ISSN 1883-1656

RRC Working Paper
Special Issue No. 50

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December 2014

RUSSIAN RESEARCH CENTER
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Abstract

In light of the growing intermediate goods trade, the WTO, the OECD, and the United Nations have emphasized the importance of a new concept of trade in value-added (TiVA) in place of traditional gross trade. Using this new concept, this study further develops theoretical and empirical research on Russia's global trade network generated by value-added chains. First, based on global and local equilibrium conditions of a global input–output model, we prove the fundamental theorem on the relationship between gross trade balances in value-added and gross terms: the total sum of a country's (country r) trade balances with many countries (countries 1, 2,…, s, …, R; $s \neq r$) in value-added equals that in gross terms, namely, the total sum of differentials between country r's trade balances with country s in value-added and gross terms equals zero: $\left(T_{r1}^{va} - T_{r1}^{g}\right) + \left(T_{r2}^{va} - T_{r2}^{g}\right) + \cdots + (T_{rs}^{va} - T_{rs}^{g}) + \cdots + (T_{rR}^{va} - T_{rR}^{g}) = 0$ for $s \neq r$, where T_{rs}^{va} and T_{rs}^{g} denote country r's trade balances with country s in value-added and gross

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terms, respectively. Within this general identity condition, T_{rs}^{va} can be less than or greater than T_{rs}^{g}, depending on inter-country-sector technical relations and sectoral value-added ratios. We also show the equivalence theorem between TiVA and the factor (value-added) content of trade proposed by Trefler. We employ a modified version of aggregated World Input–Output Data (WIOD) with eight countries/regions (BRIC, the EU, the USA, Japan, and the Rest of the World (ROW)) and twenty sectors for 2005 and 2010. Modifications are performed to correct an underestimation of Russian oil and gas trade flows and the value-added ratios in the original data, which is essential to correctly understand Russia's value chains with the EU and other countries.

JEL classification codes: F1, C67, D57, R15

Keywords: value chain, trade in value-added, gross trade, input–output, BRIC

1. Introduction

In view of the development of the intermediate goods trade, Johnson and Noguera (2012) and the WTO and Institute of Developing Economies (IDE) (2011) proposed a new concept of trade in value-added (TiVA) in place of conventional trade in gross terms. The WTO and OECD also provided empirical results based on some international input–output tables. The global trade network captured and generated by TiVA is called a global value chain (GVC). The new concept of value-added exports from an origin country to a destination country is defined as the origin country's value-added induced by the destination country's final demand, excluding intermediate goods exports, for the world. In this study, we present an alternative definition of value-added trade based on the study of Trefler and Zhu (2012), and prove that this alternative definition is bilaterally equivalent to the definition of TiVA. Further, using a general framework, we prove a fundamental theorem on the identity between the total sum of a country's value-added trade balances and gross trade balances (net "gross exports" or net exports). That is to say, the total sum of differentials between balances in value-added and those in gross terms equals zero. We also prove that a country's total factor content of trade is simply net exports in conventional terminology. Employing several versions of aggregated World Input–Output data (WIOD; see Timmer *et al*. 2012), we demonstrate evidence supporting the theorem. This study presents our analysis of Russia's GVC based on a modified version of the original WIOD. Modifications introduced concern only about Russia's trade flows and value-added for sectors related to oil (both crude and refined) and natural gas that are the key sectors of the present Russian as well as EU economies. We also explain the needs and procedures for the modifications in detail.

2. Model

Following Isard (1951) and Johnson and Noriega (2012), we reproduce an inter-country multi-sector model in a general framework.[1]

We assume that there are r, s =1, 2, …, R countries (areas or regions), each of which produces and inputs $r(i)$, $s(j)$ = 1, 2, .., n products. We further assume the classical Leontief open input–output model with fixed input coefficients and final demand for each country. In this model, each sector produces a single commodity without joint production. We regard the last country R as ROW. We consider an international input–output system not in physical terms but in *value terms*. Table 1 shows the basic data structure of the system.

Table 1. Data structure of an international input-output table

	Intermediate demand/input								Final demand (destination)								
	Country 1	Country 2	…	Country r	…	Country s	…	ROW R	Country 1	Country 2	…	Country r	…	Country s	…	ROW R	Output
									$\boldsymbol{F}_1$	$\boldsymbol{F}_2$	⋯	$\boldsymbol{F}_r$	⋯	$\boldsymbol{F}_s$	⋯	$\boldsymbol{F}_R$	$\boldsymbol{X}$
Country 1	$\underline{\boldsymbol{X}}_{11}$	$\underline{\boldsymbol{X}}_{12}$	…	$\underline{\boldsymbol{X}}_{1r}$	…	$\underline{\boldsymbol{X}}_{1s}$	…	$\underline{\boldsymbol{X}}_{1R}$	$\boldsymbol{Y}_{11}$	$\boldsymbol{Y}_{12}$	…	$\boldsymbol{Y}_{1r}$	…	$\boldsymbol{Y}_{1s}$	…	$\boldsymbol{Y}_{1R}$	$\boldsymbol{X}_1$
Country 2	$\underline{\boldsymbol{X}}_{21}$	$\underline{\boldsymbol{X}}_{22}$	…	$\underline{\boldsymbol{X}}_{2r}$	…	$\underline{\boldsymbol{X}}_{2s}$	…	$\underline{\boldsymbol{X}}_{2R}$	$\boldsymbol{Y}_{21}$	$\boldsymbol{Y}_{22}$	…	$\boldsymbol{Y}_{2r}$	…	$\boldsymbol{Y}_{2s}$	…	$\boldsymbol{Y}_{2R}$	$\boldsymbol{X}_2$
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Country r	$\underline{\boldsymbol{X}}_{r1}$	$\underline{\boldsymbol{X}}_{r2}$	…	$\underline{\boldsymbol{X}}_{rr}$	…	$\underline{\boldsymbol{X}}_{rs}$	…	$\underline{\boldsymbol{X}}_{rR}$	$\boldsymbol{Y}_{r1}$	$\boldsymbol{Y}_{r2}$	…	$\boldsymbol{Y}_{rr}$	…	$\boldsymbol{Y}_{rs}$	…	$\boldsymbol{Y}_{rR}$	$\boldsymbol{X}_r$
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Country s	$\underline{\boldsymbol{X}}_{s1}$	$\underline{\boldsymbol{X}}_{s2}$	…	$\underline{\boldsymbol{X}}_{sr}$	…	$\underline{\boldsymbol{X}}_{ss}$	…	$\underline{\boldsymbol{X}}_{sR}$	$\boldsymbol{Y}_{s1}$	$\boldsymbol{Y}_{s2}$	…	$\boldsymbol{Y}_{sr}$	…	$\boldsymbol{Y}_{ss}$	…	$\boldsymbol{Y}_{sR}$	$\boldsymbol{X}_s$
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
ROW R	$\underline{\boldsymbol{X}}_{R1}$	$\underline{\boldsymbol{X}}_{R2}$	…	$\underline{\boldsymbol{X}}_{Rr}$	…	$\underline{\boldsymbol{X}}_{Rs}$	…	$\underline{\boldsymbol{X}}_{RR}$	$\boldsymbol{Y}_{R1}$	$\boldsymbol{Y}_{R2}$	…	$\boldsymbol{Y}_{Rr}$	…	$\boldsymbol{Y}_{Rs}$	…	$\boldsymbol{Y}_{RR}$	$\boldsymbol{X}_R$
Value-added	$\boldsymbol{V}_1$	$\boldsymbol{V}_2$	…	$\boldsymbol{V}_r$	…	$\boldsymbol{V}_s$	…	$\boldsymbol{V}_R$									
Output	$\boldsymbol{X}_1$	$\boldsymbol{X}_2$	…	$\boldsymbol{X}_r$	…	$\boldsymbol{X}_s$	…	$\boldsymbol{X}_R$									

Notes:

$\underline{\boldsymbol{X}}_{rs}$ ($s \neq r$): country r's gross export matrix of intermediate goods to country s or country s's gross import matrix of intermediate goods from country r.

$\underline{\boldsymbol{X}}_{rr}$: country r's input matrix of intermediate goods domestically produced.

$\boldsymbol{V}_r$: country r's value-added vector.

We denote the following:

- $\boldsymbol{A}_{rs} = (a_{r(i)s(j)})$ $(n \times n)$: country r's export coefficient matrix to country s or country s's import coefficient matrix from country r if $r \neq s$, and country r's input coefficient matrix of domestically produced intermediate goods if $s = r$;
- $\boldsymbol{Y}_r = [Y_{r(i)}]$ $(n \times 1)$: country r's final demand vector in an international input–output table;
- $\widetilde{\boldsymbol{Y}}_r = [\widetilde{\boldsymbol{Y}}_{r(i)}]\,(n \times 1)$: country r's final demand vector, including exports of intermediate goods, in each country's input–output system;
- $\boldsymbol{Y}_{rs} = [Y_{r(i)s}]$ $(n \times 1)$: country s's final demand vector for country r $(n \times 1)$ or country r's final goods export vector to country s if $r \neq s$;
- $\boldsymbol{F}_s = [\boldsymbol{Y}_{rs}]$ $((n \times R) \times 1)$: country s's final demand vector for all countries;
- $\boldsymbol{X}_r = [X_{r(i)}]$ $(n \times 1)$: country r's output vector;
- $\boldsymbol{X} = [\boldsymbol{X}_r]$ $((n \times R) \times 1)$: an overall output vector;
- $\boldsymbol{I}$: an $(n \times R)$ dimensional identity matrix; and
- $\boldsymbol{I}_n$: an n-dimensional identity matrix.

We assume that non-negative matrixes $\boldsymbol{A}$ and $\boldsymbol{A}_{rr}$ are productive.

Denoting $\boldsymbol{X}^*$ as the equilibrium output vector, the global equilibrium (market clearing) condition for an Isard type of non-competitive inter-country multi-sector input–output table in value terms can be written as:

$$\boldsymbol{X}^* = \boldsymbol{A}\boldsymbol{X}^* + \boldsymbol{Y};\ \boldsymbol{X}^* = \boldsymbol{B}\boldsymbol{Y}, \text{where } \boldsymbol{B} = (\boldsymbol{I} - \boldsymbol{A})^{-1}, \tag{1}$$

where

$$\boldsymbol{A} = \begin{bmatrix} \boldsymbol{A}_{11} & \boldsymbol{A}_{12} & \dots & \boldsymbol{A}_{1s} \dots & A_{1R} \\ \dots & \dots & \dots & \dots & \dots \\ \boldsymbol{A}_{r1} & \boldsymbol{A}_{r1} & \dots & \boldsymbol{A}_{rs} \dots & \boldsymbol{A}_{rR} \\ \dots & \dots & \dots & \dots & \dots \\ \boldsymbol{A}_{R1} & \boldsymbol{A}_{R2} & \dots & \boldsymbol{A}_{Rs} \dots & \boldsymbol{A}_{RR} \end{bmatrix},$$

$$\boldsymbol{B} = (\boldsymbol{I}-\boldsymbol{A})^{-\mathbf{1}} = \begin{bmatrix} \boldsymbol{B}_{11} & \boldsymbol{B}_{12} & \dots & \boldsymbol{B}_{1s} & \boldsymbol{B}_{1R} \\ \dots & \dots & \dots & \dots & \dots \\ \boldsymbol{B}_{r1} & \boldsymbol{B}_{r1} & \dots & \boldsymbol{B}_{rs} & \boldsymbol{B}_{rR} \\ \dots & \dots & \dots & \dots & \dots \\ \boldsymbol{B}_{R1} & \boldsymbol{B}_{R2} & \dots & \boldsymbol{B}_{Rs} & \boldsymbol{B}_{RR} \end{bmatrix}, \text{ and}$$

$$\boldsymbol{Y} = \begin{bmatrix} \boldsymbol{Y}_1 \\ \dots \\ \boldsymbol{Y}_r \\ \dots \\ \boldsymbol{Y}_R \end{bmatrix} = \begin{bmatrix} \boldsymbol{Y}_{11} \\ \dots \\ \boldsymbol{Y}_{r1} \\ \dots \\ \boldsymbol{Y}_{R1} \end{bmatrix} + \dots + \begin{bmatrix} \boldsymbol{Y}_{1s} \\ \dots \\ \boldsymbol{Y}_{rs} \\ \dots \\ \boldsymbol{Y}_{Rs} \end{bmatrix} + \dots + \begin{bmatrix} \boldsymbol{Y}_{1R} \\ \dots \\ \boldsymbol{Y}_{rR} \\ \dots \\ \boldsymbol{Y}_{RR} \end{bmatrix} = \boldsymbol{F}_1 + \dots + \boldsymbol{F}_s + \dots + \boldsymbol{F}_R; \boldsymbol{X} = \begin{bmatrix} X_1 \\ \dots \\ X_r \\ \dots \\ X_R \end{bmatrix}.$$

Overall output $\boldsymbol{X}^*_{*s}$ and country *r*'s output $\boldsymbol{X}^*_{r*s}$, induced by a fixed destination country $*$s's final demand $\boldsymbol{F}_{*s}$, are given by

$$\boldsymbol{X}^*_{*s} = \boldsymbol{A}\boldsymbol{X}^*_{*s} + \boldsymbol{F}_{*s} = (\boldsymbol{I}-\boldsymbol{A})^{-\mathbf{1}}\boldsymbol{F}_{*s};\ \boldsymbol{X}^*_{r*s} = \Sigma_k \boldsymbol{A}_{rk}\boldsymbol{X}^*_{k*s} + \boldsymbol{Y}_{r*s}\,. \qquad (2)$$

This equation is essential for the definition of value-added exports.

By the given definitions of $\boldsymbol{F}_s$ and $\boldsymbol{Y}_{rs}$, we have

$$\boldsymbol{X}^* = \Sigma_s \boldsymbol{X}^*_{*s};\ \ X^*_{r*s} = \Sigma_i X^*_{r(i)*s}\,. \qquad (3)$$

Country *r*'s gross exports to country *s*, denoted as $\boldsymbol{E}_{rs}$, are given by $\boldsymbol{E}_{rs} = \boldsymbol{A}_{rs}\boldsymbol{X}^*{}_s + \boldsymbol{Y}_{rs}$ $(s \neq r)$. Hence, the local equilibrium (market clearing) condition that each country must satisfy is given by

$$\boldsymbol{X}^*_r = (\boldsymbol{I}_n - \boldsymbol{A}_{rr})^{-\mathbf{1}}\widetilde{\boldsymbol{Y}}_r, = (\boldsymbol{I}_n - \boldsymbol{A}_{rr})^{-\mathbf{1}}\left(\Sigma_{s\neq r}\boldsymbol{E}_{rs} + \boldsymbol{Y}_{rr}\right). \qquad (4)$$

This can also be written as $\boldsymbol{X}^*_r = \boldsymbol{B}^r\widetilde{\boldsymbol{Y}}_r,$ where $\boldsymbol{B}^r = (\boldsymbol{I}_n - \boldsymbol{A}_{rr})^{-\mathbf{1}}$. Generally, $\boldsymbol{B}^r \neq \boldsymbol{B}_{rr}$. It is noteworthy that the global equilibrium and local equilibria are simultaneously satisfied for the international input–output system.

Let us define country *r*'s *i*-th value-added ratio as $v_{r(i)} = V_{r(i)}/X_{r(i)}$, where $V_{r(i)}$ is country *r*'s *i*-th value-added. Country *r*'s value-added ratio vector and the overall vector are $\boldsymbol{v}_r = (v_{r(i)})(1 \times n)$ and $\boldsymbol{v} = (\boldsymbol{v}_r)(1 \times (n \times R))$, respectively. Then, by virtue of definitions of input coefficients and value-added ratios, we have

$$\boldsymbol{u} = \boldsymbol{uA} + \boldsymbol{v};\ \ \boldsymbol{u}_n = \boldsymbol{u}_n \Sigma_k \boldsymbol{A}_{kr} + \boldsymbol{v}_r\ \ . \tag{5}$$

Therefore, value-added ratios are given by

$$\boldsymbol{v} = \boldsymbol{u}(\boldsymbol{I} - \boldsymbol{A});\ \ \boldsymbol{v}_r = \boldsymbol{u}_n(\boldsymbol{I}_n - \Sigma_k \boldsymbol{A}_{kr})\ \ . \tag{6}$$

where $\boldsymbol{u} =$ (1,1,…,1) (1×(*n*×*R*)) and $\boldsymbol{u}_n = (1,1,\dots,1)$ (1×*n*) are aggregation vectors of unities. That is to say, the price vector associated with an input–output system in value terms always equals an aggregation vector.

3. Definitions and theorems for value-added trade

The new concept of value-added trade is defined as follows:

Definition 1. (Johnson and Noguera 2012). The new concept of value-added exports and TiVA:

Country *r*'s value-added exports to country *s* are defined as $\widehat{\boldsymbol{V}}_r \boldsymbol{X}^*_{rs}$, where $\widehat{\boldsymbol{V}}_r = diag\left\{v_{r_{(1)}}, \dots, v_{r_{(n)}}\right\}$ (*n* × *n*). The total value-added exports of origin country *r* to destination country *s* amount to $\boldsymbol{u}_n \widehat{\boldsymbol{V}}_r \boldsymbol{X}^*_{rs} = \boldsymbol{v}_r \boldsymbol{X}^*_{rs}$. Country *r*'s value-added trade balance with country *s* is then

$$T^{va}_{rs} = \boldsymbol{u}_n \widehat{\boldsymbol{V}}_r \boldsymbol{X}^*_{rs} - \boldsymbol{u}_n \widehat{\boldsymbol{V}}_s \boldsymbol{X}^*_{sr} = \boldsymbol{v}_r \boldsymbol{X}^*_{rs} - \boldsymbol{v}_s \boldsymbol{X}^*_{sr}\,. \tag{7}$$

Country *r*'s gross trade balance with country *s* is defined as

$$T^{g}_{rs} = \boldsymbol{u}_n(\boldsymbol{E}_{rs} - \boldsymbol{E}_{sr}) = \boldsymbol{u}_n(\boldsymbol{A}_{rs}\boldsymbol{X}^*{}_s + \boldsymbol{Y}_{rs}) - \boldsymbol{u}_n(\boldsymbol{A}_{sr}\boldsymbol{X}^*{}_r + \boldsymbol{Y}_{sr})\,. (s \neq r) \tag{8}$$

Using Definition 1, we obtain the following theorem:

Theorem 1. (Fundamental theorem; Stehrer 2012, Benedetto 2012, and Kuboniwa 2014a). The identity between the total sum of a country's trade balances with many countries in value-added and in gross terms. For $s \neq r$

$$T_{r1}^{va} + T_{r2}^{va} + \cdots + T_{rs}^{va} + \cdots + T_{rR}^{va} = T_{r1}^{g} + T_{r2}^{g} + \cdots + T_{rs}^{g} + \cdots + T_{rR}^{g}; \tag{9}$$

$$(T_{r1}^{va} - T_{r1}^{g}) + (T_{r2}^{va} - T_{r2}^{g}) + \cdots + (T_{rs}^{va} - T_{rs}^{g}) + \cdots + (T_{rR}^{va} - T_{rR}^{g}) = 0 \tag{10}$$

Proof

We consider origin country 1's trade with destination countries 2, 3, …,*s*,… *R* (*r* = 1; *s* = 2, 3, …,*R*) without loss of generality. Then, by virtue of equations (1) to (5) and the definition given for $\boldsymbol{E}_{rs} = \boldsymbol{A}_{rs}\boldsymbol{X}_s^* + \boldsymbol{Y}_{rs}$ $(s \neq r)$, we have

$$\begin{aligned}
& T_{12}^{va} + T_{13}^{va} + \cdots + \cdots + T_{1R}^{va} \\
&= \boldsymbol{v}_1(\boldsymbol{X}_{12}^* + \boldsymbol{X}_{13}^* + \cdots + \boldsymbol{X}_{1R}^*) - (\boldsymbol{v}_2\boldsymbol{X}_{21}^* + \boldsymbol{v}_3\boldsymbol{X}_{31}^* + \cdots + \boldsymbol{v}_R\boldsymbol{X}_{R1}^*) \\
&= \boldsymbol{v}_1\boldsymbol{X}_1^* - \boldsymbol{v}_1\boldsymbol{X}_{11}^* - (\boldsymbol{v}_2\boldsymbol{X}_{21}^* + \boldsymbol{v}_3\boldsymbol{X}_{31}^* + \cdots + \boldsymbol{v}_R\boldsymbol{X}_{R1}^*) \\
&= \boldsymbol{v}_1\boldsymbol{X}_1^* - \boldsymbol{v}\boldsymbol{B}\boldsymbol{F}_1 = \boldsymbol{v}_1\boldsymbol{X}_1^* - \boldsymbol{u}(\boldsymbol{I} - \boldsymbol{A})\boldsymbol{B}\boldsymbol{F}_1 = \boldsymbol{v}_1\boldsymbol{X}_1^* - \boldsymbol{u}\boldsymbol{F}_1 \\
&= \boldsymbol{u}_n(\boldsymbol{I}_n - \boldsymbol{A}_{11})\boldsymbol{B}^1\widetilde{\boldsymbol{Y}}_1 - \boldsymbol{u}_n\Sigma_{k\neq 1}\boldsymbol{A}_{k1}\boldsymbol{X}_1^* - \boldsymbol{u}\boldsymbol{F}_1 \\
&= \boldsymbol{u}_n(\Sigma_{s\neq 1}\boldsymbol{E}_{1s} + \boldsymbol{Y}_{11}) - \boldsymbol{u}_n(\Sigma_{s\neq 1}\boldsymbol{E}_{s1} - \Sigma_{s\neq 1}\boldsymbol{Y}_{s1}) - \boldsymbol{u}_n\Sigma_s\boldsymbol{Y}_{s1} \\
&= \boldsymbol{u}_n(\Sigma_{s\neq 1}\boldsymbol{E}_{1s} - \Sigma_{s\neq 1}\boldsymbol{E}_{s1}) \\
&= T_{12}^{g} + T_{13}^{g} + \cdots + \cdots + T_{1R}^{g}.
\end{aligned}$$

Q.E.D.

This theorem is “fundamental” in two senses. First, Theorem 1 clearly links value-added trade with conventional gross trade. Sectoral trade balances in value-added differ from those in the gross conception, depending upon sectoral value-added ratios and international input–output relations within the macro identity of the theorem. Second, a country’s GDP on the expenditure side, which incorporates a conventional trade balance as an essential element, is free from the so-called double accounting problems arising when using gross trade. The theorem ensures that the paradigm shift from gross to value-added trade does not change the GDP concept on the expenditure side at all.

Kuboniwa (2014b) demonstrated the bilateral equivalence between TiVA and the factor content of trade. TiVA, which is based on value-added exports and is proposed by Johnson–Noguera and OECD–WTO, measures an origin country’s value-added employed worldwide to produce a destination country’s final demand, excluding intermediates. The factor (value-added) content of trade, proposed by Trefler and Zhu (2010), measures a country’s value-added employed worldwide to produce the country’s net trade vector, which appropriately arranges gross exports and imports, including intermediates, as positive and negative elements, respectively. At a glance, these two measures may look quite different. However, we can show that in the world with many countries and sectors, these two measures of TiVA and the factor (value-added) content of trade are bilaterally equivalent.

Corresponding to Definition 1, we can define a country’s factor content of trade employed worldwide to produce the country’s net trade vector as follows:

Definition 2. (Trefler and Zhu 2010**;** Kuboniwa 2014b). The factor content of gross exports in the case with many countries and sectors:

We consider the following equation for country *r*'s gross output vector $\boldsymbol{Z}_r$ employed to produce the country's net trade vector $\boldsymbol{E}_r^{net}$ for *r* = 1, 2, …,*R* (*r* ≠ *s*) in the case that country *r* exports to and imports from countries 1, …, *s*,…, *R* (*s* ≠ *r*):

$$\boldsymbol{Z}_r = \boldsymbol{A}\boldsymbol{Z}_r + \boldsymbol{E}_r^{net} = \boldsymbol{B}\boldsymbol{E}_r^{net}, \tag{11}$$

where

$$\boldsymbol{Z}_r = \begin{pmatrix} -\boldsymbol{X}_{1r}^{**} \\ \cdots \\ \boldsymbol{X}_{r1}^{**} + \cdots + \boldsymbol{X}_{rR}^{**} \\ \cdots \\ -\boldsymbol{X}_{Rr}^{**} \end{pmatrix} \text{ and } \boldsymbol{E}_r^{net} = \begin{pmatrix} -\boldsymbol{E}_{1r} \\ \cdots \\ \boldsymbol{E}_{r1} + \cdots + \boldsymbol{E}_{rR} \\ \cdots \\ -\boldsymbol{E}_{Rr} \end{pmatrix}.$$

$\boldsymbol{X}_{rs}^{**}$ $(n \times 1)$ is country *r*'s gross output vector employed worldwide to produce the gross exports of country *r* to country *s* or the gross imports of country *s* from country *r*. Then, the factor content of gross exports from origin country *r* to destination country *s* is defined as $\widehat{\boldsymbol{V}}_r\boldsymbol{X}_{rs}^{**}$**.** The total factor content of gross exports from origin country *r* to destination country *s* amounts to $\boldsymbol{v}_r\boldsymbol{X}_{rs}^{**}$.

As proven by Kuboniwa (2014b), we obtain $\boldsymbol{X}_{rs}^{**} = \boldsymbol{X}_{rs}^{*}$, $\widehat{\boldsymbol{V}}_r\boldsymbol{X}_{rs}^{**} = \widehat{\boldsymbol{V}}_r\boldsymbol{X}_{rs}^{*}$ and $\boldsymbol{v}_r\boldsymbol{X}_{rs}^{**} = \boldsymbol{v}_r\boldsymbol{X}_{rs}^{*}$ for *r, s*=1, 2,…., *R* (*s*≠*r*). That is to say, we arrive at the following equivalence theorem:

Theorem 2. (**Bilateral equivalence theorem;** Kuboniwa 2014b).
Definition 1 is bilaterally equivalent to Definition 2.

This equivalence theorem may suggest that TiVA induced by a destination country's final demand, excluding imports of intermediate goods, is rather meaningful and robust as a theory of international trade.

The original definition of the factor content of trade provided by Trefler and Zhu (2010) can be described in our framework assuming "production of commodities by means of commodities with a single primary factor" as follows:

Definition 3. (Trefler and Zhu 2010, Theorem 1, and Foster-McGregor and Stehrer 2013). The factor content of trade:

Country *r*'s factor content of trade is given by

$$\boldsymbol{w}_r = \widehat{\boldsymbol{V}}\boldsymbol{Z}_r = \widehat{\boldsymbol{V}}\boldsymbol{B}\boldsymbol{E}_r^{net}, \text{where } \widehat{\boldsymbol{V}} = diag\{\widehat{\boldsymbol{V}}_1, \dots, \widehat{\boldsymbol{V}}_r, \dots, \widehat{\boldsymbol{V}}_R\} \ ((n \times \mathrm{R}) \times (n \times \mathrm{R})). \quad (12)$$

Then, country *r*'s total factor content of trade is

$$w_r = \boldsymbol{u}\boldsymbol{w}_r = \boldsymbol{u}\widehat{\boldsymbol{V}}\boldsymbol{Z}_r = \boldsymbol{v}\boldsymbol{Z}_r = \boldsymbol{v}\boldsymbol{B}\boldsymbol{E}_r^{net}, \text{where } \boldsymbol{v} = (\boldsymbol{v}_1, \dots, \boldsymbol{v}_r, \dots, \boldsymbol{v}_R). \quad (13)$$

By virtue of the price equation (6), as given by Foster-McGregor and Stehrer (2013), we immediately have

$$\begin{aligned} w_r &= \boldsymbol{u}(\boldsymbol{I} - \boldsymbol{A})\boldsymbol{B}\boldsymbol{E}_r^{net} = \boldsymbol{u}\boldsymbol{E}_r^{net} \\ &= \boldsymbol{u}_n(\Sigma_{s\neq r}\boldsymbol{E}_{rs} - \Sigma_{s\neq r}\boldsymbol{E}_{sr}) = T_{12}^{g} + T_{13}^{g} + \cdots + \cdots + T_{1R}^{g}. \end{aligned} \quad (14)$$

This implies the following theorem, which is essentially Theorem 1.

Theorem 1'.

Country *r*'s total factor content of trade is simply its total gross trade balance (net "gross exports") or net exports in conventional terminology.

4. Data: constructing a modified version of WIOD (M-WIOD)

We employ an aggregated version of WIOD with eight countries (BRIC, the USA, the EU, Japan, and ROW) and 20 sectors for 2005 and 2010 (for sector classification, see Table A1 in the appendix). Needless to say, WIOD is well designed and completed. However, as for Russia's major exports and the value-added of mining and oil products, the original WIOD may suffer from serious underestimation due to Russia's statistical and institutional singularity. Therefore, we try to convert the original WIOD to its modified version, i.e., M-WIOD, to improve our understanding of Russia's international input–output relations.

Table 2. Global exports of China and Russia

(bln US$)

	China		Russia	
	WIOD	Official SNA	WIOD	Official SNA
1995	168.0	147.2	82.2	91.8
1996	171.7	171.7	90.0	102.2
1997	207.2	207.2	87.1	100.1
1998	207.4	207.4	91.3	84.6
1999	218.5	221.0	73.6	84.7
2000	279.5	279.6	98.8	114.4
2001	299.4	299.4	96.6	113.1
2002	365.4	365.4	104.7	121.7
2003	485.0	485.0	128.8	151.7
2004	655.8	658.3	175.0	203.4
2005	836.7	836.6	226.9	269.0
2006	1,061.6	1,061.5	285.1	333.9
2007	1,342.0	1,341.6	326.7	392.0
2008	1,581.5	1,581.8	424.6	520.0
2009	1,333.2	1,333.2	286.7	341.6
2010	1,743.5	1,743.4	371.7	445.5
2011	2,086.2	2,089.0	485.5	576.6
2012	NA	2,248.4	NA	597.1
2013	NA	2,439.6	NA	594.8

Sources: WIOD, CEIC, Rosstat, SAFE and WDI websites.

Notes: NA means "not available."

Table 2 presents a comparison of data on total exports of goods and services in China and Russia between those given by the original WIOD and those in the official national accounts. China's data is originally provided by its State Administration of Foreign Exchange (SAFE). Data on exports to the world in the original WIOD for China are consistent with the official data except for 1995, whereas those for Russia are about 15% smaller than the official data from Rosstat (Statistics Russia) except for 1998. Clearly, we need further improvements in WIOD to decrease this substantial gap.

As is well known, Russia's major exports comprise oil and gas with the EU (EU27 then and EU28 now) being its major export destination for these goods. Exports of crude oil and natural gas are recorded in the mining industry, and those of oil products are included in the coke, refined petroleum products, and nuclear fuel industry in WIOD, the OECD STAN bilateral trade database, and the Rosstat national accounts. Table 3 shows data on Russia's exports of mining and oil products to the world, as provided by WIOD and OECD. We note that the OECD data are exactly derived from Russia's official data. The OECD data on mining exports (Free on Board (FOB)) for the world in 2005 and 2010 are US$119 billion and US$193 billion, respectively, whereas Russia's total exports of mining products in WIOD are merely US$79 billion and US$130 billion, respectively. In other words, the figures for total mining exports in WIOD are smaller than those given in the OECD data by 33–34%. Russian official data on the total exports (FOB) of oil products in 2005 and 2010 are US$35 billion and US$70 billion, respectively, while those in WIOD are only US$12 billion and US$26 billion, and are smaller than the figures given in the official data by about 65%. Given that Russia's total exports (FOB) of mining and oil products industries also form the initial basis for destination importers, these discrepancies between the original WIOD and Russian official data are rather serious for international input–output data. Distribution of the total exports (FOB) of oil products and mining except for natural gas among import countries is an easy task due to OECD data (FOB) availability by country. However, data on natural gas exports (FOB) in US$ by country have not been published in order to avoid violating the privacy of the world largest gas giant, Gazprom. It should be noted that the category "extraction of crude oil and gas" in OECD data by country covers only crude oil. This has rather serious implications for the EU, which heavily depends on Russia's natural gas.[2] As physical quantity export data in thousand cubic meter (tcm) by country are available, we estimate Russia's natural gas exports to the EU27 in US$ using the German borderline natural gas price/tcm as a proxy for Russia's natural gas exports (FOB) in US$ to the EU. As natural gas is not exported to Brazil, China, India, Japan, and the USA due to the absence of gas pipelines, we do not have to estimate natural gas exports to these countries. Natural gas exports to ROW are estimated by the residual.

An estimate of Russia's exports of mining, including natural gas and oil products, is shown in Table 4 along with the original WIOD. Conversion rates from WIOD to our M-WIOD for mining and oil products are not at all small. We uniformly apply these conversion rates to Russia's export rows of mining and oil products to the EU27.

Table 3. Russia's global exports of mining and oil products

(bln US$)

	WIOD		OECD (FOB)		Differences (OECD-WIOD)		
	Mining	Oil products	Mining	Oil products	Mining	Oil products	total
1995	20.3	2.0	NA	NA	NA	NA	NA
1996	21.8	2.0	30.7	7.7	8.9	5.7	14.7
1997	21.4	2.1	32.0	8.2	10.6	6.1	16.7
1998	18.8	1.4	24.9	4.4	6.1	3.0	9.1
1999	16.0	1.5	25.9	5.6	9.9	4.2	14.1
2000	26.9	3.2	41.6	11.1	14.7	7.9	22.6
2001	27.1	2.4	43.7	9.5	16.6	7.0	23.7
2002	28.6	2.9	45.5	11.6	16.9	8.7	25.6
2003	37.5	4.5	59.5	14.5	22.0	10.0	32.0
2004	54.5	6.3	81.1	20.1	26.6	13.8	40.4
2005	78.8	12.4	116.9	34.8	38.1	22.5	60.6
2006	83.3	18.9	147.1	45.0	63.8	26.1	89.9
2007	107.3	18.5	166.7	53.0	59.3	34.6	93.9
2008	140.4	28.3	231.9	80.4	91.5	52.0	143.6
2009	96.6	17.9	144.3	48.2	47.6	30.3	78.0
2010	130.0	26.3	193.9	71.2	63.8	45.0	108.8
2011	167.5	42.5	260.0	94.1	92.5	51.6	144.1
2012	NA	NA	270.0	106.6	NA	NA	NA

Sources: WIOD and OECD Stan Bilateral Trade database as of September 2014.

Notes: The OECD data are compiled by data reported by Russia's authorities. "Oil products" include "coke and refined petroleum products."

Table 4. Estimates on Russia's exports of mining and oil products to EU27

	WIOD	WIOD	M-WIOD	M-WIOD	OECD	Estimate (bln US$)	Conversion rate (times)	
	Mining	Oil products	Estimate Mining including natural gas	OECD Oil products	Mining excluding natural gas	Natural gas	Mining	Oil products
	a	b	c=e+f	d	e	f	c/a	d/b
2000	24.6	2.4	31.9	8.0	18.0	13.9	1.296	3.258
2001	21.9	1.8	34.2	6.9	19.0	15.2	1.566	3.918
2002	20.6	1.8	32.5	6.9	22.0	10.6	1.578	3.773
2003	29.2	2.7	43.9	8.0	29.7	14.2	1.506	2.952
2004	44.1	3.1	60.9	11.3	44.9	16.0	1.381	3.597
2005	58.5	6.6	94.1	21.4	67.4	26.7	1.609	3.233
2006	54.6	9.7	120.9	29.3	82.9	37.9	2.212	3.021
2007	78.4	10.0	126.5	33.0	91.8	34.7	1.614	3.303
2008	99.2	12.2	180.3	48.4	122.7	57.6	1.817	3.965
2009	59.0	8.9	105.8	30.4	76.7	29.1	1.793	3.403
2010	75.2	14.4	126.7	45.9	102.9	23.8	1.684	3.176
2011	102.8	24.6	164.3	58.1	132.7	31.7	1.599	2.364
2012	NA	NA	169.6	33.8	135.8	33.8	NA	NA

Sources: WIOD, OECD Stan Bilateral Trade database as of September 2014 and author's estimates.

Notes: Column f is estimated by natural gas exports in cubic meter (CEIC) ×German border gas price (IMF)×0.93 (adjustment rate for gas pressure of Russian natural gas in Europe).

We also modify Russia's exports of mining and oil products to five other countries and ROW, employing OECD data and our estimates. As the OECD export data (FOB) for mining and oil products include both export taxes and trade and transport (T&T) margins, we have to subtract these margins from exports of the T&T industry in the original WIOD. Table 5 shows the results and conversion rates for 2005 and 2010. We uniformly apply these conversion rates to Russia's export rows of mining, oil products, and T&T industries to each country. The operations of additions and subtractions of exports in these three industries lead to an increase in the coverage of exports of input–output data in the official System of National Accounts (SNA) from 85% to 94%. We do not modify sectoral value-added and output in any countries/regions other than Russia. All changes in intermediate inputs arising from modification of Russia's export flows are absorbed into an additional dummy row vector to adjust for given intermediate inputs.

Row-wise modifications of the exports of three industries should be linked to column-wise ones of these industries' value-added. Table 6 shows our estimates of value-added in mining, oil products, and T&T for 2005–2013. Our estimates of value-added in mining, oil products, and T&T industries at basic prices are about 2 times, 1.5 times, and 0.85 times the official data, respectively.[3]

Table 5. Russia's exports to seven countries/regions in 2005 and 2010

From RUS		to BRA	to CHN	to IND	to JPN	to EU27	to USA	to ROW	to World
2005									
WIOD									(bln US$)
Mining	a	0.009	5.2	0.002	0.829	58.5	2.8	11.5	78.8
Oil products	b	0.008	0.226	0.005	0.089	6.6	1.3	4.1	12.4
T&T	c	0.010	3.2	0.025	0.531	43.9	2.0	30.9	80.7
M-WIOD: OECD or estimates for EU and ROW									
Mining	d	0.021	3.1	0.027	1.267	94.1	0.7	17.7	116.9
Oil products	e	0.022	1.5	0.031	0.070	21.4	0.6	11.2	34.8
T&T	f	0.005	1.8	0.014	0.301	24.9	1.2	17.5	45.8
Conversion rate									(times)
Mining	g=d/a	2.173	0.605	12.03	1.528	1.609	0.246	1.543	1.484
Oil products	h=e/b	2.831	6.414	6.638	0.783	3.233	0.497	2.710	2.816
T&T	i=f/c	0.567	0.567	0.567	0.567	0.567	0.567	0.567	0.567
2010									
WIOD									(bln US$)
Mining	a	0.120	10.1	0.090	6.7	75.2	6.3	31.5	130.0
Oil products	b	0.017	0.6	0.009	0.5	14.4	3.4	7.3	26.3
T&T	c	0.088	5.5	0.057	4.3	51.1	4.3	77.3	142.7
M-WIOD: OECD or estimates for EU and ROW									
Mining	d	0.082	9.3	0.230	8.4	126.7	4.2	44.9	193.9
Oil products	e	0.389	1.9	0.164	2.0	45.9	1.9	19.0	71.2
T&T	f	0.047	3.0	0.031	2.3	27.5	2.3	41.6	76.7
Conversion rate									(times)
Mining	g=d/a	0.685	0.922	2.561	1.253	1.684	0.672	1.425	1.491
Oil products	h=e/b	22.95	3.244	18.88	3.918	3.176	0.542	2.612	2.711
T&T	i=f/c	0.538	0.538	0.538	0.538	0.538	0.538	0.538	0.538

Sources: WIOD, OECD Stan Bilateral Trade database as of September 2014 and author's estimates.

Notes: T&T means "trade and transport." ROW is the residuals. Estimates of T&T are derived from WIOD data *minus* estimated margins of exports of oil and gas (Table 6).

Table 6. Estimates of value-added of mining, oil products, and trade and transport (T&T)

(bln US$)

		2005	2006	2007	2008	2009	2010	2011	2012	2013
Value-added at basic prices										
WIOD										
Mining	1	73.0	92.3	112.1	133.2	98.4	135.1	180.1	NA	NA
Oil products	2	26.2	28.1	35.9	51.1	36.9	44.0	64.6	NA	NA
T&T	3	200.7	262.3	343.6	441.6	327.1	406.7	491.7	NA	NA
Official data (Rosstat)										
Mining	4	73.0	92.3	112.0	132.2	90.9	126.5	173.9	188.9	195.3
Oil products	5	25.8	27.6	35.2	50.0	30.5	36.7	58.2	57.2	63.7
T&T	6	200.7	262.1	343.3	432.7	304.1	398.0	466.2	485.2	500.7
Export taxes										
Official data (Minfin)										
Crude oil and gas	7	39.6	56.8	56.8	91.5	51.5	61.4	92.5	94.8	88.9
Oil products	8	7.0	11.6	12.9	21.0	11.9	19.9	31.9	36.6	38.1
Transfers of oil and gas export margins										
Estimate										
Crude oil and gas	9	33.7	38.2	50.7	67.5	45.3	63.9	72.6	60.8	64.7
Oil products	10	1.2	-1.0	0.1	1.4	-0.9	2.0	0.6	-1.6	0.7
Value-added at basic prices										
Estimate										
Mining	11 =4+7+9	146.3	187.3	219.6	291.2	187.7	251.9	339.0	344.6	348.9
Oil products	12 =5+8+10	34.0	38.1	48.2	72.4	41.5	58.6	90.7	92.3	102.6
T&T	13 =6-9-10	165.7	225.0	292.4	363.9	259.8	332.1	392.9	426.0	435.2

Sources: WIOD, Rosstat, Minfin (Russian ministry of finance) websites, and author's estimates.

Notes: Rows (7+9) and (8+10) are estimated by the difference between exports in foreign trade prices (CEIC) and those in domestic basic prices (Rosstat). Rows 9 and 10 are residuals.

Unlike other oil/gas-rich countries such as Norway, Russia imposes taxes on exported crude oil, refined oil, and natural gas in place of corporate income taxes. Furthermore, all oil and gas company revenues (net of export taxes) from exports that are generated by the difference between higher international prices and lower domestic basic prices are recorded as T&T margins in the national accounts. This method results in an underestimation of the value-added of oil and gas and GDP of Russia (Kuboniwa *et al*.

2005). This method also introduces deteriorations in Russia's trade flows to other countries. Therefore, we perform two-step modifications for the WIOD and the official SNA as well.

Step 1. All taxes on oil and gas exports are regarded as corporate taxes on the oil and gas industries, as in Norway. This requires export taxes to be added to exports of mining and oil products (row) at domestic basic prices and to the official value-added of these industries at basic prices (column).

Step 2. All T&T margins for oil and gas exports should be transferred to the value-added of mining and oil products industries, as in Norway.

When we modify the WIOD using these procedures, we can obtain meaningful data on Russia's value-added and exports (FOB). According to the OECD data on oil and gas exports, we have to increase value-added and output at basic prices by both export taxes and T&T margins as well as reduce the value-added and output of the T&T industry by margin transfers to the mining and oil products industries. Table 7 presents our estimates of total intermediate input, value-added, and output of the mining, oil products, and T&T industries in 2005 and 2010. We employ official data on total intermediate inputs for these industries. The value-added ratio of the mining industry at basic prices in 2005 (2010) markedly increases from 0.645 (0.679) of WIOD to 0.785 (0.781) of M-WIOD. Our estimate is rather plausible for the mining industry when crude oil and natural gas dominate the mining industry. For instance, the Norwegian value-added ratio for the mining industry in 2005 (2010) is 0.860 (0.769), based on the Statistics Norway website. We would like to note that within WIOD, value-added ratios for the mining industries in Denmark, Indonesia, Mexico, and the Netherlands for 2005 (2010) are 0.880 (0.822), 0.819 (0.819), 0.815 (0.819), and 0.727 (0.764), respectively. The value-added ratio for the oil products industry at basic prices in 2005 (2010) also remarkably increases from 0.365 (0.298) of WIOD to 0.433 (0.369) of M-WIOD, which is rather higher than the value-added ratios for the oil products industry in other countries. However, this change may be reasonable because intermediate inputs of crude oil in the oil products industry are still evaluated at domestic prices, which are lower than international prices, and exports of oil products generate rents for the industry.

Our combination of WIOD with official data or estimate results are presented in Table 8, which shows data on Russia's total output and GDP for 2005 and 2010 in WIOD, official statistics, and M-WIOD. We do not intend to revise Russia's official GDP at current market prices because it should rather be regarded as the control total for our estimates. As for 2005, our estimate, which is greater than that in WIOD, is sufficiently close to the official GDP. Our estimate for 2010 is greater than that in WIOD. However, it is smaller than the official GDP by 2.7%. Methods to further improve our estimates will be devised in our future work.

Modification of exports also requires changes in domestic intermediate demand (row), given domestic final demand of WIOD and export and output estimates. Table 9 provides our estimates of domestic intermediate demand in 2005 and 2010. We apply average conversion rates for domestic intermediate demand in the mining and oil products industries uniformly to each row vector. Statistical errors for intermediate inputs (column) due to this modification are absorbed into the additional dummy row vector for adjustments. Our modification is thus complete.

Table 7. Output and value-added of mining, oil products and T&T in 2005 and 2010

(bln US$)

	2005			2010		
	Mining	oil products	T&T	Mining	oil products	T&T
WIOD						
Intermediate input	40.2	45.6	132.4	63.8	104.0	287.9
Value-added at basic prices	73.0	26.2	200.7	135.1	44.0	406.7
Output at basic prices	113.2	71.8	333.1	198.9	148.0	694.5
Rosstat						
Intermediate input	40.2	44.5	132.4	70.5	100.4	297.4
Value-added at basic prices	73.0	25.8	200.7	126.5	36.7	398.0
Output at basic prices	113.1	70.3	333.0	197.0	137.1	695.4
M-WIOD (estimate)						
Intermediate input	40.2	44.5	132.4	70.5	100.4	297.4
Value-added at basic prices	146.3	34.0	165.7	251.9	58.6	332.1
Output at basic prices	186.4	78.5	298.1	322.3	159.0	629.4
Value-added ratio at basic prices						
WIOD	0.645	0.365	0.603	0.679	0.298	0.586
Rosstat	0.645	0.367	0.603	0.642	0.268	0.572
M-WIOD (estimate)	0.785	0.433	0.556	0.781	0.369	0.528

Sources: WIOD, website of Rosstat and author's estimates.

Table 8. Total output and GDP of Russia in 2005 and 2010

(bln US$)

	2005			2010		
	WIOD	Rosstat	M-WIOD	WIOD	Rosstat	M-WIOD
Intermediate input at purchasers' prices	654.3	654.2	653.2	1,338.7	1,348.8	1,351.3
Value-added at basic prices	654.8	654.7	700.9	1,296.4	1,353.2	1,353.2
Output at basic prices	1,309.0	1,308.9	1,354.1	2,635.1	2,702.0	2,704.4
Net taxes on products						
including export taxes		109.3			206.4	
excluding export taxes	77.5		62.8	151.6		125.1
GDP at market prices	732.3	764.0	763.6	1,448.1	1,559.6	1,478.3
Output at market prices	1,386.5	1,418.2	1,416.8	2,786.7	2,908.4	2,829.6
Value-added ratio at basic prices	0.500	0.500	0.518	0.492	0.501	0.500
Value-added ratio at market prices	0.528	0.539	0.539	0.520	0.536	0.522

Sources: WIOD, website of Rosstat and author's estimates.

Table 9. Estimate on domestic intermediate demand in 2005 and 2010

	Domestic intermediate demand	Domestic final demand	Exports	Output (bln US$)	Conversion rate of intermediate demand (times)
2005					
WIOD					
Mining	33.7	0.7	78.8	113.2	
Oil products	54.2	5.2	12.4	71.8	
T&T	138.1	114.3	80.7	333.1	
M-WIOD (estimate)					
Mining	68.8	0.7	116.9	186.4	2.042
Oil products	38.4	5.2	34.8	78.5	0.709
T&T	138.1	114.3	45.8	298.2	1.000
Input adjustment	19.3	0.0	25.7	45.0	
2010					
WIOD					
Mining	67.9	0.9	130.0	198.9	
Oil products	112.6	9.1	26.3	148.0	
T&T	313.2	238.7	142.7	694.5	
M-WIOD (estimate)					
Mining	127.5	0.9	193.9	322.3	1.878
Oil products	82.6	9.1	71.2	159.0	0.733
T&T	313.2	238.7	76.7	628.6	1.000
Input adjustment	29.6	0.0	105.4	68.5	

Sources: WIOD and author's estimates.

5. Russia’s value chain using the modified WIOD (M-WIOD)

In M-WIOD, there are several vectors including an intermediate adjustment dummy, net taxes on products, and international transport margins, which are not distributed to an endogenous intermediate quadrant. We aggregate these undistributed vectors into a single dummy vector. We define country r’s i-th dummy ratio as $d_{r(i)} = D_{r(i)}/X_{r(i)}$, where $D_{r(i)}$ is country r’s i-th dummy value. Country r’s dummy ratio vector and the overall dummy vector are $\boldsymbol{d}_r = (d_{r(i)})(1 \times n)$ and $\boldsymbol{d} = (\boldsymbol{d}_r)(1 \times (n \times R))$, respectively. Then, by virtue of the definitions of input coefficients and value-added ratios, equation (5) can now be rewritten as

$$\boldsymbol{u} = \boldsymbol{uA} + \boldsymbol{d} + \boldsymbol{v};\ \boldsymbol{u}_n = \boldsymbol{u}_n \Sigma_k \boldsymbol{A}_{kr} + \boldsymbol{d}_r + \boldsymbol{v}_r\,. \tag{5'}$$

Accordingly, in the world with many countries and sectors, equation (9) (*r*=1) is rewritten as

$$(T_{12}^{va} + \boldsymbol{d}_1\boldsymbol{X}_{12}^* - \boldsymbol{d}_2\boldsymbol{X}_{21}^*) + \cdots + (T_{1s}^{va} + \boldsymbol{d}_1\boldsymbol{X}_{1s}^* - \boldsymbol{d}_s\boldsymbol{X}_{s1}^*) + \cdots + (T_{1R}^{va} + \boldsymbol{d}_1\boldsymbol{X}_{1R}^* - \boldsymbol{d}_R\boldsymbol{X}_{R1}^*)$$
$$= T_{12}^{g} + T_{13}^{g} + \cdots + \cdots + T_{1R}^{g}. \tag{9'}$$

The terms of the left-hand side of this equation, $(T_{1s}^{va} + \boldsymbol{d}_1\boldsymbol{X}_{1s}^* - \boldsymbol{d}_s\boldsymbol{X}_{s1}^*)$, are called the value-added trade balance adjusted for the dummy sector.

Using M-WIOD, we can calculate value-added trade balances (net "value-added exports") for Russia with BICs (Brazil, India, and China), Japan, the EU27, the USA, and ROW (*r* = Russia). Figure 1 summarizes these results by country for 2005 and 2010 with alternative results using the original WIOD. Using M-WIOD, the total sum of Russia's value-added trade balances (adjusted for a dummy sector) with seven countries/regions in 2005 (2010), US$114.9 billion (US$134.6 billion), exactly equals that of gross trade balances (net "gross exports"), or simply net exports. Using the original WIOD, the total sum of Russia's value-added trade balances (adjusted for a dummy sector) with seven countries/regions in 2005 (2010), US$89.2 billion (US$91.7 billion), also exactly equals that in gross terms. Theorem 1 is thus proven to be true. Based on M-WIOD, Russia's trade balances with the EU and the ROW in 2005 (2010) are 11.1% (12.9%) and 2.2% (14.9%) smaller, respectively, when measured in value-added. On the other hand, those with India, Brazil, China, and the USA are largely improved when measured in value-added. Russia's trade imbalance with Japan in 2005 is improved by 44.6% in value-added terms, while its trade balance (surplus) in 2010 is 13.5% smaller in value-added terms.

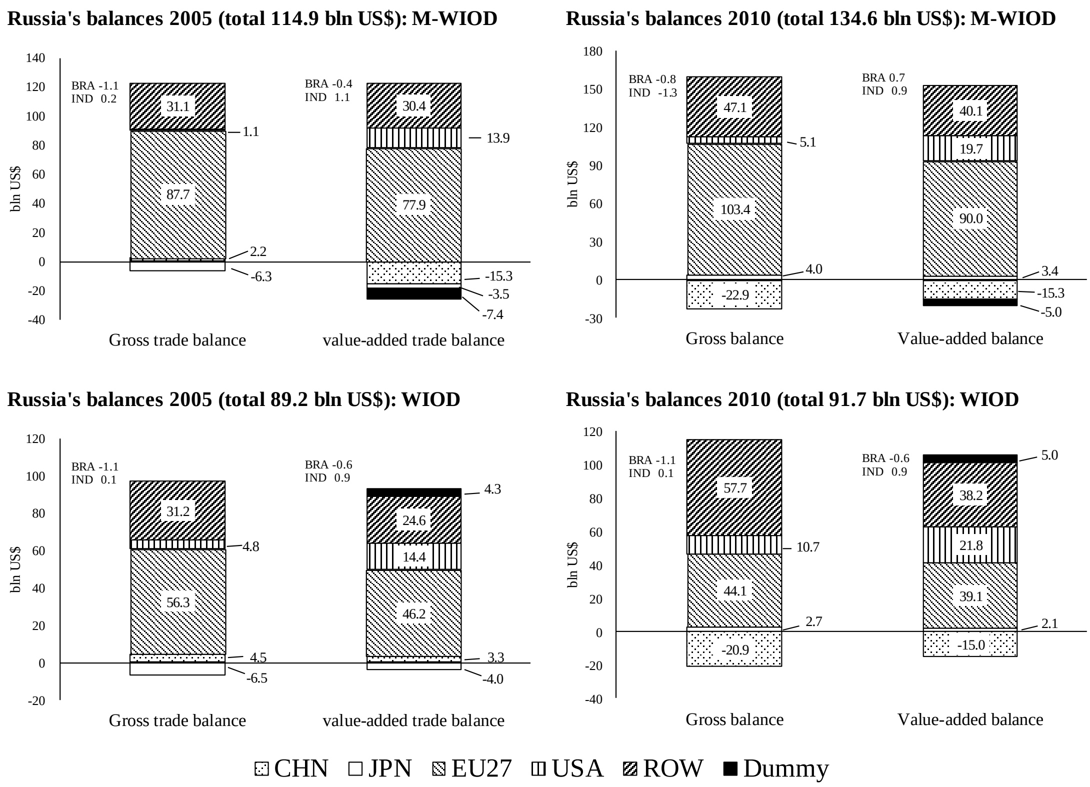

Figure 1. **Russia's trade balances with BICs, the EU, the USA, Japan and ROW: 2005, 2010**

Important indicators to understand value-added trade balances by sector are value-added ratios and ratios of value-added exports to gross exports (VAX) by sector and country. Tables 10, 11, and 12 provide these indicators for 2010.

Table 10. Value-added ratios of eight countries/regions, $v_{r(i)}$: 2010 (M-WIOD)

	RUS	BRA	CHN	IND	JPN	EU27	USA	ROW
Agriculture	0.481	0.569	0.586	0.778	0.500	0.447	0.424	0.615
Mining	0.781	0.391	0.464	0.777	0.175	0.620	0.565	0.603
Food	0.242	0.187	0.243	0.147	0.367	0.238	0.253	0.284
Textile	0.359	0.391	0.204	0.254	0.366	0.308	0.381	0.312
Wooden products	0.391	0.410	0.224	0.389	0.310	0.297	0.330	0.335
Pulp, paper and printing	0.365	0.396	0.242	0.243	0.445	0.344	0.380	0.377
Chemical products	0.307	0.282	0.206	0.272	0.280	0.279	0.340	0.286
Oil products	0.369	0.224	0.178	0.116	0.354	0.075	0.264	0.187
Rubber products	0.218	0.321	0.187	0.145	0.242	0.311	0.365	0.315
Non-metallic mineral products	0.359	0.364	0.274	0.332	0.321	0.339	0.384	0.395
Metals and metal products	0.296	0.354	0.197	0.206	0.269	0.283	0.325	0.270
Industrial machinery	0.314	0.305	0.230	0.249	0.352	0.337	0.436	0.270
Electronic equipment	0.332	0.279	0.161	0.248	0.315	0.297	0.634	0.256
Transport equipment	0.185	0.196	0.195	0.241	0.238	0.211	0.209	0.246
Other manufacturing products	0.277	0.431	0.377	0.130	0.210	0.322	0.497	0.334
Electricity, gas and water	0.267	0.507	0.284	0.339	0.429	0.378	0.720	0.349
Construction	0.451	0.514	0.231	0.345	0.457	0.397	0.516	0.327
Trade and transport	0.528	0.592	0.519	0.611	0.607	0.490	0.619	0.564
Other services	0.647	0.681	0.558	0.792	0.665	0.630	0.631	0.646
Public administration	0.515	0.648	0.549	1.000	0.691	0.657	0.599	0.607

Table11. Johnson-Noguera's VAX (E^{va}/E) from Russia to other seven countries/regions: 2010 (M-WIOD)

	From RUS							
	to							
	BRA	CHN	IND	JPN	EU	USA	ROW	World
Agriculture	14.20	0.62	20.35	0.70	2.15	5.94	0.88	0.95
Mining	19.85	1.28	7.48	1.09	0.81	3.77	1.10	0.99
Food	67.58	0.40	1.36	0.42	0.88	0.73	0.42	0.49
Textile	501.17	1.84	2.32	8.71	1.20	13.81	0.93	1.26
Wooden products	315.63	0.42	54.79	0.49	0.57	1.62	0.60	0.58
Pulp, paper and printing	1.21	0.46	0.58	1.08	1.00	7.04	0.57	0.70
Chemical products	0.38	0.38	0.44	2.24	0.58	0.81	0.41	0.49
Oil products	0.90	0.83	1.67	0.62	0.42	1.25	0.51	0.49
Rubber products	6.15	82.60	22.45	73.66	3.88	10.93	0.98	2.00
Non-metallic mineral products	16.64	945.86	5.58	102.86	4.70	1.62	1.21	2.01
Metals and metal products	0.91	0.71	0.92	0.44	0.46	0.92	0.49	0.53
Industrial machinery	0.62	0.94	0.78	25.09	1.07	0.89	0.43	0.61
Electronic equipment	1.18	1.25	1.73	8.99	1.35	2.26	0.61	0.92
Transport equipment	1.17	3.63	2.39	50.58	2.04	5.82	0.37	0.63
Other manufacturing products	-	44.40	0.26	15.75	3.02	0.78	3.41	1.49
Electricity, gas and water	-	57.00	-	-	5.98	41.23	4.27	6.43
Construction	-	7.12	-	-	-	-	1.61	3.61
Trade and transport	17.91	1.81	27.11	1.55	1.15	3.16	0.75	1.05
Other services	3.18	2.95	6.50	26.45	-	7.00	9.53	11.20
Public administration	-	14.91	-	15.01	12.32	-	11.61	13.77

Table12. Johnson-Noguera's VAX (E^{va}/E) from seven countries/regions to Russia: 2010 (M-WIOD)

	From							
	BRA	CHN	IND	JPN	EU27	USA	ROW	World
	to RUS							
Agriculture	2.88	9.75	2.67	9.00	1.04	1.11	0.87	1.12
Mining	371	39.97	25.40	9.63	9.29	6.40	7.68	8.82
Food	0.25	1.59	0.32	2.28	0.35	0.51	0.46	0.45
Textile	0.96	0.41	0.38	3.99	0.39	0.74	0.39	0.40
Wooden products	1.97	1.31	4.89	3.56	0.68	1.80	0.99	0.88
Pulp, paper and printing	13.72	7.25	1.80	8.45	0.71	3.14	1.56	1.14
Chemical products	5.83	1.51	0.57	3.02	0.38	0.99	0.67	0.57
Oil products	8.13	4.17	3.95	6.48	0.23	1.58	0.40	0.56
Rubber products	24.89	3.04	0.59	4.78	1.63	5.26	2.60	2.29
Non-metallic mineral products	1.49	0.93	1.15	3.22	0.80	2.28	0.70	0.86
Metals and metal products	3.56	1.73	1.48	3.40	1.23	2.98	0.84	1.29
Industrial machinery	0.68	0.45	0.64	0.62	0.42	0.58	0.35	0.43
Electronic equipment	2.79	0.33	0.55	1.42	0.54	1.64	0.95	0.57
Transport equipment	1.18	0.42	0.37	0.40	0.28	0.39	0.33	0.33
Other manufacturing products	2.45	0.58	0.24	0.48	0.51	1.04	0.63	0.56
Electricity, gas and water	-	98.57	792	27.90	12.26	-	24.99	21.35
Construction	-	-	-	-	0.66	-	2.26	0.77
Trade and transport	-	3.67	-	42.09	2.15	-	2.67	2.91
Other services	-	-	-	-	10.51	-	17.92	16.23
Public administration	16.85	-	-	30.08	1.34	6.00	1.85	1.69

Figure 2 shows Russia’s trade balances with the EU (EU27) by sector in 2005 and 2010. The largest source of Russia’s positive trade balance with the EU is mining, followed by oil products and T&T. Based on M-WIOD, the value-added trade balance with the EU for mining in 2005 (2010) amounts to US$74.4 billion (US$102.3 billion), which is 21% (19%) smaller than the gross trade balance. The change in the trade balance with the paradigm shift from gross to value-added trade, based on M-WIOD, seems to reflect only Russia’s value-added ratio for the mining industry. Value-added for mining induced by direct and indirect output effects through the Leontief inverse is rather small. Using the original WIOD, the value-added trade balance with the EU for mining in 2005 (2010) is US$35.6 billion (US$49 billion), which is 39% (35%) smaller than the gross trade balance. The amount of value-added trade balance with the EU for mining based on the original WIOD is about half that based on M-WIOD. The change in the trade balance for mining with the paradigm shift from gross to value-added trade, based on the original WIOD, is about twice that based on M-WIOD.

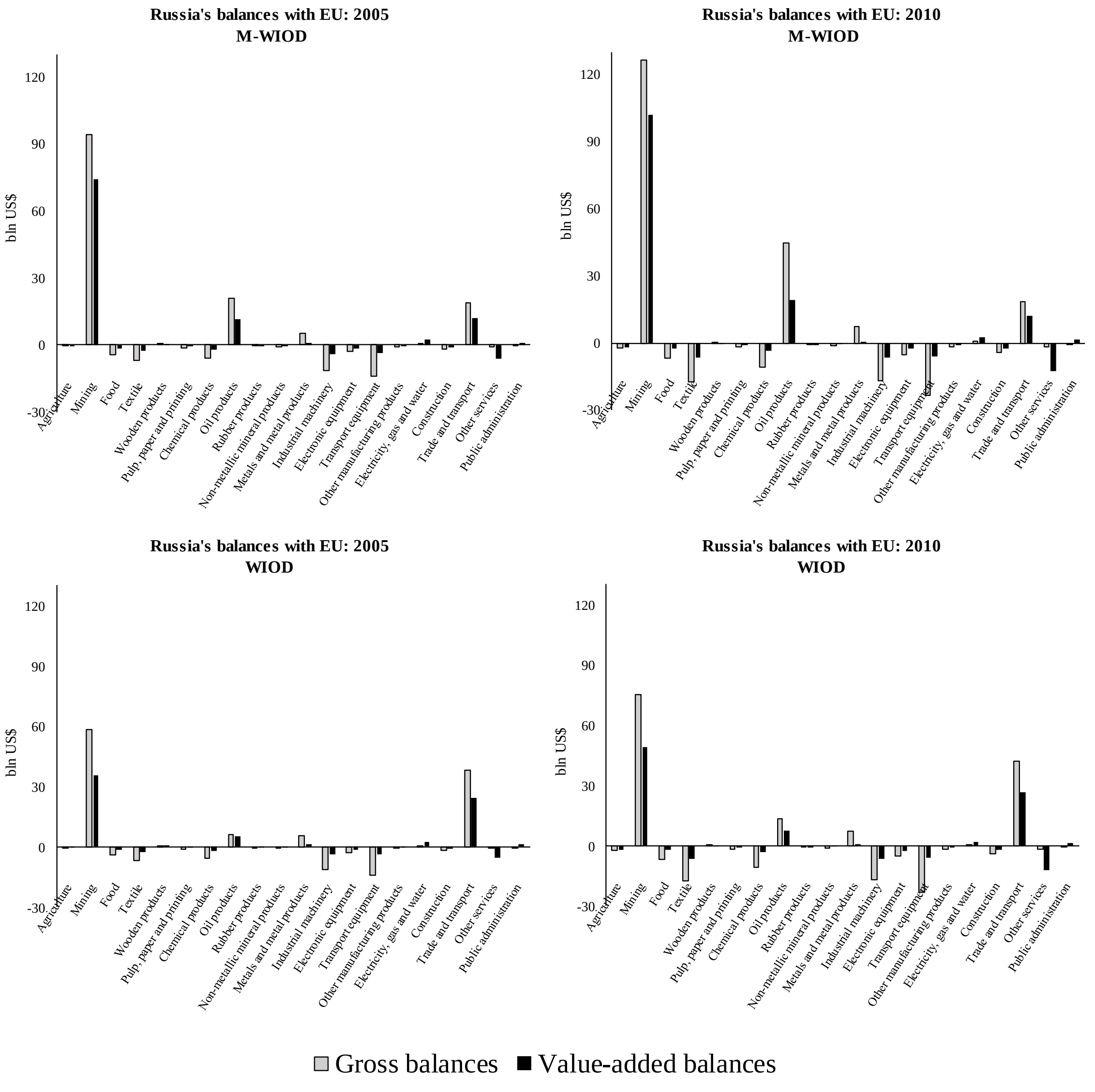

Figure 2. Russia's trade balances with the EU by sector in 2005 and 2010

Using M-WIOD, the value-added trade balance with the EU for oil products in 2005 (2010) amounts to US$11.4 billion (US$19.1 billion), which is 46% (57%) smaller than the gross trade balance. Using the original WIOD, the value-added trade balance with the EU for mining in 2005 (2010) is US$5.2 billion (US$7.3 billion), which is 14% (45%) smaller than the gross trade balance. The amount of value-added trade balance with the EU for oil products based on the original WIOD is less than half that based on M-WIOD. In contrast to that seen for mining, the change in the trade balance for oil products with the paradigm shift from gross to value-added trade, based on the original WIOD, is much smaller than that based on M-WIOD.

Using M-WIOD, the value-added trade balance with the EU for T&T in 2005 (2010) amounts to US$12.1 billion (US$11.9 billion), which is 36% (35%) smaller than the gross trade balance. Using the original WIOD, the value-added trade balance with the EU for T&T in 2005 (2010) is US$24.3 billion (US$26.4 billion), which is 36% (37%) smaller than the gross trade balance. The amount of value-added trade balance with the EU for T&T based on the original WIOD is about twice that based on M-WIOD. The change in the trade balance for T&T with the paradigm shift from gross to value-added trade, based on the original WIOD, is similar to that based on M-WIOD.

The major sources of Russia’s trade imbalance (deficit) with the EU are industrial machinery and transport equipment when we do not consider the “other services” industry. Using M-WIOD, value-added trade imbalances of industrial machinery and transport equipment in 2005 (2010) are US$4 billion (US$6.3 billion) and US$3.8 billion (US$6.2 billion), respectively, which are 66% (62%) and 74% (74%) smaller than the respective gross trade imbalances. These results are almost the same as those derived using the original WIOD. The largest source of Russia’s trade imbalance with the EU is the “other services” industry. Based on M-WIOD, the value-added trade imbalance with the EU for this industry in 2005 (2010) is US$6.1 billion (US$12.8

billion), which is 6.2 times (6.7 times) the gross trade imbalance. Using the original WIOD, we also reach similar results.

Figure 3 shows Russia's trade balances with China by sector using M-WIOD for 2005 and 2010. The largest positive element of Russia's trade balances with China is also mining, followed by oil products. The value-added trade balance with China for mining in 2005 (2010) is US$3.7 billion (US$10.1 billion), which is 18% (9%) larger than the gross trade balance. This change in the trade balance with the paradigm shift is rather interesting in comparison with the case for the EU. The value-added trade balance with China for oil products in 2005 (2010) is US$0.8 billion (US$1.2 billion), which is 40% (33%) smaller than the gross trade balance.

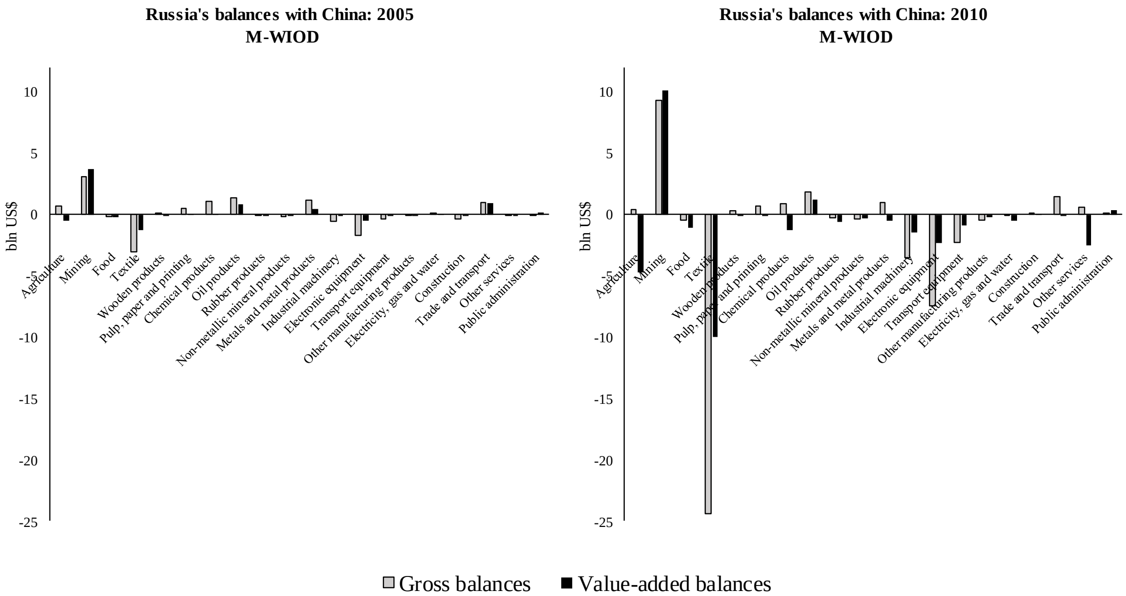

Figure 3. Russia's trade balances with China by sector in 2005 and 2010

The largest source of Russia's trade imbalances with China is textiles, followed by electronic equipment. The value-added trade imbalance for textiles in 2005 (2010) is

US$1.2 billion (US$10 billion), which is 60% (59%) smaller than the gross trade imbalance due to the low value-added ratio of China's textile industry, as shown in Table 10. The value-added trade imbalance of textiles in 2005 (2010) is US$0.5 billion (US$2.4 billion), which is 71% (68%) smaller than the gross trade imbalance due to the extremely low value-added ratio of China's electronic equipment industry. These changes in trade imbalances with China for textiles and electronic equipment also play a decisive role in understanding the USA's trade imbalances with China.

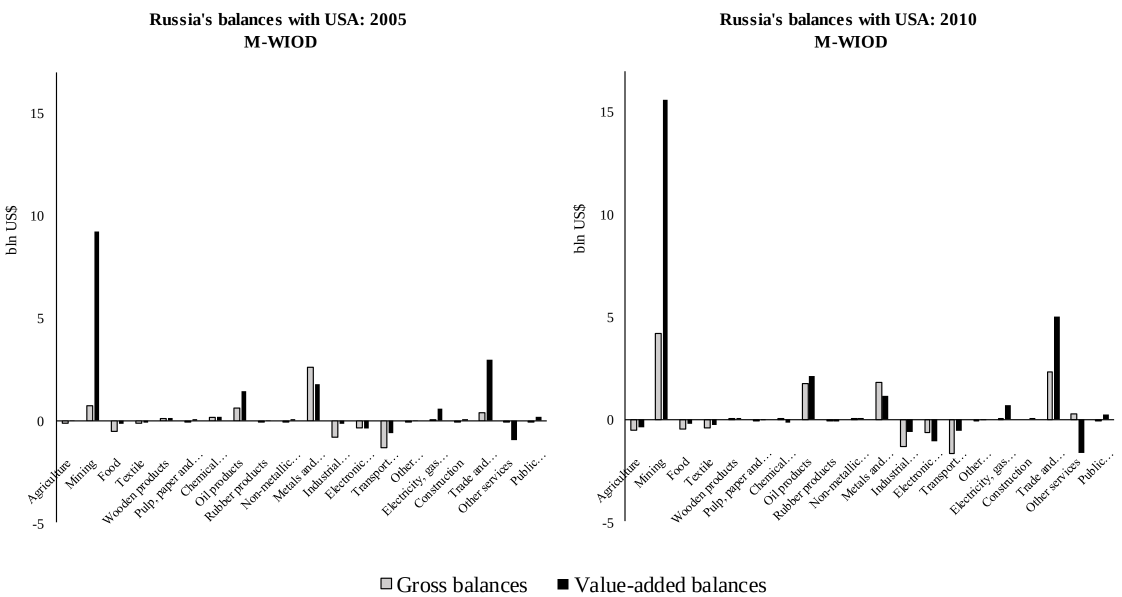

Figure 4. Russia's trade balances with the USA by sector in 2005 and 2010

Figure 4 demonstrates Russia's trade balances with the USA by sector using M-WIOD for 2005 and 2010. The largest source of Russia's value-added trade balances with the USA is mining, followed by T&T and oil products. The value-added trade balance with the USA for mining in 2005 (2010) is US$9.2 billion (US$15.6 billion), which is 13.3 times (3.7 times) larger than the gross trade balance. This change in the trade balance with the paradigm shift is also interesting in comparison to the EU case. The value-added trade balance with the USA for oil products in 2005 (2010) is US$1.4 billion (US$2.1 billion), which is 2.5 times (22.5%) larger than the gross trade balance. This change in the trade balance with the paradigm shift is very interesting because it is not found in Russia's oil products trade balances with other countries. The value-added trade balance with the USA for T&T in 2005 (2010) is US$2.9 billion (US$5 billion), which is 7.5 times (2.2 times) the gross trade balance. We might conclude that the USA is a desirable trade partner for Russia in light of the value-added generated by gross exports of crude and refined oil and T&T.

Figures 5, 6, and 7 show Russia's trade balances with Japan, Brazil, and India, respectively, by sector using M-WIOD for 2005 and 2010.

The key sector contributing to Russia's trade balances with Japan, Brazil, and India is mining. Russia's value-added trade balances with Japan, Brazil, and India for mining in 2005 (2010) are US$2.8 billion (US$9.1 billion), US$0.4 billion (US$1.5 billion), and US$0.7 billion (US$1.6 billion), respectively, which are 2.3 times (8.4%), 22 times (18 times), and 30 times (7 times) larger than the respective gross trade balances. These provide Russia with value-added exports much larger than gross exports, as shown by Table 11. However, VAX may show some decline as the level of gross exports becomes higher.

The value-added balances with Japan and Brazil for oil products in 2005 (2010) are US$0.3 billion (US$1.1 billion) and US$0.1 billion (US$0.3 billion), respectively, which are 4.6 times and 3.7 times larger (47% and 21% smaller) than the respective gross balances. As gross exports increase from a sufficiently low to a higher level, value-added exports and balances appear to be normalized. The value-added balances with India for oil products in 2005 (2010) are US$0.1 billion (US$0.2 billion), which is 4.4 times (53%) larger than the gross balance. This change with the paradigm shift might be due to a sufficiently low level of Russian oil product exports to India.

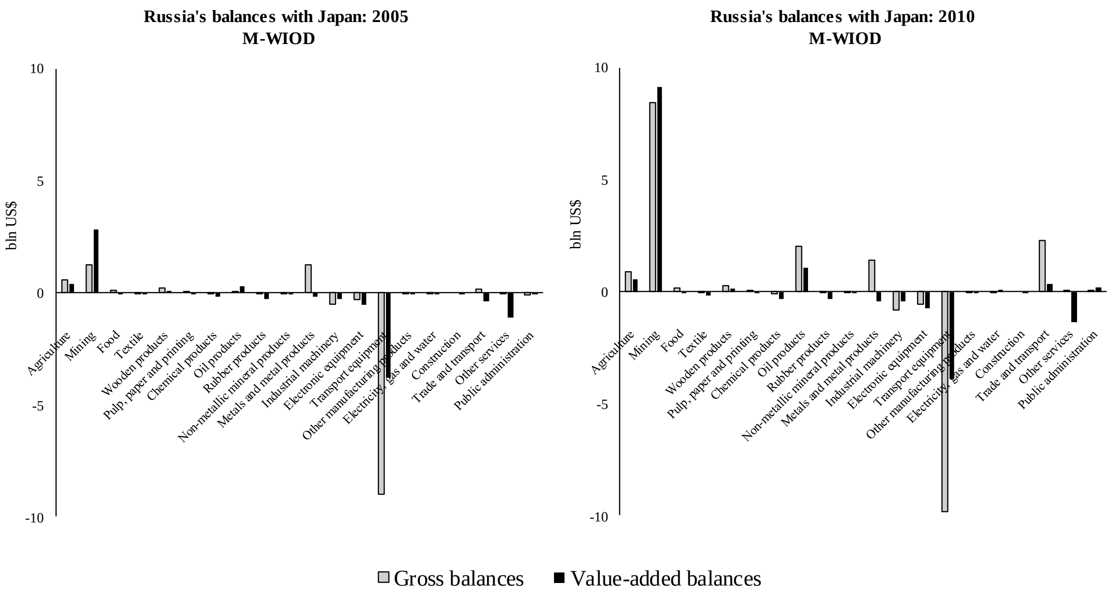

Figure 5. Russia’s trade balances with Japan by sector in 2005 and 2010

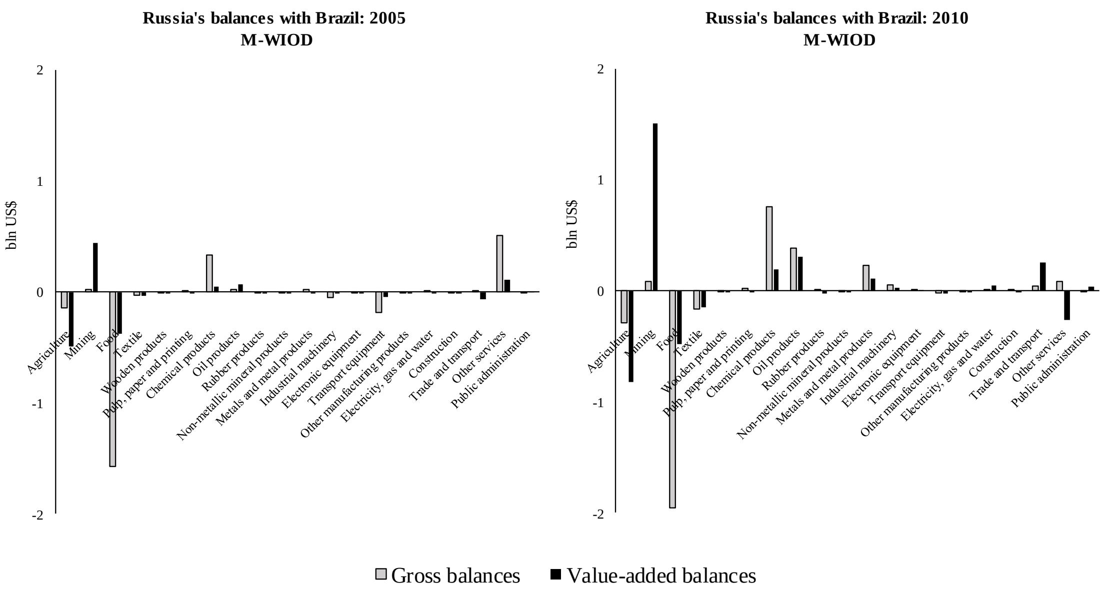

Figure 6. Russia’s trade balances with Brazil by sector in 2005 and 2010

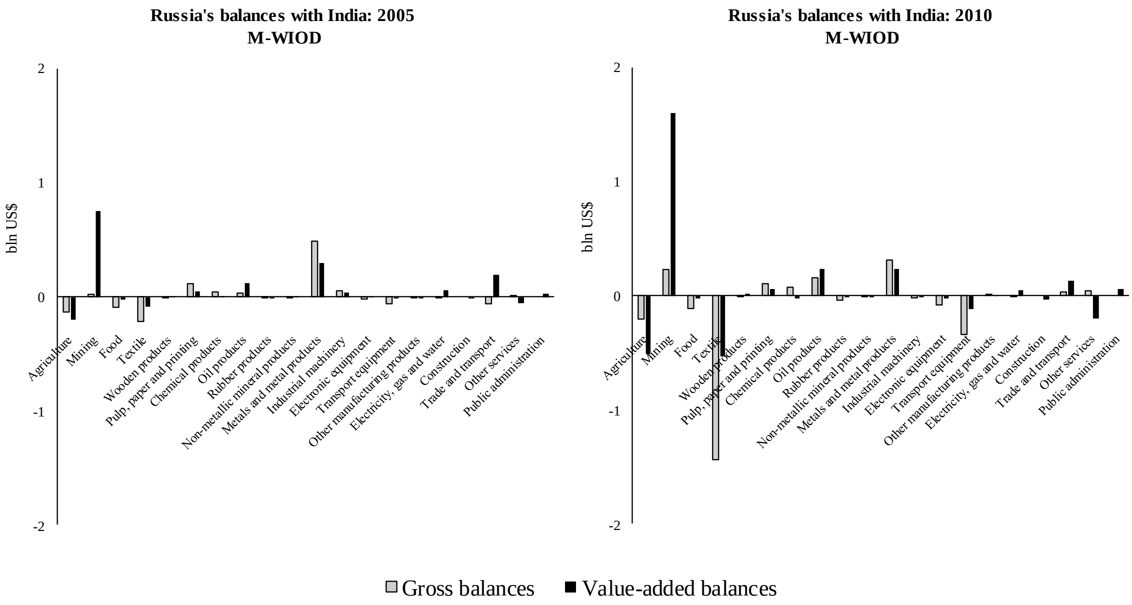

Figure 7. Russia's trade balances with India by sector in 2005 and 2010

Another source of trade balance with Japan is agriculture, including fisheries. The value-added trade balance with Japan for agriculture in 2005 (2010) is US$0.4 billion (US$0.5 billion), which is 29% (38%) lower than the gross trade balance. Another source of trade balance with India is the metals and metal products industry. The value-added trade balance of the metals and metal products industry with India in 2005 (2010) is US$0.3 billion (US$0.2 billion), which is 39% (24%) lower than the gross trade balance. These changes in trade balances with the paradigm shift can be easily understood, considering the respective value-added ratios (Table 10).

The major source of Russia's trade imbalance with Japan is transport equipment, including passenger automobiles. The value-added imbalance with Japan for transport equipment in 2005 (20010) is US$3.8 billion (US$3.9 billion), which is 58% (60%) lower than the gross trade imbalance. This change with the paradigm shift is brought about by the relatively low value-added ratio of transport equipment in Japan

(Table 10). The sources of Russia's trade imbalance with Brazil are agriculture and food industries. The value-added imbalance with Brazil for agriculture in 2005 (2010) is US$0.5 billion (US$0.8 billion), which is 3.3 times (2.8 times) the gross trade imbalance. The value-added imbalance with Brazil for food in 2005 (2010) is US$0.4 billion (US$0.5 billion), which is 76% (76%) larger than the gross trade imbalance due to the Brazilian value-added ratio for food (Table 10). The sources of Russia's trade imbalance with India are agriculture and textiles related to cotton fiber and cotton products. The value-added trade imbalance with India for agriculture in 2005 (2010) is US$0.2 billion (US$0.5 billion), which is 52% (2.5 times) higher than the gross trade imbalance. The value-added trade imbalance with India for textiles in 2005 (2010) is US$0.1 billion (US$0.5 billion), which is 58% (63%) smaller than the gross trade imbalance due to the Indian value-added ratio of textiles (Table 10).

Figure 8 presents Russia's trade balances with the ROW by sector using M-WIOD for 2005 and 2010. The ROW includes all countries other than BRIC, the EU27, Japan, and the USA. The key sector of Russia's trade balances with the ROW is mining, followed by T&T and oil products. The value-added trade balance with the ROW for mining in 2005 (2010) is US$20.2 billion (US$39.1 billion), which is 27% higher (10% smaller) than the gross trade balance. The value-added trade balance with the ROW for T&T in 2005 (2010) is US$10.2 billion (US$20.1 billion), which is 36% (46%) lower than the gross trade balance. The value-added trade balance with the ROW for oil products in 2005 (2010) is US$ 5.6 billion (US$ 8.9 billion), which is 48% (47%) smaller than the gross trade balance due to Russia's value-added ratio of oil products. The major sources of Russia's trade imbalance with the ROW are agriculture and textiles. The value-added trade imbalance with ROW for agriculture in 2005 (2010) is

US$6 billion (US$12.9 billion), which is 6% (13%) higher than the gross trade imbalance. The value-added trade imbalance with the ROW for textiles in 2005 (2010) is US$2 billion (US$10.8 billion), which is 59% (60%) lower than the gross trade imbalance.

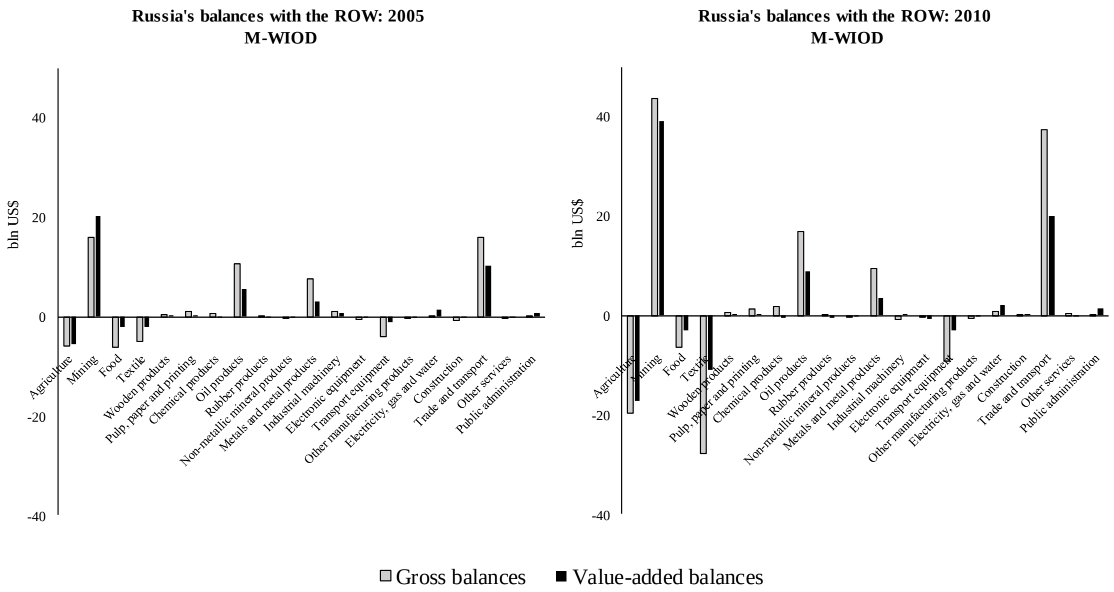

Figure 8. Russia's trade balances with the ROW by sector in 2005 and 2010

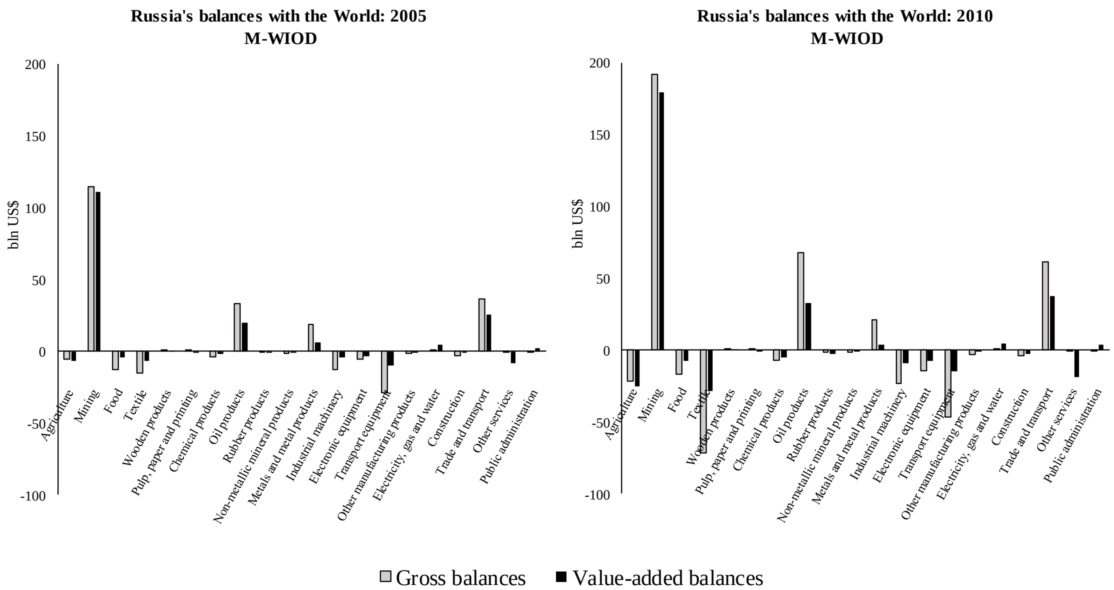

Figure 9. Russia's trade balances with the World by sector in 2005 and 2010

Figure 9 summarizes Figures 2–8, presenting Russia's trade balances with the world by sector, based on M-WIOD, for 2005 and 2010.

The major sources of Russia's trade balances (surpluses) with the world are mining, T&T, and oil products. The value-added trade balance with the world for mining in 2005 (2010) is US$111.5 billion (US$179.3 billion), which is 3% (7%) lower than the gross trade balance. This change in the trade balance with the paradigm shift reflects both of the relatively high value-added ratio of Russia's mining sector (Table 10) and outputs induced by global final demand through the international Leontief inverse (Tables 11–12). The value-added trade balance with the world for T&T in 2005 (2010) is US$25.9 billion (US$37.6 billion), which is 29% (39%) lower than the gross trade balance. After subtracting T&T margins from value-added and exports from T&T in the original WIOD, the value-added trade balance of T&T is still large. The value-added trade balance with the world for oil products in 2005 (2010) is US$19.7 billion (US$33 billion), which is 41% (51%) lower than the gross trade balance. Other sources of Russia's trade balances with the world include the metals and metal product industry, the wooden products industry, and the electricity supply industry. The value-added trade balance with the world for metals and metal products in 2005 (2010) is US$6.3 billion (US$4.2 billion), which is 66% (80%) lower than the gross trade balance due to the relatively low value-added ratio of Russian metals and metal products. The value-added trade balance with the world for metals and metal products in 2005 (2010) is US$0.5 billion (US$0.3 billion), which is 52% (72%) lower than the gross trade balance due to the relatively low value-added ratio of Russian wooden products. In contrast, the value-added trade balance with the world for electricity supplies in 2005 (2010) is US$4.6 billion (US$5 billion), which is 5.9 times (3.7 times) the gross trade balance due to high output induced by global final demand through the Leontief inverse.

The major sources of Russia's trade imbalances (deficits) with the world are machinery products, including transport equipment, industrial machinery, and electronic equipment. The value-added imbalance with the world for transport equipment in 2005 (2010) is US$9.4 billion (US$14.7 billion), which is 68% (68%) lower than the gross trade imbalance due to the relatively low value-added ratio of Russian transport equipment. The value-added imbalance with the world for industrial machinery in 2005 (2010) is US$4 billion (US$8.8 billion), which is 67% (62%) smaller than the gross trade imbalance. The value-added imbalance with the world for electronic equipment in 2005 (2010) is US$4 billion (US$8.8 billion), which is 44% (47%) smaller than the gross trade imbalance. Other sources of Russia's trade imbalance with the world include agriculture and textiles. The value-added imbalance with the world for agriculture in 2005 (2010) is US$6.9 billion (US$24.9 billion), which is 27% (15%) smaller than the gross trade imbalance. The value-added imbalance with the world for textiles in 2005 (2010) is US$6.2 billion (US$28.6 billion), which is 59% (60%) smaller than the gross trade imbalance. We note that Russia has experienced a boost in imports due to large increases in international oil prices and its mining activities in the 2000s (Kuboniwa 2012).

As shown by Theorem 1 and Figure 1, overall, Russia's total value-added balance (net "value-added exports") with the world in 2005 (2010), US$114.9 billion (US$134.6 billion), exactly equals its total gross trade balance (net "gross exports" or net exports) with the world, adjusted for the dummy. That is to say, Russia's factor content of trade simply means net exports in conventional terminology.

Judging from the shares of trade balances and changes in trade balances with the paradigm shift, one may conclude that Russia's trade structure is rather good because mining exports that contribute to a substantial amount of the value-added balance and value-added imports of machinery products, textiles, and agriculture are much lower than respective gross imports. Furthermore, one may conclude that Russia should specialize in mining with high value-added exports. However, we should also consider Russia's limited capacity for mining exports to increase per capita GDP, paying special attention to the relationship between the total gross trade balance and the total value-added balance. Diversification of the economy by developing further machinery products with higher net "gross exports" still remains Russia's main policy agenda (Kuboniwa 2012 and 2014c).

Lastly, we would like to investigate changes in Russia's value-added exports for mining with the paradigm shift, which differ by destination countries (Table 11), in detail.

Table 13 shows the top 25 contributors (of 160 factors) to Russia's value-added exports for mining to the USA in 2010 using M-WIOD. We note that Russia's value-added ratio for mining in 2010 is 0.781, and its gross exports to the USA from mining are US$4.2 billion. Column 3 of Table 13 is given by column 1 × column 2 × 0.781. As seen from the table, huge amounts of the USA's own final demand for public administration, T&T, and other services generate relatively large amounts of Russia's value-added exports to the USA, despite very low levels of elements of the Leontief inverse. The USA's own final demand for oil products as well as its final demand imports of oil products from the EU and ROW generates Russia's value-added to the USA due to relatively high levels of elements of the Leontief inverse. The USA's final demand imports of electronic equipment from China and ROW also induce Russia's value-added from mining to the USA through the Leontief inverse. These result in Russia's value-added exports of mining to the USA, which are 3.8 times gross exports (Table 11). The USA's value-added exports from mining to Russia (Russian imports from the USA) are 6.4 times gross exports (Table 12). This change is higher than the case for Russia's exports to the USA. However, the level of USA's gross exports from mining to Russia is rather small. Therefore, Russia's value-added trade balance with the USA for mining is still 3.4 times its gross trade balance.

Table 14 demonstrates the top 25 contributors to Russia's value-added exports to China for mining in 2010. Russia's value-added ratio for mining is 0.781, and its gross exports to China for mining amount to US$9.3 billion. Substantial amounts of China's own final demand for construction, other services, T&T, industrial machinery, transport equipment, and electronic equipment generate large amounts of Russia's value-added exports to China. China's final demand imports of industrial machinery, transport equipment, electronic equipment, and chemical products from the EU also contribute to Russia's value-added exports to China for mining. In addition, China's final demand imports of transport and electronic equipment from Japan slightly contribute to Russia's value-added exports to China for mining. These lead to Russia's value-added exports of mining to China, which are 1.3 times the gross exports (Table 11).

Table 13. Top 25 contributors to Russia's value added exports to the USA of mining: 2010 (M-WIOD)

Rank	Product (j)	Country (s)	Leontief inverse $brus(mining)s(j)$	USA's final demand $Fusa, s(j)$ bln US$	Russia's value-added exports of mining to USA bln US$
1	Public administration	USA	0.00091	2,907.7	2.07
2	Trade and transport	USA	0.00086	3,050.7	2.05
3	Other services	USA	0.00037	5,476.6	1.57
4	Construction	USA	0.00180	846.6	1.19
5	Oil products	USA	0.00819	178.6	1.14
6	Oil products	EU27	0.18011	6.4	0.90
7	Chemical products	EU27	0.01862	38.0	0.55
8	Oil products	ROW	0.04523	15.2	0.54
9	Transport equipment	USA	0.00248	250.9	0.49
10	Food	USA	0.00138	419.6	0.45
11	Chemical products	USA	0.00322	163.8	0.41
12	Chemical products	ROW	0.01607	28.0	0.35
13	Transport equipment	ROW	0.00511	80.3	0.32
14	Electricity, gas and water	USA	0.00201	201.5	0.32
15	Electronic equipment	ROW	0.00521	74.9	0.31
16	Electronic equipment	CHN	0.00362	94.4	0.27
17	Industrial machinery	USA	0.00202	124.3	0.20
18	Textile	ROW	0.00375	63.1	0.185
19	Transport equipment	EU27	0.00716	31.6	0.1771
20	Oil products	RUS	0.38403	0.6	0.1766
21	Mining	USA	0.00178	116.0	0.16
22	Industrial machinery	ROW	0.00826	23.9	0.15
23	Electronic equipment	USA	0.00105	158.8	0.13
24	Industrial machinery	EU27	0.00691	22.8	0.123
25	Pulp, paper and printing	USA	0.00117	129.1	0.118
	Subtotal			14,503.3	14.3
	Total			15,097.4	15.9

Sources: WIOD and author's estimates

Table 14. Top 25 contributors to Russia's value added exports to China of mining: 2010 (M-WIOD)

Rank	Product (*j*)	Country (*s*)	Leontief inverse $b_{rus(mining)s(j)}$	China's final demand $F_{usa,s(j)}$ bln US$	Russia's value-added exports of mining to China bln US$
1	Construction	CHN	0.00346	1,640.5	4.43
2	Other services	CHN	0.00158	1,112.6	1.37
3	Trade and transport	CHN	0.00196	570.8	0.87
4	Industrial machinery	CHN	0.00372	240.2	0.70
5	Transport equipment	CHN	0.00326	247.6	0.63
6	Electronic equipment	CHN	0.00362	215.7	0.61
7	Public administration	CHN	0.00140	387.6	0.42
8	Food	CHN	0.00135	381.8	0.40
9	Agriculture	CHN	0.00116	320.7	0.29
10	Textile	CHN	0.00219	137.7	0.24
11	Metals and metal products	CHN	0.00610	41.5	0.20
12	Industrial machinery	EU27	0.00691	36.3	0.20
13	Electronic equipment	ROW	0.00521	46.3	0.19
14	Industrial machinery	ROW	0.00826	23.3	0.15
15	Chemical products	CHN	0.00603	29.5	0.14
16	Transport equipment	EU27	0.00716	23.4	0.13
17	Electricity, gas, and water	CHN	0.00411	26.9	0.09
18	Chemical products	EU27	0.01862	5.4	0.078
19	Electronic equipment	EU27	0.00581	15.0	0.0680
20	Oil products	CHN	0.01782	4.8	0.0671
21	Chemical products	ROW	0.01607	4.6	0.06
22	Rubber products	CHN	0.00454	12.0	0.04
23	Electronic equipment	JPN	0.00256	18.1	0.04
24	Industrial machinery	JPN	0.00273	16.5	0.035
25	Oil products	EU27	0.18011	0.2	0.025
	Subtotal			5,558.7	11.5
	Total			5,687.2	11.9

Sources: WIOD and author's estimates.

We also select two other examples to examine changes in exports with the paradigm shift. Table 15 shows the top 25 contributors to Russia's value-added exports to China for non-metallic mineral products (NMMP) in 2010. Russia's value-added ratio of NMMP is 0.3595, and its gross exports of NMMP to China amount to US$60,003.5. China's own final demand for construction, other services, T&T, and all machinery products generates Russia's value-added NMMP exports to China. China's final demand imports for all machinery products from the EU also contribute to Russia's value-added exports of NMMP. These result in Russia's value-added exports of NMMP, US$56.8 million, which is about 950 times gross exports (Table 11). Table 16 shows the top 25 contributors to Russia's value-added exports to Brazil for textiles in 2010. Russia's value-added ratio of textiles is 0.3591 whereas its gross exports of textiles to Brazil amount to US$6,911. Brazil's own final demand for other services, construction, T&T, transport equipment, chemical products, and food generates Russia's value-added exports of textiles to Brazil. Brazil's final demand imports for oil products from Russia and the EU also contribute to Russia's value-added exports of textiles to Brazil. In all, Russia's value-added exports to Brazil for textiles amount to US$3.5 million, which are about 500 times gross exports (Table 11).

Table 15. Top 25 contributors to Russia's value added exports to China of non-metallic mineral products (nmmp): 2010 (M-WIOD)

Rank	Product (j)	Country (s)	Leontief inverse $brus(nmmp)s(j)$	China's final demand $Fchn, s(j)$ bln US$	Russia's value-added exports of nmmp to China bln US$
1	Construction	CHN	0.00003	1,640.5	0.02
2	Other services	CHN	0.00002	1,112.6	0.01
3	Trade and transport	CHN	0.00002	570.8	0.00
4	Industrial machinery	CHN	0.00004	240.2	0.00
5	Electronic equipment	CHN	0.00004	215.7	0.00
6	Transport equipment	CHN	0.00003	247.6	0.00
7	Public administration	CHN	0.00001	387.6	0.00
8	Food	CHN	0.00001	381.8	0.00
9	Agriculture	CHN	0.00001	320.7	0.00
10	Electronic equipment	ROW	0.00008	46.3	0.00
11	Textile	CHN	0.00002	137.7	0.00
12	Industrial machinery	ROW	0.00013	23.3	0.00
13	Industrial machinery	EU27	0.00007	36.3	0.00
14	Food	RUS	0.00650	0.3	0.00
15	Metals and metal products	CHN	0.00004	41.5	0.00
16	Transport equipment	EU27	0.00007	23.4	0.00
17	Chemical products	CHN	0.00005	29.5	0.00
18	Industrial machinery	RUS	0.00833	0.2	0.000
19	Electronic equipment	EU27	0.00006	15.0	0.0003
20	Chemical products	ROW	0.00017	4.6	0.0003
21	Electricity, gas, and water	CHN	0.00003	26.9	0.00
22	Rubber products	CHN	0.00005	12.0	0.00
23	Trade and transport	RUS	0.00787	0.1	0.00
24	Chemical products	EU27	0.00011	5.4	0.000
25	Oil products	CHN	0.00010	4.8	0.000
	Subtotal			5,524.4	0.1
	Total			5,687.2	0.1

Sources: WIOD and author's estimates.

Table 16. Top 25 contributors to Russia's value added exports of textile to Brazil: 2010 (M-WIOD)

Rank	Product (j)	Country (s)	Leontief inverse $brus(nmmp)s(j)$	Brazil's final demand $Fbra, s(j)$ bln US$	Russia's value-added exports of txtile to Brazil bln US$
1	Other services	BRA	0.00000	592.1	0.00
2	Construction	BRA	0.00000	169.0	0.00
3	Trade and transport	BRA	0.00000	314.7	0.00
4	Transport equipment	BRA	0.00001	77.6	0.00
5	Chemical products	BRA	0.00001	48.9	0.00
6	Food	BRA	0.00000	124.0	0.00
7	Public administration	BRA	0.00000	275.6	0.00
8	Industrial machinery	BRA	0.00001	44.3	0.00
9	Oil products	ROW	0.00015	2.0	0.00
10	Textile	BRA	0.00001	42.0	0.00
11	Agriculture	BRA	0.00001	45.2	0.00
12	Electronic equipment	BRA	0.00001	36.7	0.00
13	Transport equipment	ROW	0.00003	8.5	0.00
14	Industrial machinery	RUS	0.00269	0.1	0.00
15	Textile	ROW	0.00026	0.9	0.00
16	Oil products	BRA	0.00001	32.6	0.00
17	Oil products	RUS	0.00141	0.1	0.00
18	Other manufacturing product	BRA	0.00001	21.6	0.000
19	Chemical products	ROW	0.00006	2.1	0.0000
20	Chemical products	EU27	0.00004	3.1	0.0000
21	Industrial machinery	EU27	0.00002	5.5	0.00
22	Electronic equipment	CHN	0.00001	8.5	0.00
23	Electricity, gas, and water	BRA	0.00000	36.4	0.00
24	Electronic equipment	ROW	0.00003	3.7	0.000
25	Oil products	EU27	0.00028	0.3	0.000
	Subtotal			1,895.7	0.0
	Total			1,970.9	0.0

Sources: WIOD and author's estimates.

6. Concluding remarks

The growing global intermediate goods trade requires further investigation from both theoretical and empirical perspectives in international trade. We tried to further develop the theory of value-added trade and conduct an empirical analysis of Russia's value chains using a modified version of WIOD. Although we modified the original WIOD in relation to Russia's exports of oil and gas, further investigation of these modifications element by element remains a future task. We also need to further study the relationships between long-run economic growth and value-added trade.

Acknowledgements

I thank Yoshisada Shida (Hitotsubashi University) for his diligent assistance. This study was supported by the IDE JETRO, the JSPS Grants-in-Aid for Scientific Research (B), number 24330085, and the Sumitomo Mitsui Banking Overseas Cooperation Foundation Grant. The usual disclaimer applies.

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Appendix

Table A1. Sector classification

M-WIOD		WIOD	IDE-BRICs IIOT
code	Sector	code	code
1	Agriculture	c1	1-4
2	Mining	c2	5-6
3	Food	c3	7
4	Textile	c4-c5	8
5	Wooden products	c6	9
6	Pulp, paper and printing	c7	10
7	Chemical products	c9	11
8	Oil products	c8	12
9	Rubber products	c10	13
10	Non-metallic mineral products	c11	14
11	Metals and metal products	c12	15
12	Industrial machinery	c13	16
13	Electronic equipment	c14	17-18
14	Transport equipment	c15	19
15	Other manufacturing products	c16	20
16	Electricity, gas and water	c17	21
17	Construction	c18	22
18	Trade and transport	c19-c27	23
19	Other services	c28-c30, c32-c35	24
20	Public administration	c31	25

[1] The model below is essentially equivalent to the model presented by Johnson and Noriega (2012) except for our explicit exposition of a dual price system associated with an input–output system.

[2] It is not clear how the original WIOD dealt with this problem.

[3] In the original WIOD, Russia's export taxes are recorded as zero because no other countries have such export taxes. However, these taxes, which constitute the major part of Russia's net taxes on products in the official SNA, do not seem to be transferred to value-added or exports in the WIOD. That is to say, an important part of Russia's GDP at market prices and its federal budget disappears in the original WIOD.