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Carbon emissions embodied in Russia's trade

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Approaches to the emissions accounting

- The difference between production-based and consumption-based emissions consists in emissions embodied in net exports of a country

$$E_{prod} = E_{cons} + E_{exp} - E_{imp}$$

Emissions embodied in net exports

- E_{prod} – production-based emissions
- E_{cons} – consumption-based emissions
- E_{exp} – emissions embodied in exports
- E_{imp} – emissions embodied in imports

Motivation 1

Significant share of emissions embodied in trade in total emissions

- Peters et al., 2011: *"emissions from the production of traded goods and services have increased from 4.3 Gt CO_2 in 1990 (20% of global emissions) to 7.8 Gt CO_2 in 2008 (26%)"*
- Sato, 2013: *30% of all CO_2 emissions are released during the production of internationally traded goods*

Motivation 2

Failure of international climate agreements to reflect emissions embodied in trade

- Developed (Annex I) countries have opportunities to fulfil their commitments on reducing emissions from production by raising imports of carbon-intensive goods from developing (non-Annex I) countries
- Peters et al., 2011: *"The net emission transfers via international trade from developing to developed countries increased from 0.4 Gt CO_2 in 1990 to 1.6 Gt CO_2 in 2008, which exceeds the Kyoto Protocol emission reductions"*
- Aichele and Felbermayr, 2014: *"Binding commitments under Kyoto have increased committed countries' embodied carbon imports from non-committed countries by around 8%"*

What we did

- With the help of IO analysis accounted consumption-based emissions, emissions embodied in exports and emissions embodied in imports for Russia
- Compared it with other states
- Determined factors explaining large emissions embodied in Russia's exports
- Provided some implications for international climate change regime

Related literature

- IO analysis for externalities evaluation: Leontief, 1970
- IO analysis for analysis of carbon leakage: Gay and Proops, 1994
- Estimation of emissions embodied in trade globally: Ahmad and Wykoff, 2003; Lenzen, 2004; Peters, 2007; Peters and Hertwich, 2008; Davis, Caldeira, and Peters, 2011; Peters et al., 2011; Boitier, 2012; Sato, 2013; Lenzen et al., 2013; Aichele and Felbermayr, 2014
- Estimation of emissions embodied in trade in China: Peters et al., 2007; Xu, Allenby, and Chen, 2009; Liu et al., 2010; Lin and Sun, 2010; Dietzenbacher, Pei, and Oosterhaven, 2012; Su, Ang, Low, 2013
- Estimation of emissions embodied in trade in Russia: Mehra et al., 2011

Two approaches to accounting emissions embodied in trade

- *Environmentally extended bilateral trade (EEBT)* – we convert all the bilateral trade flows from dollars to units of emissions

- *Multi-regional input-output analysis (MRIO)* – we convert all the cells of IO tables from dollars to units of emissions

Data

- World Input-Output Database (WIOD), national GHG inventories (for Annex I countries), WRI CAIT 2.0 database (for non-Annex I countries)
  - Period: 2000-2011
  - Countries: 40 countries and 'rest of the world'
  - Industries: 35 industries and final consumption as a separate source of emissions
  - Emissions: only CO_2

Methodology

$$x = Ax + f$$

$$\begin{pmatrix} x_1 \\ \vdots \\ x_m \\ \vdots \\ x_N \end{pmatrix} = \begin{pmatrix} A_{11} & \cdots & A_{1v} & \cdots & A_{1N} \\ \vdots & \ddots & \vdots & & \vdots \\ A_{m1} & \cdots & A_{mv} & \cdots & A_{mN} \\ \vdots & & \vdots & \ddots & \vdots \\ A_{N1} & \cdots & A_{Nv} & \cdots & A_{NN} \end{pmatrix} \begin{pmatrix} x_1 \\ \vdots \\ x_m \\ \vdots \\ x_N \end{pmatrix} + \sum_{m=1}^{N} \begin{pmatrix} f_{1m} \\ \vdots \\ f_{vm} \\ \vdots \\ f_{Nm} \end{pmatrix}$$

x_m is the vector of total output in country *m*,

A_{mv} the inter-industrial matrix between country *m* and country *v*, where the elements are measured per unit of output;

f_{vm} is a vector of the final demands in country *m* addressed to country *v*.

Methodology

$$x = \sum_{m} (I - A)^{-1} f_m$$

$$x = \sum_{m} y_m$$

$$y_m = y_{m,m} + y_{m,v}$$

$$y_{m,m} = (I - A_{m,m})^{-1} f_{m,m}$$

$$y_{m,v} = (I - A_{m,v})^{-1} f_{m,v}$$

Multi-regional input-output table in W*IOD*

		Intermediate consumption							Final consumption			Output (row total)
		C_1			…	C_{41}			C_1	…	C_{41}	
		I_1	…	I_{35}	…	I_1	…	I_5				
C_1	I_1											
	…											
	I_{35}											
…	I_1											
	…											
	I_{35}											
C_{41}	I_1											
	…											
	I_{35}											
GVA at basic prices												
Output at basic prices (column total)												

Value of production of industry 1 country *m* for consumption of industry 35 country 1

O_i industry $i = 1, \ldots, 35$.

C_m country $m = 1, \ldots, 41$; C1, …, C40 – countries, C41 – rest of the world

domestic production of country m for domestic consumption of country *m*

exports (from country *m* to country *v*)

imports (country *m* from country *v*)

Methodology

To convert the flows of resources and goods from dollars to units of emissions we use the emission coefficient:

$$e = \frac{industry\ \ CO_2\ emissions}{industry\ output}$$

Emissions for domestic consumption

$$E_{m,m} = e_m y_{m,m} = e_m (I - A_{m,m})^{-1} f_{m,m}$$

Emissions embodied in exports:

$$E^{exp} = \sum_{v \neq m} E_{m,v} = e_m y_{m,v} = e_m (I - A_{m,v})^{-1} f_{m,v}$$

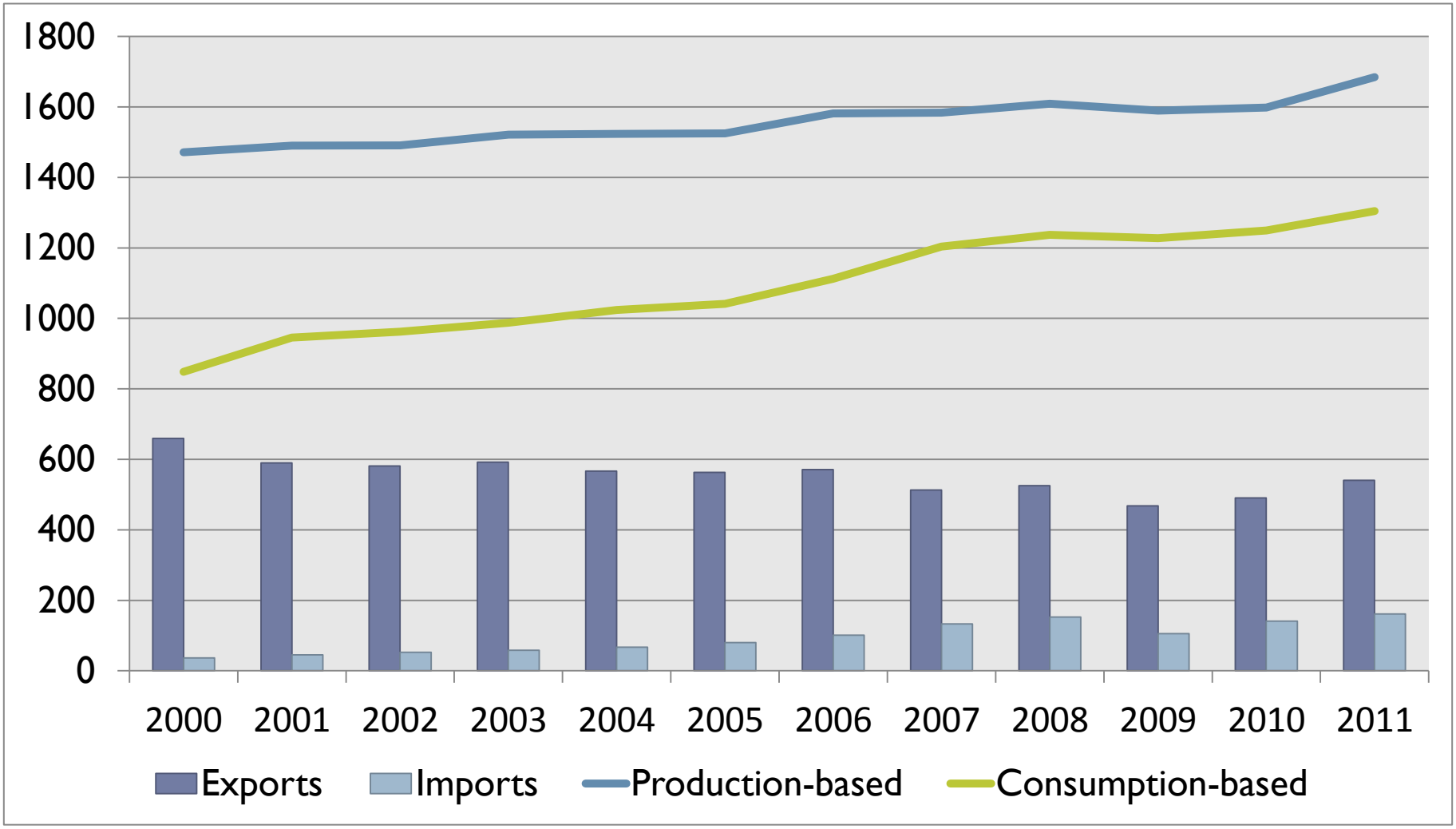
Emissions embodied in imports:

$$E^{imp} = \sum_{m \neq v} E_{v,m} = e_v y_{v,m} = e_v (I - A_{v,m})^{-1} f_{v,m}$$

Production-based emissions: $E^{prod} = E_{m,m} + E^{exp} + E^{H}$

Consumption-based emissions: $E^{cons} = E_{m,m} + E^{imp} + E^{H}$

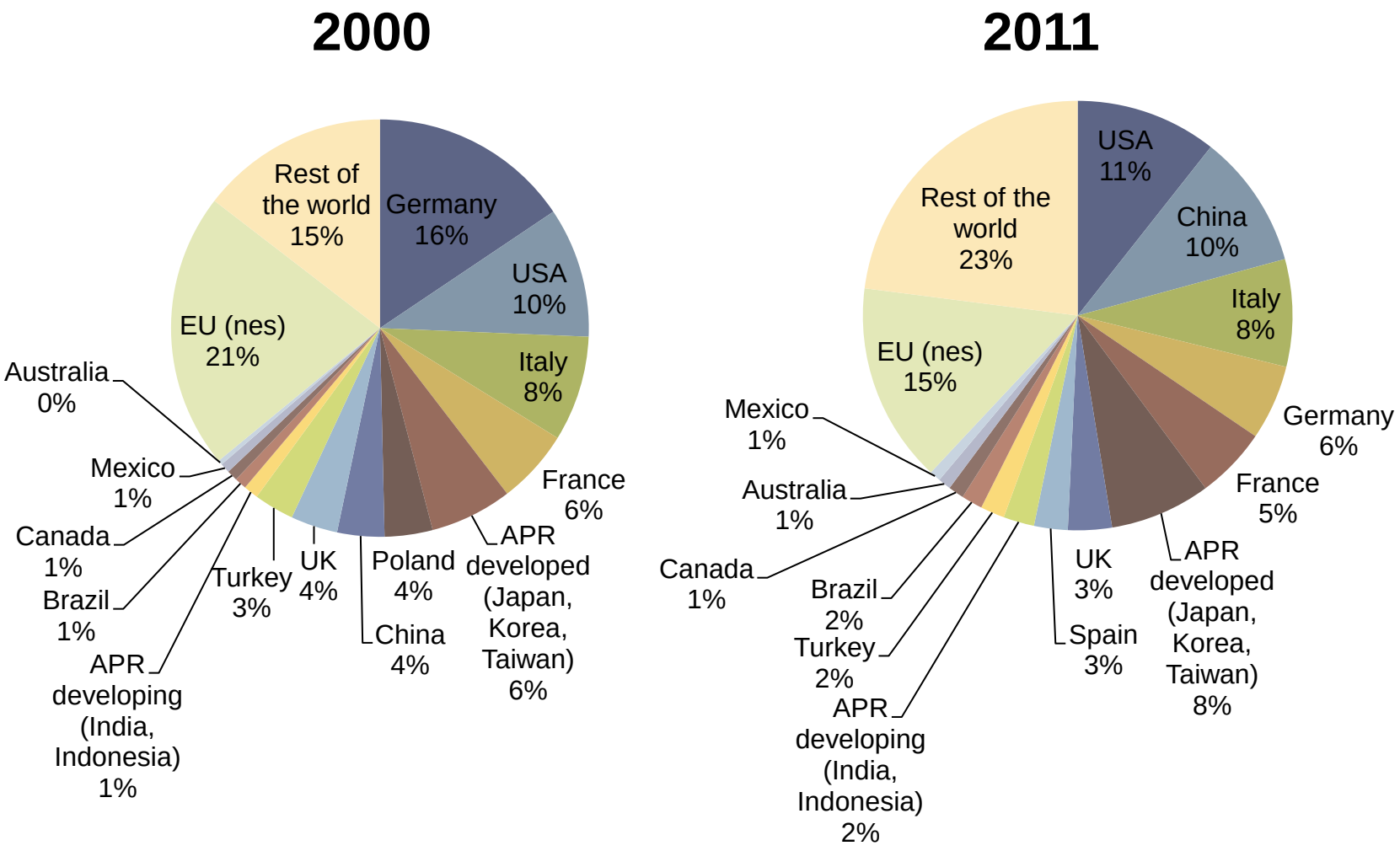
Production-based and consumption-based emissions, CO_2 embodied in exports and imports, Mt, 2000-2011



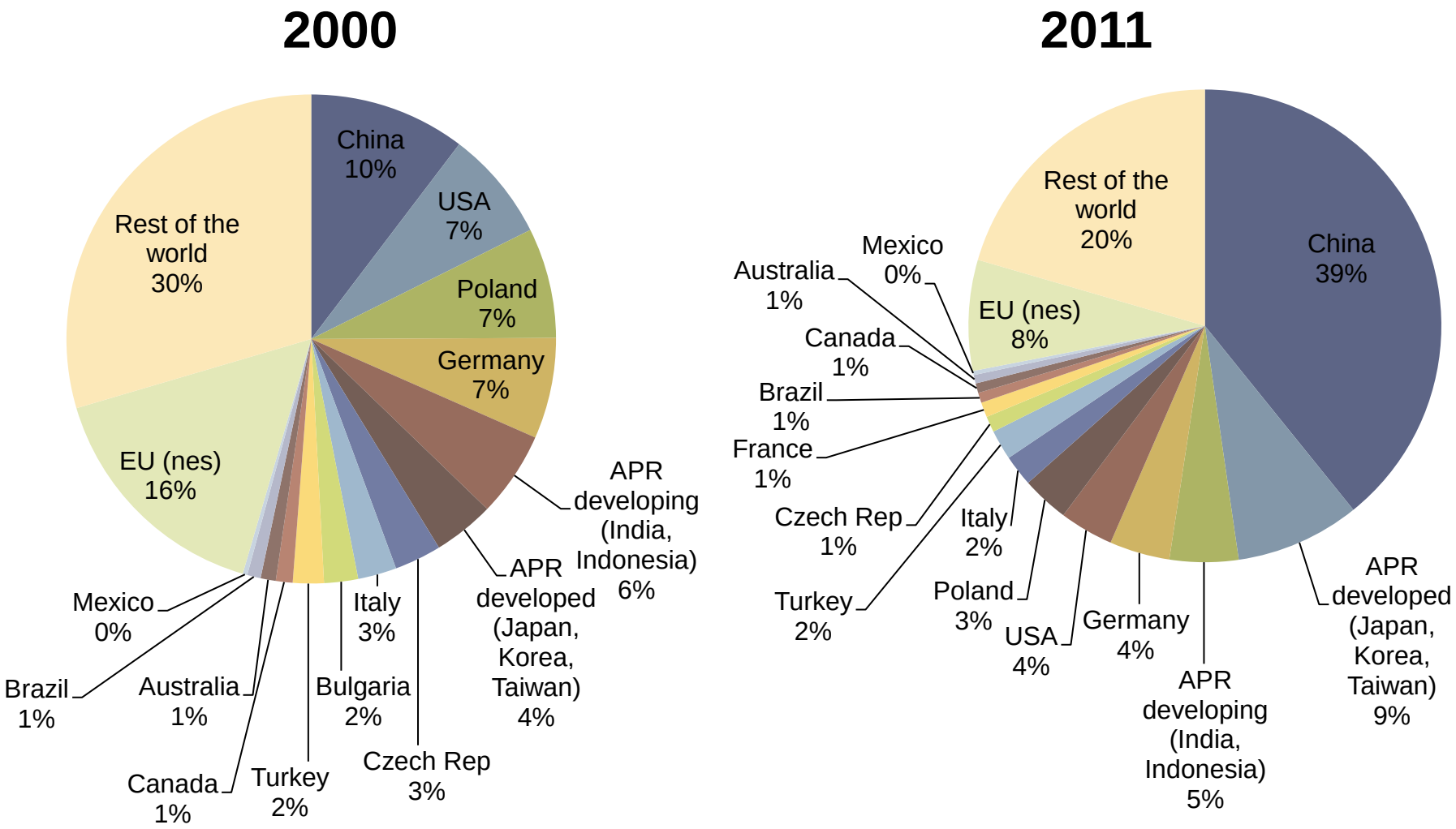
Other estimates of Russia's emissions embodied in exports in 2000-2011, Mt

	Data	Method	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
This paper	***WIOD***	***MRIO***	***659***	***590***	***581***	***592***	***567***	***563***	***571***	***513***	***525***	***468***	***490***	***541***
Lenzen et al. (2013)	Eora	MRIO	604	596	649	631	568	504	557	522	506	483	414	-
Boitier (2012)	WIOD	MRIO	703	625	615	635	606	604	614	555	558	469	-	-
Mehra et al. (2011)	IO - Russia	EEBT	-	-	372	-	-	-	-	-	-	-	-	-
Peters and Hertwich (2008)	GTAP	MRIO simpl.	-	413	-	-	-	-	-	-	-	-	-	-
Davis, Caldeira, and Peters (2011)	GTAP	MRIO	-	-	-	-	422	-	-	-	-	-	-	-

Structure of emissions embodied in Russia's exports in 2000 and 2011 by trade partner



Structure of emissions embodied in Russia's imports in 2000 and 2011 by trade partner



Emissions in different countries

№	Country	Production-based emissions, Mt	Consumption-based emissions, Mt	Emissions embodied in exports, Mt	Emissions embodied in imports, Mt	Net emission exports, Mt	Share in production-based . . . %	Share in consumption-based . . . %
1	China	9034.7	7503.4	2116.4	585.0	1531.4	30%	25%
2	USA	5603.8	6303.6	522.5	1222.3	-699.8	19%	21%
3	India	1860.9	1782.2	319.0	240.3	78.7	6%	6%
4	Russia	1684.4	1304.9	540.7	161.2	379.6	6%	4%
5	Japan	1240.7	1475.1	249.9	484.3	-234.4	4%	5%
6	Germany	798.1	981.3	243.4	426.7	-183.3	3%	3%
7	South Korea	611.7	555.8	236.8	181.0	55.9	2%	2%
8	Canada	555.6	593.2	180.3	217.8	-37.6	2%	2%
9	United Kingdom	464.6	604.4	118.5	258.3	-139.8	2%	2%
10	Mexico	458.1	505.0	87.5	134.4	-46.9	2%	2%
11	Indonesia	447.2	457.2	103.2	113.2	-10.0	1%	2%
12	Brazil	443.2	524.7	66.6	148.1	-81.5	1%	2%
13	Italy	414.2	548.7	98.9	233.4	-134.5	1%	2%
14	Australia	406.6	503.3	87.0	183.7	-96.7	1%	2%
15	Rest of the World	6254.4	6215.0	1401.5	1362.1	39.4	21%	21%

Reasons for large volumes of emissions embodied in Russia's exports

- **Structure of exports of goods**, which consist to the huge extent of hydrocarbons and energy-intensive products
- **Technological backwardness** relative to developed countries

Emissions embodied in Russia's exports and imports under the assumption that all countries apply clean technologies

Assume that all the countries apply the same technologies as Germany:

$$\begin{pmatrix} x_1 \\ \vdots \\ x_{RUS} \\ \vdots \\ x_N \end{pmatrix} = \begin{pmatrix} A_{1,1} & \cdots & A_{1,RUS} & \cdots & A_{1,N} \\ \vdots & \ddots & \vdots & & \vdots \\ A_{RUS,1} & \cdots & A_{RUS,RUS} & \cdots & A_{RUS,N} \\ \vdots & & \vdots & \ddots & \vdots \\ A_{N,DEU} & \cdots & A_{N,RUS} & \cdots & A_{NN} \end{pmatrix} \begin{pmatrix} x_1 \\ \vdots \\ x_{RUS} \\ \vdots \\ x_N \end{pmatrix} + \sum_{m=1}^{N} \begin{pmatrix} f_{1,m} \\ \vdots \\ f_{RUS,m} \\ \vdots \\ f_{Nm} \end{pmatrix} =$$

$$= \begin{pmatrix} A_{DEU,DEU} & \cdots & A_{DEU,RUS} & \cdots & A_{DEU,N} \\ \vdots & \ddots & \vdots & & \vdots \\ A_{DEU,1} & \cdots & A_{DEU,DEU} & \cdots & A_{DEU,N} \\ \vdots & & \vdots & \ddots & \vdots \\ A_{N,DEU} & \cdots & A_{DEU,v} & \cdots & A_{DEU,DEU} \end{pmatrix} \begin{pmatrix} x_1 \\ \vdots \\ x_{RUS} \\ \vdots \\ x_N \end{pmatrix} + \sum_{m=1}^{N} \begin{pmatrix} f_{1,m} \\ \vdots \\ f_{RUS,m} \\ \vdots \\ f_{N,m} \end{pmatrix}$$

Assume that emissions coefficients in all the countries are equal to corresponding coefficients of Germany ($e_m = e_{DEU}$).

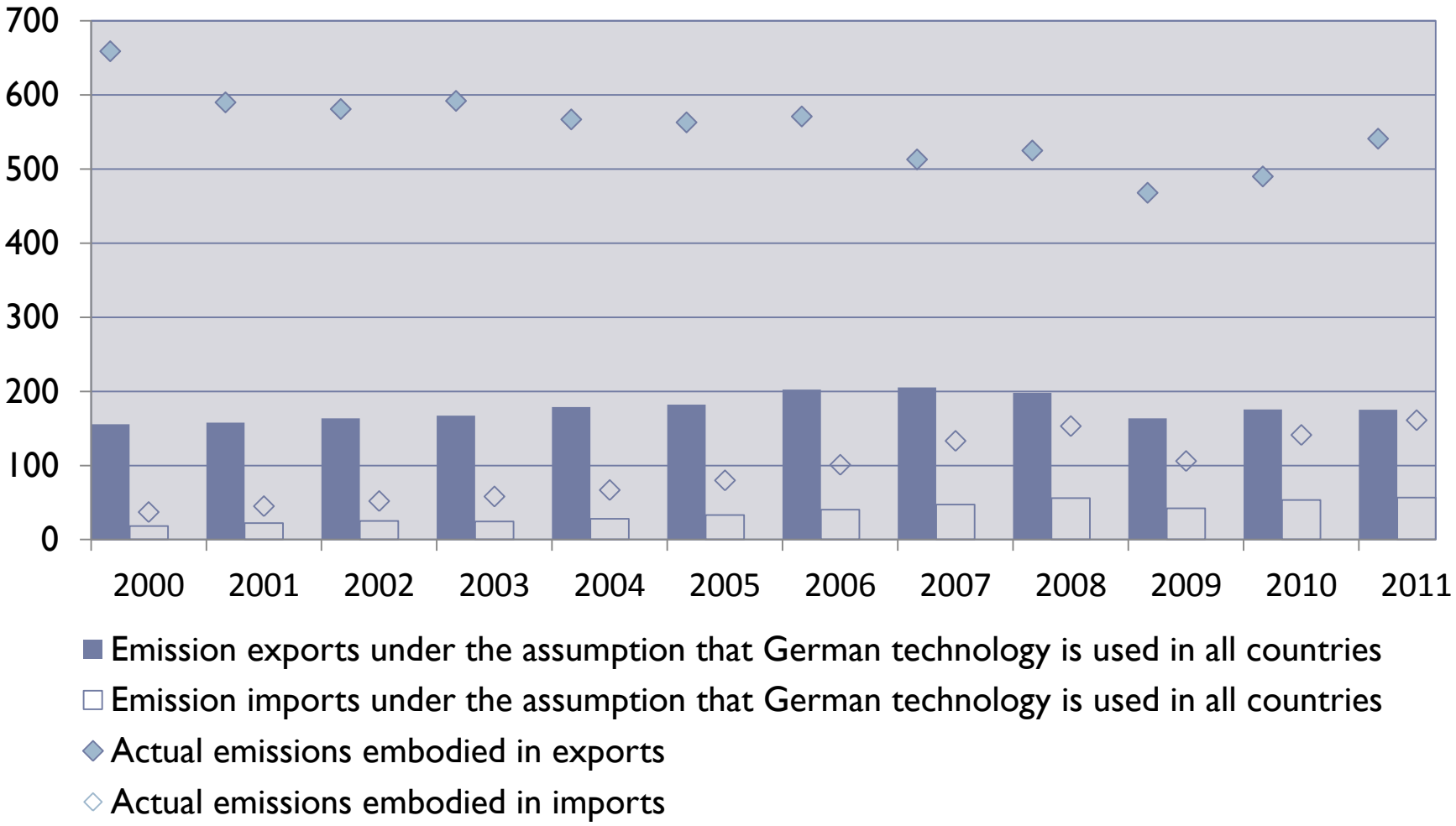
Emissions embodied in exports of Russia:

$$E_{RUS}^{exp} = \sum_{v \neq RUS} E_{RUS,v} = e_{DEU} y_{RUS,v} = e_{DEU} (I - A_{DEU,v})^{-1} f_{RUS,v}$$

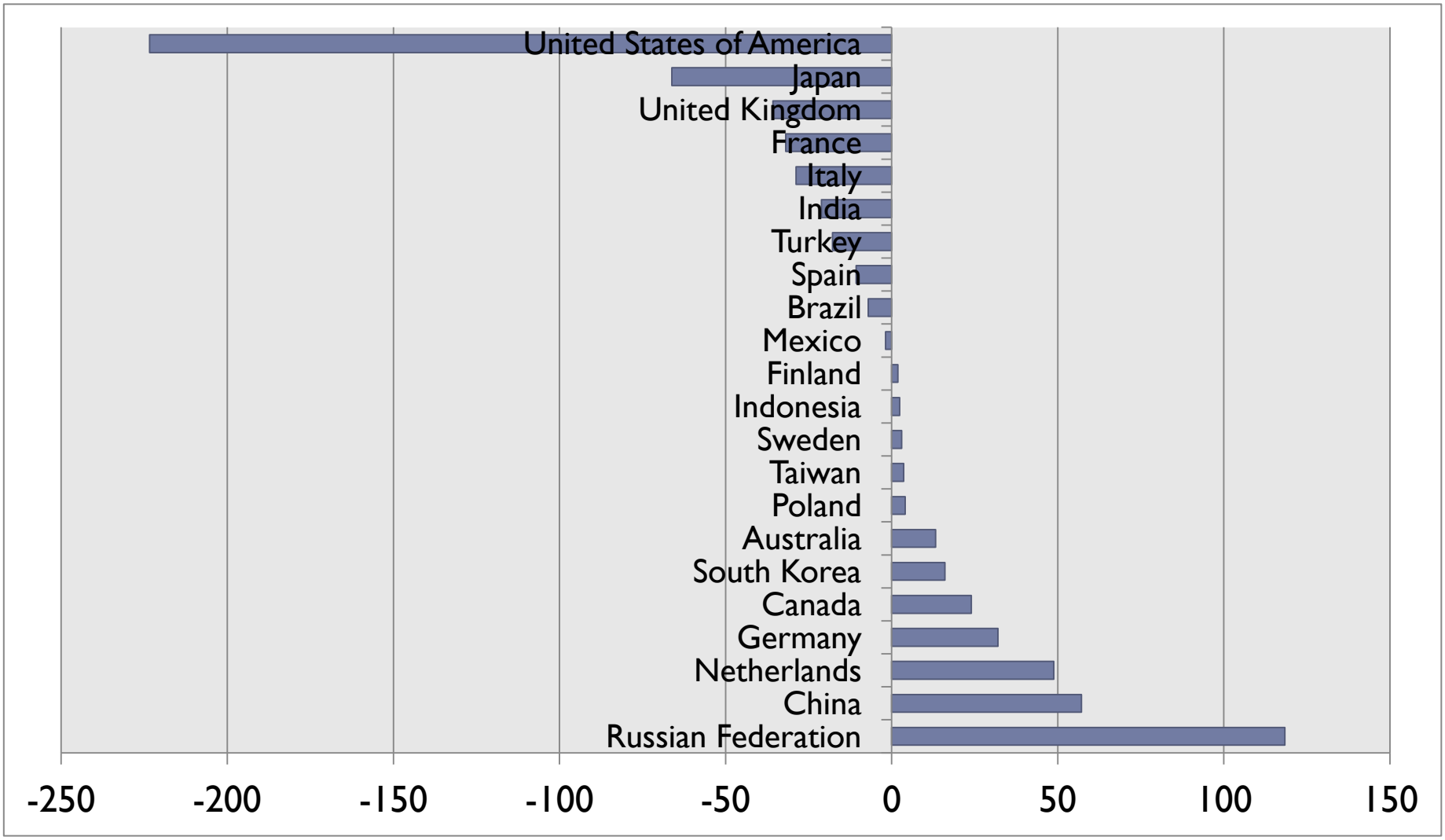
Emissions embodied in imports of Russia:

$$E_{RUS}^{imp} = \sum_{v \neq RUS} E_{v,RUS} = e_{DEU} y_{v,RUS} = e_{DEU} (I - A_{v,DEU})^{-1} f_{v,RUS}$$

Emissions embodied in Russia's exports and imports in 2000-2011 under the assumption that all the countries apply clean technologies, Mt



Emissions embodied in net exports in 2011 under the assumption that all the countries apply clean technologies, Mt



Implications for climate change regime

- Flows of emissions embodied in international trade are too large to ignore them within international climate change regime
- Consumption-based emissions should be taken into account within international agreements along with production-based emissions
- Consumption-based emissions accounting would make participation of developing countries in international climate change regime more attractive
- **Russia is now the only large net exporter of emissions among Annex I countries**. Large part of Russia's emissions is released for consumption in developed countries, while responsibility for these emissions lays on Russia alone

Implications for climate politics

- Mechanisms of **sharing responsibility for CO_2 emissions released for production of exported goods** between an exporter and an importer could be implemented
- Such proposals are justified only in relation to that part of emissions which is determined by large volumes and/or peculiarities of commodity structure of exports (about a third of emissions embodied in Russia's exports)
- Other two thirds of emissions from Russia is a result of technological backwardness relative to developed countries (Germany) and responsibility for these emissions lays on Russia alone

Thanks for attention!

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