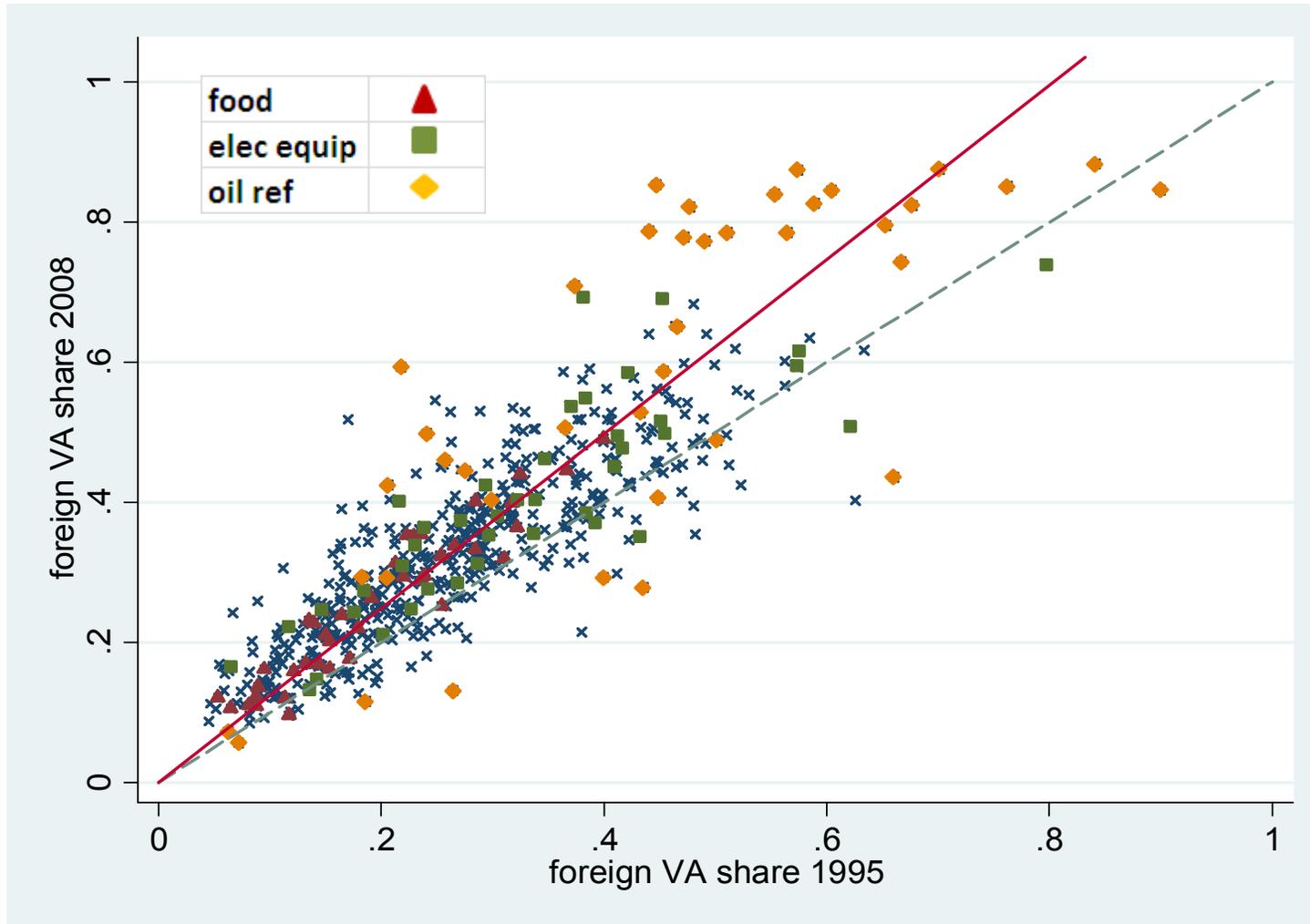


# Factor content of a global value chain: graphical representation





## FACT 1 : Increasing fragmentation between 1995 and 2008, but domestic value added remains high



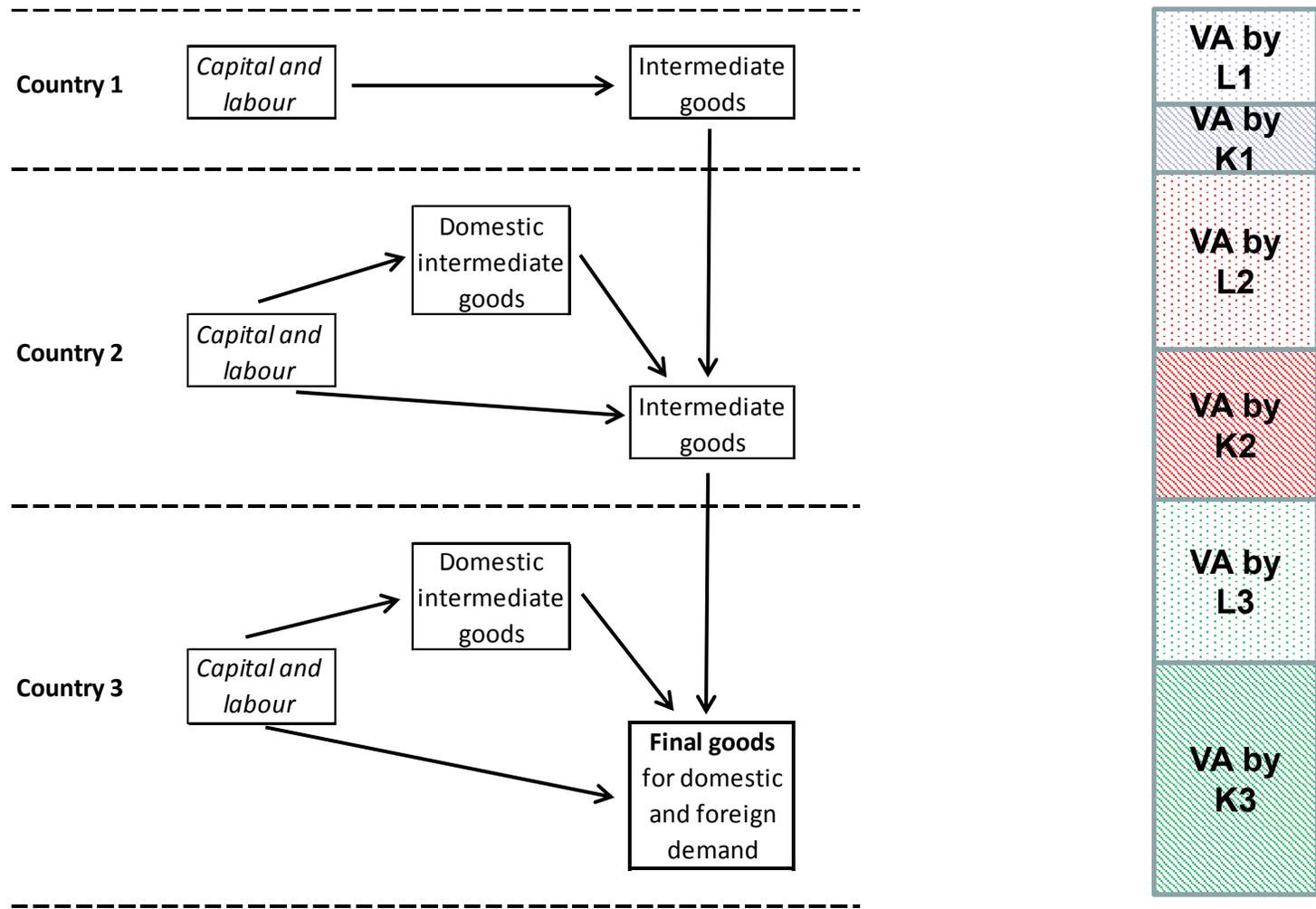
Foreign value added share in final output of each of 14 manufacturing industries in 40 countries

Solid line is OLS with significant slope of 1.20.

NB Output is at basic (ex-factory gate) prices



# Factor content of a global value chain: graphical representation



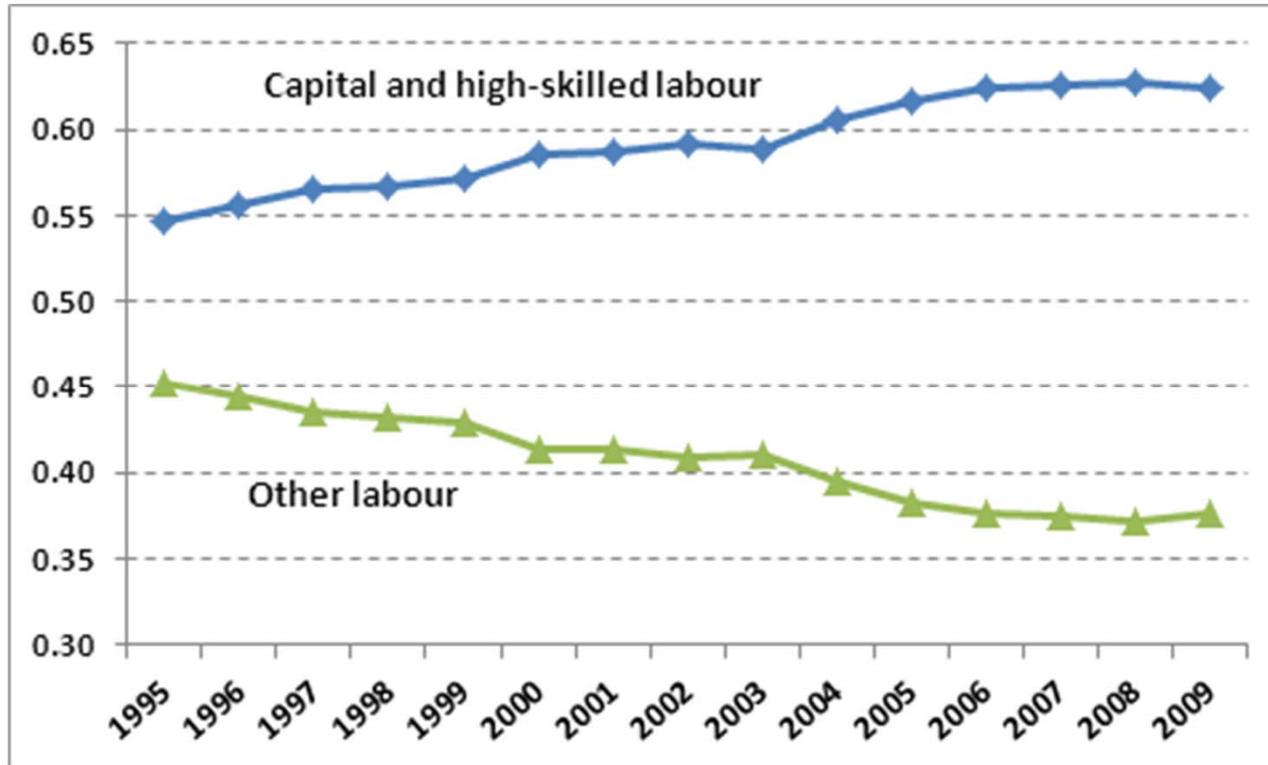


## DATA: factor incomes by industry-country

- **Wages and quantities of labour** by skill type
  - Number of workers (incl. self-employed) by three skill types based on levels of educational attainment (ISCED classification)
  - Wages reflect total costs for employer, including imputed wage for self-employed workers (Gollin, JPE, 2002)
  - For advanced countries data taken from EU KLEMS database (see O'Mahony and Timmer, 2009)
  - Other countries: similar methodology based on country-specific labour force surveys and additional materials (Erumban et al., 2011)
- **Capital income** is defined as residual such that the accounting identity will hold:
  - capital income = *value added minus labour compensation*.
  - It reflects income to all capital assets, including intangibles



## FACT 2 Increasing value added by capital and high-skilled labor, globally



Note: The graph shows value added by factors as share of global final manufactures output.



## FACT 3 Increasing value added by capital and high-skilled labor in most value chains

	Observations > 0
<b>Value added by capital and high-skilled labor</b>	<b>83%</b>
high-skilled	93%
capital in mining	96%
capital in non-mining	47%
<b>Value added by other labor</b>	<b>17%</b>
low-skilled	9%
medium-skilled	44%

### Change in value added shares by factors in 560 detailed manufactures GVCs

Note: Observations are the percentage change in the share of a production factor in total value added in a particular industry-country GVC between 1995 and 2008.

Capital split into *mining capital* (defined as capital in mining sector) and *non-mining capital* (other sectors).



## Change in value added shares by factors in 560 detailed manufactures GVCs (% points)

	Observations > 0	First quartile	Median	Third quartile	Ave- rage	Weighted average
<b>Value added by capital and high-skilled labor</b>	<b>83%</b>	<b>2.1</b>	<b>6.5</b>	<b>10.5</b>	<b>6.3</b>	<b>8.0</b>
high-skilled	93%	2.3	4.0	5.4	3.9	1.5
capital in mining	96%	1.2	1.8	3.3	3.1	4.1
capital in non-mining	47%	-5.3	-0.6	3.8	-0.8	2.4
<b>Value added by other labor</b>	<b>17%</b>	<b>-10.5</b>	<b>-6.5</b>	<b>-2.1</b>	<b>-6.3</b>	<b>-8.0</b>
low-skilled	9%	-8.2	-4.7	-1.8	-5.4	-3.8
medium-skilled	44%	-4.2	-0.8	2.5	-1.0	-4.2

*Note:* Observations are the percentage change in the share of a production factor in total value added in a particular industry-country GVC between 1995 and 2008.



## Possible determinants of factor value added shares

From production theory: change in cost shares can be explained by:

- changes in factor prices,
- substitution elasticities across all factors in all countries and
- factor-biased technical change

Some loose suggestions:

- Declining costs of international fragmentation has increased substitution possibilities of low-skilled labour across countries
- Prices of natural resources increased + limited substitution possibilities
- Declining ICT prices + complementarity of ICT and high skills
- Expansion of demand for final products with large fixed capital costs (e.g. brand names or software system) in imperfect sales markets



## Concluding remarks

- This paper proposed a new method to identify and analyse the factor content of vertically integrated production at a macro-economic level.
- Based on the new world input-output database (WIOD) we found three trends in GVCs of manufactures:
  1. International production fragmentation has increased rapidly (but there is still a large share of domestic value added)
  2. Globally, increasing shares of value added by capital and high-skilled workers
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## More information

- For more information, see accompanying WIOD working papers “Fragmentation, Income and Jobs” and “Slicing up Global Value Chains” (downloadable from wiod website).
  
- **WIOD database**
  - Is publicly available at [www.wiod.org](http://www.wiod.org)
  - Offers many more opportunities for analysis, e.g. also includes environmental accounts
  - Is a proto-type database as many statistical challenges remain and will need coordinated international effort to bring forward as now put forward by e.g. OECD/WTO Trade in value added project.



## **Additional material**



## Simple illustration of GVC income concept and why exports stats are misleading

EU demand for CARS produced in EU: 100 million euro

### Activities needed for producing a CAR:

- (A) Assembly: value added is 10% of car value
- (B) Component manufacturing: 30%
- (C) Branding: 60%

Activities carried		GVC income		Exports by EU
EU	Non-EU	EU	Non-EU	
A,B,C	-	100	0	0
B,C	A	90	10	30
C	A,B	60	40	0
-	A,B,C	0	100	0



# A stylized world input-output table

	Intermediate use ( $S$ columns per country)			Final use ( $C$ columns per country)			Total
	1	...	$N$	1	...	$N$	
S Industries, country 1	$\mathbf{Z}^{11}$	$\mathbf{Z}^{1\cdot}$	$\mathbf{Z}^{1N}$	$\mathbf{F}^{11}$	$\mathbf{F}^{1\cdot}$	$\mathbf{F}^{1N}$	$\mathbf{x}^1$
...	$\mathbf{Z}^{\cdot 1}$	$\mathbf{Z}^{\cdot\cdot}$	$\mathbf{Z}^{\cdot N}$	$\mathbf{F}^{\cdot 1}$	$\mathbf{F}^{\cdot\cdot}$	$\mathbf{F}^{\cdot N}$	$\mathbf{x}^{\cdot}$
S Industries, country $N$	$\mathbf{Z}^{N1}$	$\mathbf{Z}^{N\cdot}$	$\mathbf{Z}^{NN}$	$\mathbf{F}^{N1}$	$\mathbf{F}^{N\cdot}$	$\mathbf{F}^{NN}$	$\mathbf{x}^N$
Value added	$(\mathbf{w}^1)'$	$(\mathbf{w}^2)'$	$(\mathbf{w}^N)'$				
Output	$(\mathbf{x}^1)'$	$(\mathbf{x}^2)'$	$(\mathbf{x}^N)'$				

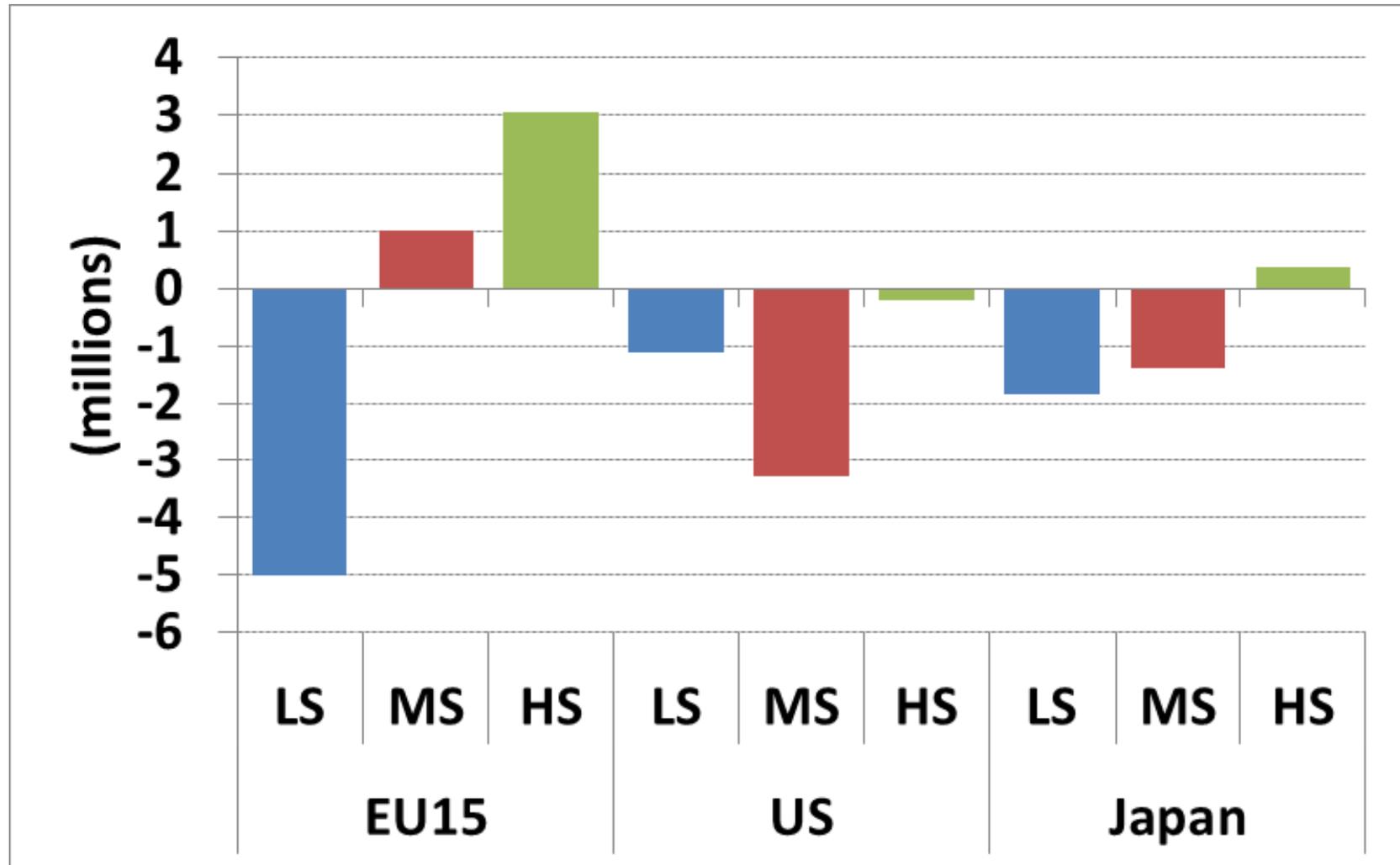


## Slicing up global value chains (% of final output value)

	Transport equipment from Germany		Electrical machinery from China	
	1995	2008	1995	2008
<b>Domestic value added</b>	79	66	78	69
<b>Foreign value added</b>	21	34	22	31
<b>Total final output</b>	100	100	100	100

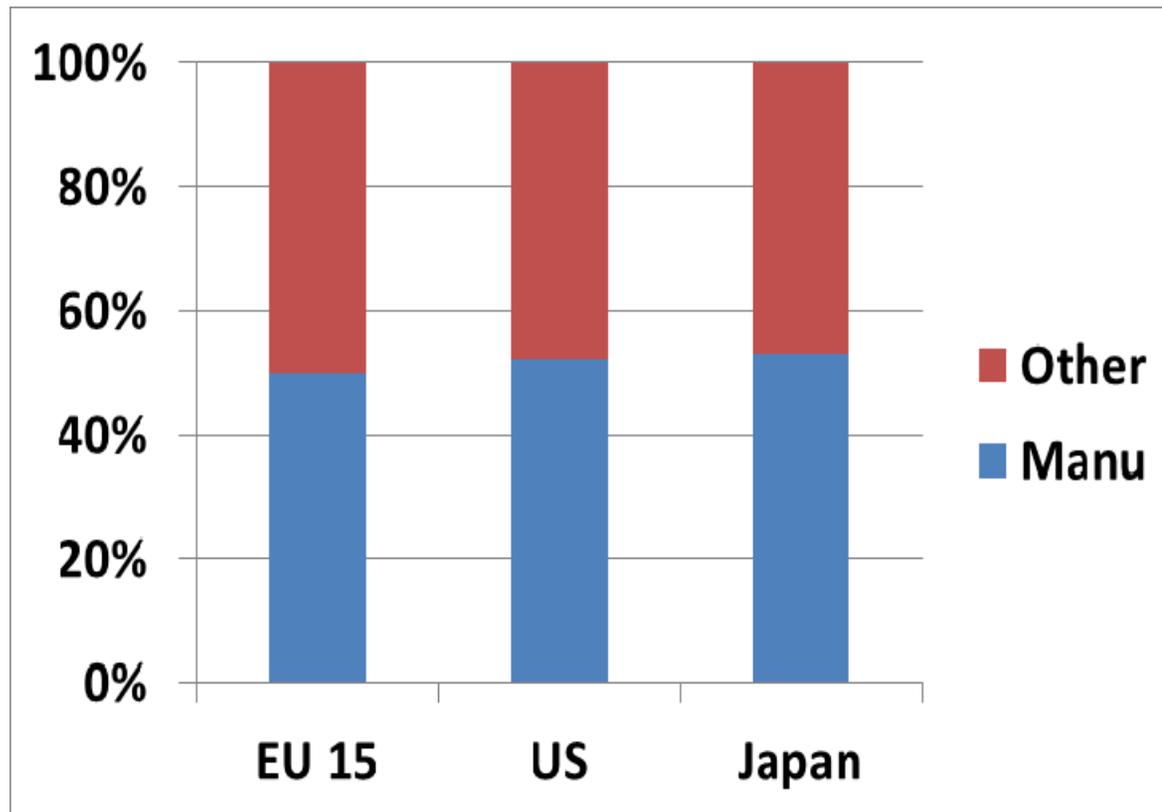


## Change in number of GVC jobs by skill type between 1995 and 2008





## Halve of the jobs in manufacturing GVCs is in non-manufacturing sectors



Sector distribution of jobs which are directly and indirectly related to production of final manufactures (%), 2008



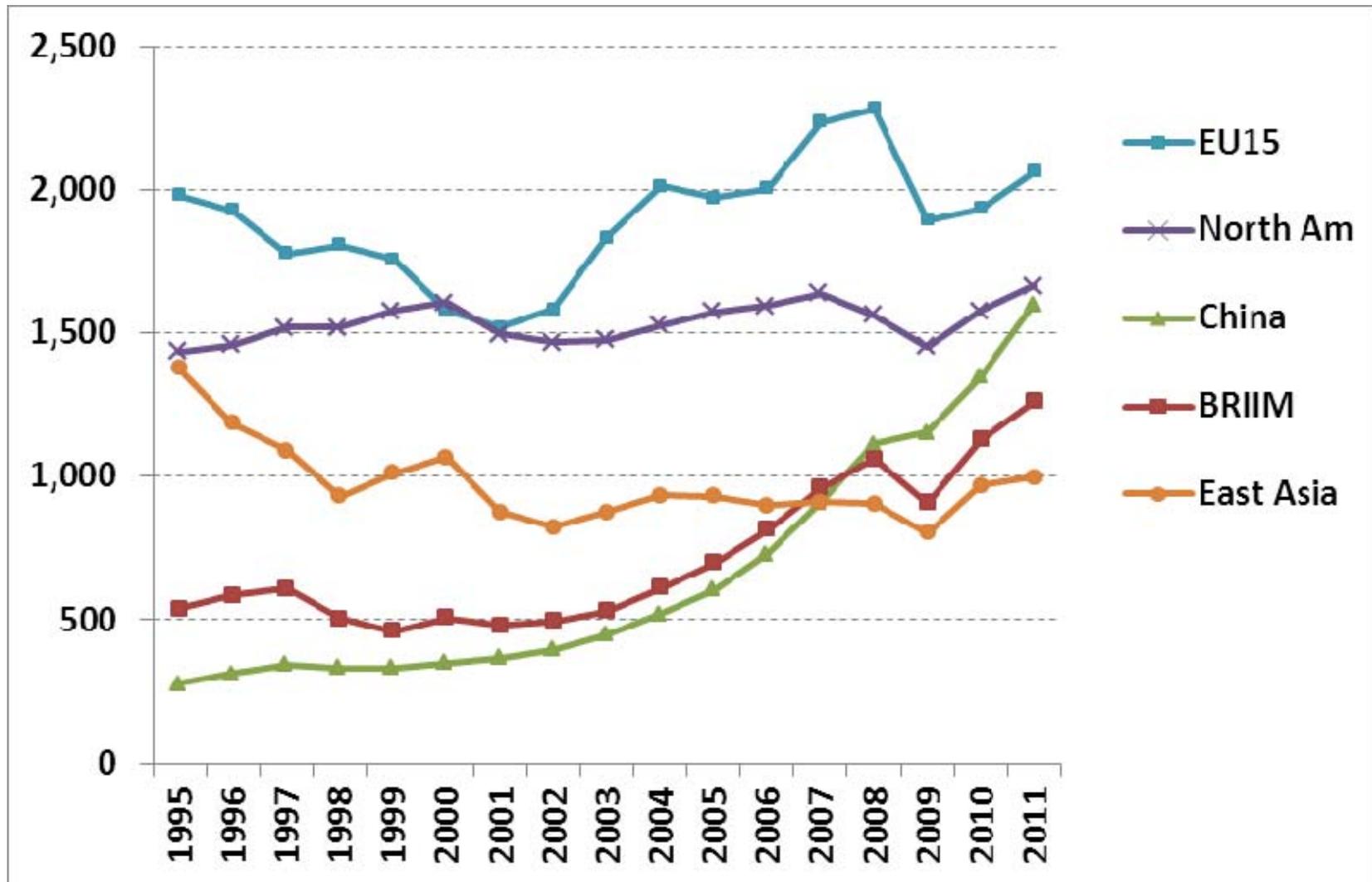
## Value added to global output of final manufactures, 1995 and 2008

	1995	2008	Change
<b>Value added in North America, EU15 and East Asia (billion US\$),</b>	<b>4,863</b>	<b>4,864</b>	<b>1</b>
capital (%)	35.9	38.7	2.9
high-skilled labor (%)	16.8	21.8	5.0
medium-skilled labor (%)	33.3	30.3	-3.0
low-skilled labor (%)	14.0	9.1	-4.9
<b>Value added in other countries (bil US\$)</b>	<b>1,723</b>	<b>3,820</b>	<b>2,097</b>
capital (%)	55.2	58.4	3.2
high-skilled labor (%)	5.4	7.1	1.7
medium-skilled labor (%)	15.6	17.0	1.4
low-skilled labor (%)	23.8	17.5	-6.3
<b>World value added (billion constant US\$)</b>	<b>6,586</b>	<b>8,684</b>	<b>2,098</b>



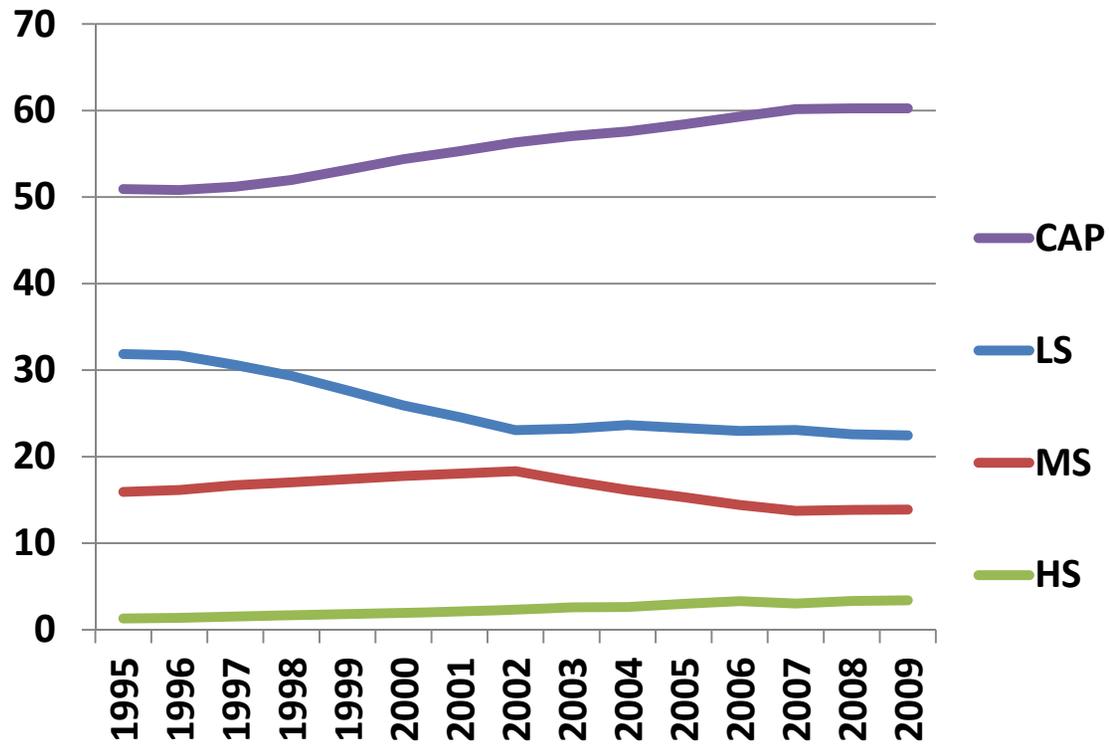
## Where is the value added?

Value added by regions to output of final manufactures  
(billion 1995US\$)





## Factor shares in GVC income of China (%): increasing importance of capital





## Enhanced specialization of advanced countries in high-skilled workers

**We define specialisation in terms in quantities of labor as follows:**

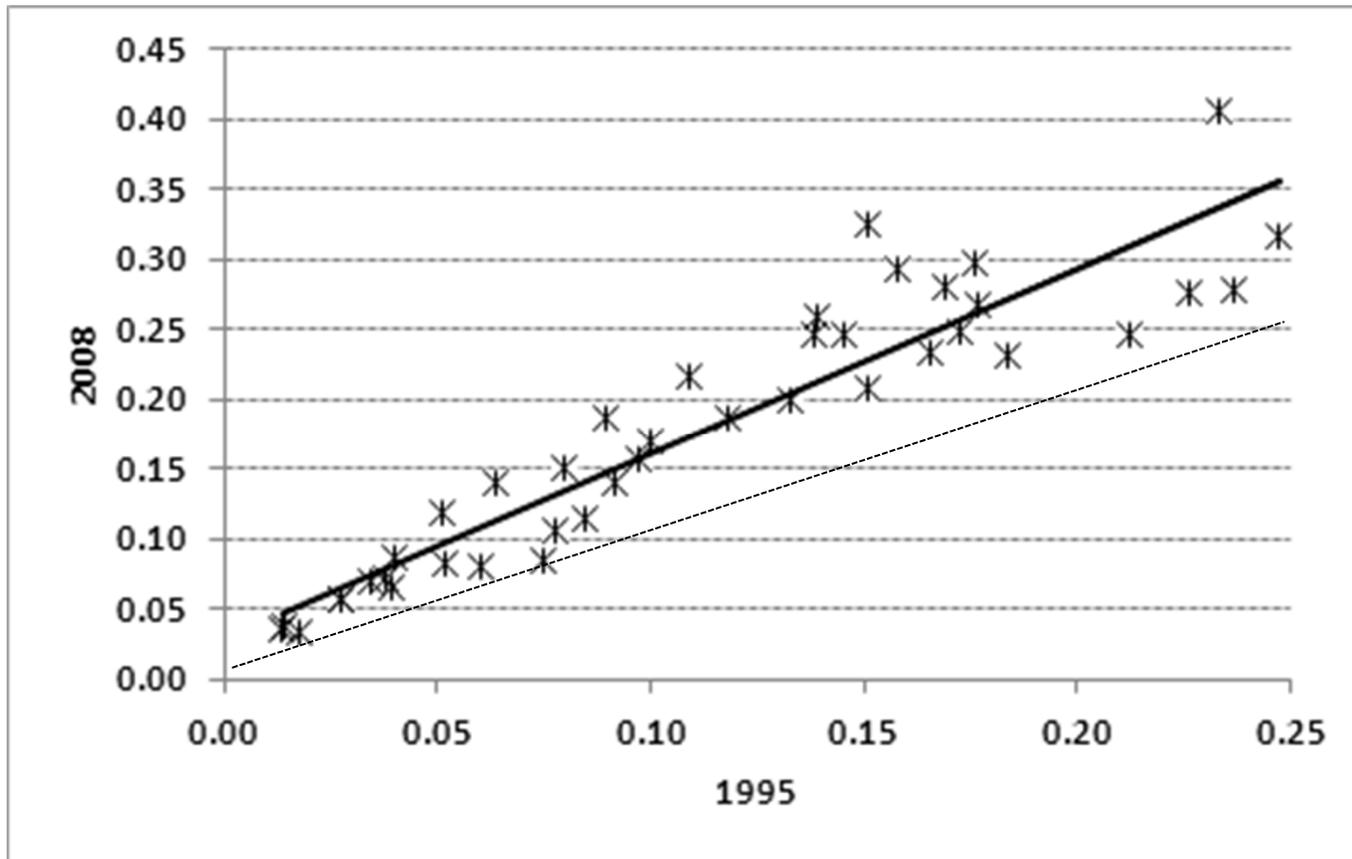
the share of high skilled in all workers of a country employed in GVCs of all final products (i,j)

$$S(HS,c) = \sum_j \sum_i F(HS,c)(i,j) / \sum_j \sum_i \sum_l F(l,c)(i,j) \quad (5)$$

And look at evolution of shares between 1995 and 2008.



## FACT 3 Enhanced specialization of advanced countries in high-skilled workers



- Note: Share of high skilled in all workers of a country employed in any manufactures GVCs in 1995 (x-axis) and in 2008 (y-axis). Observations for 40 countries covered in WIOD database. The dashed line is the 45 degree line. The solid line has been obtained by OLS regression and has a slope coefficient of 1.32 and intercept 0.029.



## Concluding remarks

- Increasing fragmentation of production requires a new metric of competitiveness: *GVC income and GVC jobs*.
  
- We found for period 1995-2008 that
  - US and Japan are quickly loosing share in global GVC income, while EU is relatively holding up (until the crisis).
  - The structure of GVC jobs is shifting
    - Half of jobs is in non-manufacturing industries and this share is increasing
    - Strong shift towards higher skilled labour
  
- Next phase: improving statistical base and explain patterns found (e.g. role of intangible capital and FDI)