The Environmental Implications of Russia’s Accession to the World Trade Organization

Christoph Böhringer
Thomas F. Rutherford
David G. Tarr
Natalia Turdyeva

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Abstract

This report investigates the environmental impacts of Russia's accession to the World Trade Organization. A 10-region, 30-sector model of the Russian economy is developed. The model is innovative and more accurate empirically in that it contains foreign direct investment, imperfectly competitive sectors, and endogenous productivity effects triggered by World Trade Organization accession along with environmental emissions data in Russia for seven pollutants that are tracked for all 30 sectors in each of the 10 regions. The decomposition analysis shows that despite the fact that World Trade Organization accession allows Russia to import better technologies and reduce pollution from the "technique effect," on balance World Trade Organization accession alone will increase environmental pollution in Russia through a shift toward dirty industries (the "composition effect") and the expansion of output with its associated increase in pollution ("scale effect"). The paper assesses the costs of three types of environmental regulations to reduce carbon dioxide emissions by 20 percent. The paper simultaneously implements a central case scenario with each of the carbon dioxide emission reduction policy initiatives. The analysis finds that the welfare gains of World Trade Organization accession are large enough to pay for the costs of any of the three environmental abatement policies, while leaving a net welfare gain. But the political economy implications are that the non-market-based policies are more costly and the command and control policy, which is not well targeted, is very costly. Based on a constant returns to scale model, the estimated welfare gains are insufficient to finance the costs of environmental regulation.

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*David G. Tarr, Consultant and Former Lead Economist, The World Bank, is the corresponding author; dgtarr@gmail.com; Christoph Böhringer is professor of economics at the University of Oldenburg; Thomas F. Rutherford is professor of agricultural and applied economics at the University of Wisconsin. Natalia Turdyeva is senior researcher at the Center for Economics and Financial Research, Moscow, Russia. The authors would like to thank Craig Meisner (as the Task Team Leader), Adriana Damianova and Kulsum Ahmed for their insight and guidance. The authors gratefully acknowledge the financial support for this project (P133836) provided through a Research Budget Grant from the World Bank's Development Research Administration (DECRA).
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1. Introduction

After 18 years of negotiations, Russia joined the World Trade Organization (WTO) in 2012. WTO accession is a comprehensive process that involves multiple reforms including maximum tariff commitments on goods, non-protective application of standards and norms, market access for foreign suppliers of services, rules on trade related investment measures and limitations on trade distorting agricultural subsidies. Such comprehensive changes in policies and institutions are likely to lead to considerable changes in the structure of the economies of the acceding countries. The structural changes can have complex impacts on the environment that are very difficult to predict based on theory. Using the terminology of Grossman and Krueger (1993), the potential environmental impacts can be decomposed into: (i) a composition effect, namely inter-industry impacts along the lines of comparative advantage (toward or away from dirty industries) and competitive pressures that would shift output toward more efficient firms, lowering input use; (ii) a scale effect due to output changes induced by trade liberalization; and (iii) a technique effect, due to the use of more efficient imported technology (which could reduce input use and emissions), changes in process efficiency, and changes in fuel mix. Policy-makers in Russia are showing an interest in the expected environmental impacts of WTO accession, as they may want to introduce regulation to either mitigate negative impacts on the environment or complement positive impacts.

In applied analysis, computable general equilibrium (CGE) models are widely used to quantify the economic and environmental impacts of policy regulations such as trade reforms or emission control policies. While most CGE assessments of environmental impacts are built on constant-returns-to-scale (CRTS) and competitive markets, these models omit potentially important productivity changes that could be associated with importing more efficient technology and processes. Further, both the scale and composition effects could be very different in a model that allows sectors subject to increasing returns to scale (IRTS). Such productivity effects are captured by CGE trade models that build on the trade theory introduced by Krugman (1979, 1980) and Ethier (1982) through the introduction of imperfect competition, increasing returns to scale and product differentiation. Yet these models typically fall short of detailed environmental accounting and the more sophisticated representation of inter-fuel substitution possibilities in production and consumption.
Against this background, we build on the ten-region, 30 sector model of the Russian economy developed by Rutherford and Tarr (2010) to assess Russian WTO accession; we incorporate environmental emissions data in Russia for seven pollutants associated with output (for non-carbon dioxide emissions) and burning of fossil fuel (for carbon dioxide emissions). Emissions are tracked for all 30 sectors in each of the ten Russian regions of our model. Our integrated trade and environment model contains increasing returns to scale sectors, foreign direct investment in business services, product differentiation and endogenous productivity effects from additional varieties of goods or services in imperfectly competitive sectors. In addition, we extend Rutherford and Tarr by allowing fuel substitution in production and consumption. We develop a methodology to quantify the decomposition of the scale, composition and technique effects of all simulations. Compared with earlier CGE research quantifying the impacts of trade on the environment based on CRTS models, we more effectively account for productivity changes that may have an important impact on emissions. In our assessment of WTO accession for Russia we find drastic differences in the economic and environmental impacts between model simulations without and with productivity changes.

With a nominal per capita income above US$14,000 per year in 2013 (and a purchasing power parity per capita income of about US$18,000), it is possible that Russia is above the point on the environmental Kuznets curve where the higher incomes coming from WTO accession may increase the demand for greater environmental regulation. In fact, Antweiler et al., (2001) have shown in their empirical study of over 40 countries, that trade liberalization has been associated with a cleaner environment due to stronger environmental regulations following trade liberalization. Notwithstanding these optimistic possibilities for environmental regulation (and the stated objectives of the Russian government outlined in the next section), we believe it is crucial to address political economy considerations of environmental regulation. That is, to minimize opposition to environmental regulation, it is crucial to design policies that minimize the costs to industry of achieving a given level of environmental abatement. In a second set of simulations, we assess the costs of three types of environmental regulations to reduce carbon dioxide emissions by 20 percent: market based “cap and trade”; emission intensity standards; and energy efficiency standards. Given that part of the income increase from WTO accession might be used to pay for environmental abatement, in a third set of scenarios, we assess the impacts of “overlapping” policy reforms where we simultaneously implement our central case scenario of WTO accession with each of our three carbon emission reduction policy initiatives. Again, the relative costs of the different environmental regulations are compared.
The remainder of this document is organized as follows. Section 2 summarizes the environmental policy debate in Russia which explains the interest of Russian policy makers on potential trade-offs between trade liberalization and environmental quality. Section 3 provides a brief literature overview on trade and the environment. Section 4 presents the CGE model and the data sources underlying our impact assessment of Russia’s WTO accession. Section 5 motivates the policy scenarios to be investigated and discusses simulation results. In section 6 we assess the sensitivity of our results to key modeling, data and parameter assumptions. Section 7 concludes. Detailed documentation of the environmental data is in the appendix.

2. Environmental Policy Debate in Russia

Russia is the largest country in the world, spanning nine time zones with a population of 143.7 million people. It is also one of the richest countries in the world for oil, gas and a wide range of minerals. Russia’s natural endowment has been a key driver of economic growth in the current millennium, based on production and export of raw materials. The impacts of extraction and manufacturing industries from the Soviet-period to today have not been neutral to environmental damage and public health. Many industries are characterized by high resource use, extremely high energy inefficiency and obsolete production processes. The quality of environmental conditions in Russia is inadequate on about 15% of the country’s territory which is home to 58% of the population. Due to high levels of air pollution, the average life expectancy of the population is reduced by about one year, while in more polluted cities by about four years. It is assumed that this factor is the reason for about 8% of deaths annually. The main sources of air pollution are Particulate Matter (PM), Sulphur Dioxide (SO2) and Nitrogen Oxide (NOx) linked to fossil fuel combustion (IFC 2008).

A major challenge for Russia to address air pollution is the potential increase of the share of coal in the fuel mix, as export markets take priority for oil and natural gas use. Russia is currently planning to triple the share of coal in the energy mix so that the amount of coal burned will grow to between 322 million and 393 million tons of coal per year by 2030. New coal generation is potentially a good option for Russia to increase its generation capacity, but care will need to be taken to identify the best “clean-coal” technologies to use in these new plants.

1 As of 1\textsuperscript{st} of April, 2014, Rosstat (2014).
2 According to Rosgidromet (2013): “In 138 cities in Russia (57\% of the urban population), the level of air pollution is characterized as high or very high.”
3 See “Energy strategy of the Russian Federation up to 2030,” appendix 4 entitled “Estimated energy balance of Russia until 2030,” by the Ministry of Energy of the Russian Federation. Available at: http://minenergo.gov.ru/aboutminen/energostrategy/pr_4.php
Russia is currently the world's fourth-largest emitter of greenhouse gas emissions. At the international level, Russia ratified the Kyoto Protocol in 2004 to be part of the global community’s solution to climate change. More recently, there has been a shift in Russian attitude to national, non-binding targets as evidenced by the refusal to renew its Kyoto Protocol commitments at the Durban conference in 2011; but following the Copenhagen accords, Russia is still pursuing a greenhouse gas emission reduction of between 15% and 25% from 1990 emission levels by 2020.

The Government of the Russian Federation has begun to formally recognize environmental challenges in their policies, strategies and programs. Russia’s Program on Environmental Protection 2012-2020 recognizes the inseparability of environmental, social and economic objectives as central for sustainable development. The new policies mark a shift towards a sustainable development model emphasizing increased investments in energy and resource efficiency, cleaner technologies, recycling and reuse of wastes. Transition to an effective system of incentives that promotes less use of resources and cleaner and greener production would typically also improve competitiveness and increase access to export markets which demand efficient, low environmental-impact materials and products. According to its state program on "Energy Saving and Energy Efficiency Improvement until 2020," Russia's is seeking to achieve a 40% reduction in energy intensity by 2020 and 56% by 2030. In addition, it is striving to achieve 53% efficiency in gas-fired power generation by 2030.

Russia’s WTO accession has engendered concerns about potentially negative environmental impacts. We now consider this in the context of the broader trade liberalization and the environment literature.

3. Trade and the Environment Literature: Implications for Russia

Impact assessment of the North American Free Trade Agreement (NAFTA) in the early 1990s stimulated theoretical and empirical analysis on the environmental impacts of

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4 On November 5, 2004, Russia ratified the Kyoto Protocol, and the Protocol came into force in February 2005. Russia is listed in Annex B of the Protocol and, as such, is subject to a constraint on its GHG emissions for the period 2008-2012. The target for Russia is that the country’s combined emissions of Kyoto gases should not exceed five times their combined 1990 levels during the period 2008-2012. This target is generally expressed in annual terms: on average, Russia’s annual emissions of the six Kyoto gases should not exceed their 1990 level – 3,048 million tons of carbon dioxide equivalent (MtCO2e) – over the period 2008-2012. Since 1999, Russia’s economy has grown at a pace of more than 6 percent per year, calling into question whether Russia will stay within the borders set by the Kyoto Protocol for the period beyond 2012.

5 See Ministry of Natural Resources and Environment of the Russian Federation (2014).

6 See Ministry of Energy of the Russian Federation (2010).
trade liberalization. In their seminal papers, Grossman and Krueger (1993) as well as Copeland and Taylor (1994, 1995) decomposed the overall impact into three effects – changes in scale, composition and technique (see introduction). In the environment-trade literature the economic drivers for changes in scale, composition and technique are most commonly captured through the classical model of comparative advantage which explains the pattern of international trade through the relative cost differences between countries (see Rauscher 1997 and Dean 1992, 2002 for overviews). The theory of comparative advantage gives rise for two complementary views on the environmental impacts of trade liberalization (Antweiler et al. 2001). The so-called Factor Endowment hypothesis suggests that – as countries specialize according to their traditional comparative advantages – freer trade leads to a further concentration of those industries that employ the relatively abundant production factor: if emissions are linked to capital-intensive industries then then trade liberalization would lead to an expansion of these industries in relatively capital-abundant countries and thereby also increase emissions. The so-called Pollution Haven hypothesis suggests that trade liberalization will make countries with less stringent environmental regulations dirtier as they possess a policy-induced cost advantage.

While the traditional theory of comparative advantage indirectly captures scale and technique effects, it focuses on composition effects through specialization. The new trade theory pioneered by Krugman (1979; 1980) or Ethier (1982) introduced imperfect competition and increasing returns to scale (IRTS). Scale and endogenous productivity effects through additional product varieties or rationalization gains are possible. The literature initiated by Melitz (2003) incorporates the Krugman-Ethier features and provides yet another source for productivity changes through firm heterogeneity. If trade liberalization leads to an expansion of industries subject to IRTS technology, such as refineries, base metals and chemicals – that are also very energy-intensive –pollution problems will be exacerbated due to the scale and composition effects compared to a CRTS reference. On the other hand, the technique effect could be offsetting. Productivity changes may emerge through trade liberalization due to rationalization gains or as the number of product varieties and technologies increase thereby rendering those sectors more productive, resulting in less resource use per unit of output and less pollution (formally represented in models of monopolistic competition with Dixit-Stiglitz varieties (Dixit and Stiglitz, 1977). Romer (1994) emphasized that the impact of trade liberalization via new products can be much more important quantitatively than improved resource allocation. The model we employ in this paper employs this feature. Finally, with firm heterogeneity, trade creates competitive pressure which induces high productivity firms to expand output and export while low productivity firms drop out of the market, increasing aggregate productivity. The intra-
industry reallocations of market shares and productive resources add to effects associated with inter-industry reallocations that are driven by comparative advantage.

The model of this paper is more closely related to the strand of the trade-environment literature that deals with the implications of Foreign Direct Investment (FDI), and more specifically FDI in services. The optimistic micro view is that FDI supports knowledge transfer and market-penetration of innovative technologies which allow firms to reduce energy-pollution-intensity of production and consumption with the potential of leapfrogging, i.e. the possibility to bypass environment-intensive developments (Gentry 1999; Mielnik and Goldemberg, 2002). Since the papers of Markusen (1989) and Francois (1990), the theoretical literature has supported the view that the wide availability of business services results in total factor productivity gains to the manufacturing sector and the economy broadly. In recent years, there is a growing body of empirical literature that has found a positive impact on total factor productivity from FDI in business services. In the case of Russia, we discuss below the wide range of commitments to foreign investors in services that Russia has made as part of its WTO accession negotiations. This includes commitments to foreign direct investors in environmental services including sewage services, refuse disposal services, sanitation services, cleaning services of exhaust gases, nature and landscape protection and environmental impact assessment services. The prospect of FDI-induced environmental improvements in host countries through better technologies and higher environmental standards is referred to as the "pollution halo" hypothesis (Zarsky 1999).

On theoretical grounds, the scale, composition and technique effect can have positive or negative signs. Given this ambiguity, there is the need for empirical analysis to quantify not only the magnitude but also the direction of the individual and the composite environmental impacts. One rigorous empirical analysis is provided by Antweiler et al. (2001) who estimated the magnitudes of the scale, composition and technique effects for the case of sulphur dioxide concentrations in more than forty countries. According to their econometric regressions, a strong negative technique effect dominated the positive scale effect leading to a decrease in emissions (the technique effect, however, was mainly due to stricter environmental regulations after trade liberalization). Another econometric assessment has been undertaken by Cole et al. (1998) on the emission impacts of trade policy changes suggested by the Uruguay Round. In their analysis the composition effect increased emissions for industrialized countries whereas for most developing countries, emissions associated with

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For the theoretical literature, see, for example, Markusen (1989) and Francois (1990) and the numerical application of Markusen, Rutherford and Tarr (2005). See Francois and Hoekman (2010) for a survey of more than a dozen empirical studies that support the finding of productivity effects from additional business services. Support comes from a variety of sources including studies that use firm level data, such as Arnold et al., (2011) for the Czech Republic and Fernandes and Paunov (2012) for Chile, Shepotylo and Vakhitov (2012) for Ukraine and Arnold et al., (2012) for India.
the composition effect declined. Trade liberalization induced an expansion of energy-intensive industries in industrialized countries and an expansion of labor-intensive manufactures in developing countries thus suggesting that in their analysis the Factor Endowment hypothesis dominates the Pollution Haven hypothesis. More recent empirical work (Frankel and Rose 2005, Kellenberg 2008) highlights the complex interplay between the Factor Endowment hypothesis and the Pollution Haven hypothesis and the need for country-specific analysis to determine which effect dominates based on real data (see also the mixed evidence on environmental impacts through FDI in Esty and Gentry, 1997 and Smarzynska and Wei, 2001). Econometric estimates on the technique effect of trade liberalization are scarce in part because of limited data availability. One exception is Martin (2012) who assesses the implications of trade openness on greenhouse gas emissions by India’s manufacturing firms. Martin found that the reduction in import tariffs led to improved fuel efficiency as fuel efficient manufacturing firms gained market share whereas fuel-inefficient firms lost market share; within the manufacturing sector, improved capital access tended to reduce fuel-intensity rather than increase it because of technological (energy-saving) progress embodied in new vintages.

A substantial part of the applied literature on the trade-environment linkage is based on computable general equilibrium analyses. Most applications focus on the mutual effects that trade policies and CO2 reduction policies can have on each other. Examples are Babiker et al. (1997) and Kuik and Gerlagh (2003), who use CRTS multi-region multi-sector CGE models of global trade and energy use. In the same vein, Vennemo et al. (2007) quantify the environmental impacts of China's accession to the WTO as the outcome of scale, composition and technique effects (they use a CRTS small open economy model). They identify a dominate composition effect in favor of clean industries which leads to a decrease of China’s greenhouse gas emissions.

4. CGE Model for Russia: Structure and Data

4.1 Production and Geographic Structure

4.1.1 Sectors, Regions and Core Data

There are 30 sectors in the model that are listed in table 1. There are three types of sectors: perfectly competitive goods and services, imperfectly competitive goods sectors and imperfectly competitive business services sectors.
We obtain data on the regions of Russia from the publication by Rosstat (2002, 2003) entitled *Regions of Russia*. The regions have several names in Russian; the most common legal jurisdiction is referred to in Russian as an “oblast.” Oblasts are analogous to states in the United States or provinces in Canada. But there are also jurisdictions known as territories, federal cities, autonomous districts and an autonomous region.

We group several contiguous regions into what we call “Regional Markets” (RMs). The mapping of regions into regional markets is shown at the top of table 2. In this paper, we shall analyze effects at the level of the Regional Market. Value-added, exports and imports by sector for our ten regional markets of Russia are presented in tables 3-11.

We assume that firms and sectors operate at the Regional Market level, primary factors of production are not able to move between Regional Markets (unless otherwise noted). We assume a nested CES structure of demand (see figures 1, 2 and 3). Since this implies that the structure of demand is both homothetic and weakly separable; consumers and firms in a representative Regional Market r employ multiple stage budgeting for all goods.

### 4.1.2 Price Determination for Competitive Goods and Services Sectors

Firms in each Regional Market have three choices for sales: sell in their own Regional Market; sell to other parts of Russia; or export to the rest of the world. This is depicted in figure 4. Firms maximize revenue for any given output level based on their transformation possibilities between the three types of goods which is defined by a constant elasticity of transformation production function. For all firms within the same Regional Market, the product they export to other parts of Russia (including other regions within their own regional market) is homogeneous. It follows from our assumptions of homogeneous demand and production outside of the own Regional Market, that for each competitive good, say good g, there will be only three prices for good g of Regional Market r: the price of good g in Regional Market r; the price of good g from Regional Market r in other parts of Russia; and the price of good g from Regional Market r in the rest of the world.

The structure of demand for goods or services from competitive sectors is shown in figure 2. Consumers and firms in a representative Regional Market r first optimize their choice of expenditures on foreign goods versus goods from Russia. Subsequently they optimally allocate their expenditures between goods from other Russian Regional Markets and their own Regional Market. Finally, they optimally allocate their expenditures between goods from the other Russian Regional Markets. This structure assumes that consumers differentiate the products of producers from different regional markets; but, they regard as

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8 The number of regions of Russia has varied over time. This study groups regions of Russia based on data from Rosstat (2002; 2003), which listed 89 regions, and had data on 88.
homogeneous the products of producers from different regions within the same regional market.

4.1.3 Structure of Production for Non-Fossil Fuel Sectors

In figure 5, we depict the structure of production for non-fossil fuel sectors. Regional firms use intermediate inputs (which can be foreign inputs, inputs from other regions of Russia or from its own region) and primary factors of production to produce output. We emphasize that business services are not part of the “other services” nest; rather business services substitute for primary factors of production in a CES nest. We show that the elasticity of substitution between business services and primary factors of production significantly impacts the results. We generalize Rutherford and Tarr (2010) by allowing for inter-fuel substitution as shown in figure 5. A mathematical description of the 30 sector national model of Russia is available as an appendix to Jensen, Rutherford and Tarr (2004).

4.1.4 Goods Produced Subject to Increasing Returns to Scale

The structure of demand for goods produced under increasing returns to scale is shown in figure 3. Consumers (and firms) in RM r, optimally allocate expenditures on good g among the goods available from the different regional markets of Russia and the rest of the world producers. Having decided how much to spend on the products from each regional market, consumers then allocate expenditures among the producers within each regional market. Since we assume identical elasticity of substitution at all levels, this is equivalent to firm level product differentiation of demand. That is, the structure is equivalent to a single stage in which consumers decide how much to spend on the output of each firm in the first stage of optimal allocation of expenditure.

We assume that imperfectly competitive manufactured goods may be produced in each region or imported. Both Russian and foreign firms in these industries set prices such that marginal cost (which is constant with respect to output) equals marginal revenue in each regional market. There is a fixed cost of operating in each region and there is free entry, which drives profits to zero for each firm on its sales in each regional market in which it sells. Quasi-rents just cover fixed costs in each region in the zero profit equilibrium. We assume that all firms that produce from the same regional market have the same cost structure, but costs differ across regions.

\footnote{For example, firms can employ an accountant or a lawyer, or contract for accounting or legal services. They can employ a driver and buy a truck, or contract for delivery services. These examples make it evident that it is more appropriate to allow substitution between business services and primary factors of production than to assume a Leontief structure.}
Foreigners produce goods abroad at constant marginal cost but incur a fixed cost of operating in each RM in Russia. The cif import price of foreign goods is simply defined by the import price; by the zero profits assumption, in equilibrium the import price (less tariffs) must cover fixed and marginal costs that foreign firms incur in each regional market.

Similar to foreign firms, Russian firms also produce their goods in their home regions; they incur a fixed cost of operation if each RM in which they operate. By the zero profit constraint, if they operate in a RM, the price of their product must just cover both fixed and marginal costs of operation in that RM.

We assume that Russian firms do not have any market power on world markets and thus act as price takers on their exports to world markets. On the exports to the rest of the world then, price equals marginal costs. On sales to Russia, firms must use a specific factor in addition to the other factors of production. The existence of the specific factor implies that additional output or firms can only come at increasing marginal costs. Imperfectly competitive Russian goods producers sell in all of Russia; but services firms do not sell in other Russian regional markets.

We employ the standard Chamberlinian large group monopolistic competition assumption within a Dixit-Stiglitz framework, which results in constant markups over marginal cost. For simplicity we assume that the ratio of fixed to marginal cost is constant with respect to all factors of production for all firms producing under increasing returns to scale (in both goods and services). This assumption in a Dixit-Stiglitz based Chamberlinian large-group model assures that output per firm for all firm types remains constant, i.e., the model does not produce rationalization gains or losses.

An increase in the number of varieties increases the productivity of the use of imperfectly competitive goods based on the standard Dixit-Stiglitz formulation. Dual to the Dixit-Stiglitz quantity aggregator is the Dixit-Stiglitz cost function which shows the productivity adjusted cost of using the available varieties in the regional market when varieties are purchased at minimum cost for a given output level. This cost function for users of goods produced subject to increasing returns to scale declines in the total number of firms in the industry. The lower the elasticity of substitution, the more valuable is an additional variety.

We have assumed that imperfectly competitive firms within a regional market have symmetric cost structures and face symmetric demand for their outputs. It follows from these assumptions that all imperfectly competitive firms from a regional market will obtain the same price in any regional market of Russia in which they operate, although the price will differ across regional markets since the fixed costs associated with entering any regional market vary across the regional markets.
4.1.5 Services Sectors That Are Produced in Russia under Increasing Returns to Scale and Imperfect Competition

These sectors include telecommunications, financial services, most business services and transportation services. In services sectors, we observe that some services are provided by foreign service providers on a cross border basis analogous to goods providers from abroad. But a large share of business services are provided by service providers with a domestic presence, both multinational and Russian. As shown in figure 5, our model allows for both types of foreign service provision in these sectors. There are cross border services allowed in this sector and they are provided from the firms outside of Russia at constant costs—this is analogous to competitive provision of goods from abroad. Cross border services from the rest of the world, however, are not good substitutes for service providers who have a presence within the regional market of Russia where consumers of these services reside.

Russian firms providing imperfectly competitive business services operate at the regional level and organize production in a manner fully analogous to imperfectly competitive Russian firms producing goods. Thus, figure 5 applies to both Russian imperfectly competitive goods and services firms. Other assumptions we made for imperfectly competitive goods producers, such as entry conditions, pricing and symmetry are also apply to imperfectly competitive services providers. The only difference is that we assume that regional services providers sell only in their own regional market (see figure 3). It follows from these assumptions that there is a unique price for all Russian providers of imperfectly competitive business services in a regional market.

There are also multinational service firm providers that choose to establish a presence in a Regional Market of Russia in order to compete with regional Russian firms directly in the Russian Regional Market. The decision to locate in a regional market by a multinational must take into account the existence of a fixed cost of operating in a regional market. As with imperfectly competitive goods producers, quasi-rents must cover the fixed plus marginal costs of producing in a regional market and we have a zero profit equilibrium.

When multinational service providers decide to establish a domestic presence in a regional market of Russia, they will import some of their technology or management expertise. That is, foreign direct investment generally entails importing specialized foreign inputs. Thus, the cost structure of multinationals differs from Russian service providers. Multinationals incur costs related to both imported primary inputs and Russian primary

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10 One estimate puts the world-wide cross-border share of trade in services at 41% and the share of trade in services provided by multinational affiliates at 38%. Travel expenditures 20% and compensation to employees working abroad 1% make up the difference. See Brown and Stern (2001, table 1).

11 Daniels (1985) found that service providers charge higher prices when the service is provided at a distance.
factors, in addition to intermediate factor inputs. Foreign provision of services differs from foreign provision of goods, since the service providers use Russian primary inputs. This is shown in figure 6, where we show multinationals combining imported primary inputs with inputs of the service good from the regions within the regional market. Domestic service providers do not import the specialized primary factors available to the multinationals. The structure of production for multinational service providers is identical to that of Russian business service providers (shown in figure 5), except for a CES nest at the top which combines the output shown in figure 5 with imported primary inputs (see figure 6 of Rutherford and Tarr, 2006 for details). Foreign service providers also must use a specific factor to produce the output and this implies that additional output can only be obtained at increasing marginal costs. Since the structure of costs for all multinational firms that provide a service $s$ in a given region $m$ is identical and demand is symmetric, there is a unique price for all multinationals providers of service $s$ in regional market $m$.

For multinational firms, the barriers to foreign direct investment affect their profitability and entry. Reduction in the constraints on foreign direct investment in a region will induce foreign entry that will typically lead to productivity gains because when more varieties of service providers are available, buyers can obtain varieties that more closely fit their demands and needs (the Dixit-Stiglitz variety effect).

### 4.1.6 Factors of Production

Primary factors include skilled and unskilled labor and three types of capital; (i) mobile capital (within regions); (ii) sector-specific capital in the energy sectors reflecting the exhaustible resource; and (iii) sector specific capital in imperfectly competitive sectors. We also have primary inputs imported by multinational service providers, reflecting specialized management expertise or technology of the firm. The existence of sector specific capital in several sectors implies that there are decreasing returns to scale in the use of the mobile factors and supply curves in these sectors slope up.

The above list of primary factors exists in all regions. In the case of skilled and unskilled labor it is natural to assume that the representative agent in the region obtains the returns from these factors of production. Consistent with standard trade models, in our central model we assume that capital and labor are immobile between Russia and the Rest of the World. However, this model is a regional disaggregation of a national model of Russia; consequently, it does not seem reasonable to assume that all capital in a region is owned by the agents in that region. Thus, we make the assumption that a fraction of the capital in any region is held by agents outside of the region, but the capital is held by residents in the
country. We take the fraction of the capital held by agents in the region to be 50 percent, but this percentage is not crucial to the solution of the model.

Regarding the capital of each region that is held outside of the region, it is convenient to think of a national mutual fund that holds the remaining capital in each region. For all three capital types ((i) mobile; (ii) specific capital in the energy sectors; and (iii) specific capital in the IRTS sectors) 50 percent of the capital used in the region is owned by this mutual fund and the balance is owned by the representative agent in the region. The national mutual fund invests in all regions and obtains an overall return. The representative agent in the region also holds shares in the national mutual fund.12.

For each region we report returns to capital as returns to the three types of regional capital held by the region’s representative agent. Plus the region’s representative agent obtains a share of the returns from the national mutual fund. The region’s return from national capital is the region’s share of the return of the national mutual fund reported as a percentage of initial consumption of the region.

4.1.7 Trade

Trade flows for perfectly competitive goods between regions and the rest of the world is specified following the Armington (1969) approach, which distinguishes goods by origin. Firm level product differentiation characterizes trade for imperfectly competitive sectors. Regions are assumed to be price takers in the world market – i.e., the representation of the rest of the world is reduced to perfectly elastic import demand and export supply functions (export and import prices from the rest of the world are exogenous). Each region has a balance of trade constraint so that any change in the value of imports (either from the rest of the world or another regional market within Russia) is matched by an increase in the value of exports. Russia as a whole, represented as an aggregate of the regional markets, must satisfy a typical economy-wide balance of the trade constraint. The real exchange rate adjusts to ensure

12 Define $M(r)$ as the representative agent’s share of the returns to the national mutual fund. We calculate $M(r)$ as follows. For each region $r$, the initial consumption income $C(r)$ equals its endowment income $E(r)$ minus the share of the trade surplus $B(r)$ attributed to the region: $C(r) = E(r) - B(r)$. Define $B(r) = [C(r)/C]* B$ where $C$ is aggregate consumption for Russia and $B$ is the aggregate trade surplus. That is, the region’s share of the trade surplus is proportional to its share of aggregate consumption.

$E(r)$ is defined above, but is also defined as: $E(r) = L(r) + K(r) + M(r)$. That is, endowment income for each region is labor income $L(r)$; plus capital income on regional capital held by the representative agent in the region $K(r)$; plus the representative agent’s share of the returns to the national mutual fund $M(r)$. $E(r)$, $L(r)$ and $K(r)$ are all known. We calculate $M(r)$ residually for each region $r$ as: $E(r) - L(r) - K(r) = C(r) - B(r) - L(r) - K(r) = M(r)$.
that any change in the aggregate value of regional imports from the rest of the world, is
matched by an equal change in the value of aggregate exports to the rest of the world.

4.1.8 Government

Government demand across all regions is fixed at exogenous real levels. The
government receives taxes to finance public expenditures. Public surpluses or deficits are
balanced through lump-sum transfers with the representative households in each region.

4.2 Emissions Modeling

The model accounts for seven pollutants whose environmental and health impacts are
listed here along with the quantity of emissions in Russia in 2001.

| Pollutant            | Abbreviation | Environmental impacts                                      | Health effects                       |
|----------------------|--------------|------------------------------------------------------------|--------------------------------------|
| Particulate matter   | PM           | Soiling and damage to materials, smog                      | Lung cancer, asthma, birth defects   |
| Sulphur dioxide      | SO₂          | Acid rain, atmospheric particulates                         | Asthmatic, alterations in the lungs  |
| Carbon monoxide      | CO           | Leads to increased concentrations of methane and tropospheric ozone | Headache, nausea, dizziness, seizures |
| Nitrogen oxide       | NOx          | Acid rain, eutrophication in coastal waters                | Difficulty breathing, fluid build-up in the lungs |
| Hydrocarbons         | CnHm         | Smog, leads to increased concentrations of tropospheric ozone | Affects the central nervous System   |
| Volatile organic components | VOC | Damage to soil and groundwater                           | Damage to liver, cancer, headaches   |
| Carbon dioxide       | CO₂          | Climate change, ocean acidification                       | High concentration: rapid heart rate, clumsiness |

Carbon dioxide (CO2) emissions, which are by far the most important greenhouse gas emissions for Russia, are linked in fixed proportions to the use of coal, natural gas and refined oil products, with CO2 coefficients differentiated by the specific carbon content of the fuels. CO2 abatement can take place by fuel switching (inter-fuel substitution) or energy savings (either by fuel-non-fuel substitution or by a scale reduction of production and final demand activities or by more efficient production technologies that use less fuel per unit of output). All non-CO2 emissions are represented in fixed proportions to output or consumption activities. Estimates of discrete abatement potentials for non-CO2 emissions and associated
costs for these technologies are directly integrated into the model by means of an activity analysis approach.

4.3 Key Data

4.3.1 Emissions Data

In our appendix, we provide detailed documentation of our data sources for pollution emissions in Russia and how we incorporated these data into our model. Here we summarize the key data that are relevant for the policy scenarios. Total emissions of our seven pollutants in Russia are listed here.

**Emission quantities of pollutants in the base year (2001).**

| Pollutant                          | Emissions |
|------------------------------------|-----------|
| CO2 in Mt                          | 1441      |
| CO2 from coal (Mt)                 | 315       |
| CO2 from gas (Mt)                  | 761       |
| CO2 from oil (Mt)                  | 364       |
| PM in kt                           | 2973      |
| SO2 in kt                          | 5254      |
| CO in kt                           | 5148      |
| NOx in kt (only stationary sources) | 1679      |
| CnHm in kt                         | 2724      |
| VOC in kt                          | 1131      |

*Note: Mt= million tons; kt= thousand tons.*

Figure 7 provides information on how the total of CO2 emissions is distributed across production activities and final consumption in the base year. We label final consumption as “c” on the horizontal axis. We see that the electricity sector is by far the most important source of CO2 emissions in the Russian economy, followed by ferrous metal production and housing services (the latter includes heating).

With respect to environmental impacts of trade liberalization and the economic implications of emission control policies, emission intensities play a key role. The more emission intensive a sector is, the more adversely its production should be affected by pricing of emission inputs (another key determinant of adjustment cost is the ease of substituting away from emission inputs as described through the nesting structure and the elasticities of substitution between inputs). In figure 7 we show the total CO2 emissions across Russian
industries; in figure 8, we show emission intensities across Russian industries (aggregate for the economy). CO2 emission intensities are composed of direct emissions from fossil fuel inputs (bottom of the bar in the figure) as well as indirect emission embodied in electricity inputs (upper part of the bar). Emission intensities in coal and gas production, electricity generation and pipeline transportation (including gas leakage) are the highest. Indirect emissions embodied in electricity play a secondary role for most sectors. In table 12c (alternately we present the same data in figure 9), we report emission intensities for non-CO2 pollutants across industries – listed in descending order for sulfur dioxide (SO2). Electricity generation, non-ferrous and ferrous industries rank highest. These sectors also show substantial emission intensities for carbon monoxide (CO) where crude oil production has by far the highest intensity. The release of hydrocarbons (CnHm) is predominantly associated with coal production and transportation activities. Energy cost shares across industries are depicted in figure 10.

4.3.2 Ad Valorem Equivalence of Barriers to Foreign Direct Investment in Services Sectors

The business services sectors have been the subject of some of the most intense negotiations associated with Russian accession. Russia has made numerous commitments in this area. In many cases, Russia has implemented changes in the services sectors prior to accession to adapt to post-WTO requirements; in other cases, the commitments may be implemented only several years after accession due to a negotiated adjustment period. The counterfactual scenario that we implement in the business services sectors attempts to encapsulate all these cumulative reforms.

Some of the key concessions are the following. Russia has agreed to increase the quota on the maximum share that foreign banks and insurance companies can attain from 15 percent to 50 percent. Russia will phase out the prohibition on foreign participation in mandatory insurance lines and has agreed to allow branches of foreign insurance companies to sell insurance in Russia nine years after the date of its accession. Russia reportedly agreed to terminate the Rostelecom monopoly on long distance fixed line telephone services as part of the Russia-EU bilateral agreement and did so several years prior to accession. (There were also multinational telephone operators operating in the Russian mobile telephone market several years prior to accession.) Russia will ensure national treatment and market access for a wide variety of professions, including lawyers, accountants, architects, engineers, marketing specialists, and health care professionals. Foreign owned companies will be permitted to
engage in wholesale and retail trade, franchise sectors and express courier services. The European Union has negotiated intensely for the rights of companies other than Gazprom to construct a gas pipeline; but no success in this area has been reported.

In banking, opposition galvanized around the branch banking issue. Russia was willing to allow subsidiaries of international banks. Subsidiaries must be registered as Russian entities, and the capital requirements would be based on capital in the Russian entity. Branches, however, do not have a separate legal status or capital requirement apart from their foreign parent bank. So branches are potentially very powerful competitors. The U.S. Treasury has been attempting to ensure branch banking is permitted in all countries admitted to the WTO. The Russian central bank maintained that it could not regulate or supervise branches adequately and that depositors would therefore be at risk. Banking interests in Russia succeeded in getting then President Putin himself to say that branch banking was a deal breaker for Russian WTO accession. Russia succeeded in avoiding a commitment on branch banking, becoming the only non-LDC acceding country to avoid such a commitment. Nonetheless, multinational banks, operating as subsidiaries, have greater market access and national treatment rights under the bilateral U.S.-Russia agreement and Russia should benefit from greater involvement of multinational banks in Russia over time.

Estimates of the ad valorem equivalence of these and other barriers to FDI in services are key to the results. Consequently, we commissioned several surveys from Russian research institutes that specialize in these sectors and econometric estimates of these barriers based on these surveys. These questionnaires provided us with data, descriptions and assessments of the regulatory environment in these sectors. Using this information and interviews with specialist staff in Russia, as well as supplementary information, Kimura, Ando and Fujii (2004a, 2004b, 2004c) then estimated the ad valorem equivalence of barriers to foreign direct investment in several Russian sectors, namely in telecommunications; banking, insurance and securities; and maritime and air transportation services. The process involved converting the answers and data of the questionnaires into an index of restrictiveness in each industry. Kimura et al. then applied methodology explained in the volume by C. Findlay and T. Warren (2000), notably papers by Warren (2000), McGuire and Schulele (2000) and Kang (2000).

13 See Tarr (2007) for details.
14 Russia agrees to reopen discussions on this issue upon consideration of membership in the OECD.
15 This information was provided by the following Russian companies or research institutes: Central Science Institute of Telecommunications Research (ZNIIS) in the case of telecommunications, Expert RA for banking, insurance and securities; Central Marine Research and Design Institute (CNIIMF) for maritime transportation services and InfoMost for air transportation services. We thank Vladimir Klimushin of ZNIIS; Dmitri Grishankov and Irina Shuvalova of ExpertRA; Boris Rybak and Dmitry Manakov of InfoMost; and Tamara Novikova, Juri Ivanov and Vladimir Vasiliev of CNIIMF. The questionnaires are available at www.worldbank.org/trade/russia-wto. The same sources provided the data on share of expatriate labor discussed below.
For each of these service sectors, authors in the Findlay and Warren volume evaluated the regulatory environment across many countries. The price of services is then regressed against the regulatory barriers to determine the impact of any of the regulatory barriers on the price of services. Kimura et al. then assumed that the international regression applies to Russia. Applying that regression and their assessments of the regulatory environment in Russia from the questionnaires and other information sources, they estimated the ad valorem impact of a reduction in barriers to foreign direct investment in these services sectors. The results of the estimates are listed in table 12a. In the case of maritime and air transportation services, we assume that the barrier will only be cut by 15 percentage points, since WTO commitments in these sectors are weak.

4.3.3 Share of Expatriate Labor Employed by Multinational Service Providers

The impact of liberalization of barriers to foreign direct investment in business services sectors on the demand for labor in these sectors will depend importantly on the share of expatriate labor used by multinational firms. We explain in the results section that despite the fact that multinationals use Russian labor less intensively than their Russian competitors, if multinationals use mostly Russian labor their expansion is likely to increase the demand for Russian labor in these sectors. We obtained estimates of the share of expatriate labor or specialized technology that is used by multinational service providers in Russia, but which is not available to Russian firms, from the Russian research institutes that specialize in these sectors. In general, we found that multinational service providers use mostly Russian primary factor inputs and only small amounts of expatriate labor or specialized technology. In particular, the estimated share of foreign inputs used by multinationals in Russia is: telecommunications, 10% plus or minus 2%; financial services, 3%, plus or minus 2%; maritime transportation, 3%, plus or minus 2%; and air transportation, 12.5%, plus or minus 2.5%.

4.3.4 Tariff and Export Tax Data

Tariff rates by sector are taken from the paper by Shepotylo and Tarr (2012). They estimate the applied MFN tariff rates at the ten digit level in Russia for all years from 2001 to

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16 Warren estimated quantity impacts and then using elasticity estimates was able to obtain price impacts. The estimates by Kimura et al. that we employ are for “discriminatory” barriers against foreign direct investment. Kimura et al. also estimate the impact of barriers on investment in services that are the sum of discriminatory and non-discriminatory barriers.

17 See Jensen, Rutherford and Tarr (2006) for an explanation of the estimate in telecommunications.

18 See Markusen, Rutherford and Tarr (2005) for a detailed explanation on why FDI may be a partial equilibrium substitute for domestic labor but a general equilibrium complement.
2020. They also provide aggregated tariff rates for the sectors of our model. From 2011 to 2012, the estimates are based on actual tariff rates and trade data in Russia. Russia will implement its tariff commitments under its WTO accession agreement progressively from 2012 to 2020. For 2012 to 2020, Shepotylo and Tarr estimate changes based on the progressive tariff reduction commitments Russia has taken under its WTO accession agreement. Unlike in the case of services, there is no evidence that Russia’s tariff commitments impacted its tariffs prior to 2012. Consequently, we take tariffs in 2011 at the benchmark tariff rates. We take the tariff rates in 2020 (when all tariff commitments are implemented) as the tariff rates in the counterfactual. These tariff are reported in table 12a.

Export tax rates are calculated from the 2001 input-output table of Rosstat and are reported in table 12a. Since we do not change export taxes in the counterfactual simulations, these parameters are not very important to the results.

### 4.3.5 Input-Output Tables

The core input-output model is the 2001 table produced by Rosstat. The official table contained only 22 sectors, and importantly has little service sector disaggregation. In order to disaggregate the table, we used costs and use shares from our 35 sector Russian input-output table for 1995 prepared by expert S. P. Baranov. (For details see [www.worldbank.org/trade/russia-wto](http://www.worldbank.org/trade/russia-wto)). When we broke up a sector such as oil and gas into oil, gas and oil processing, we assumed that the cost shares and use shares of the sector were the same in 2001 as they were in the 1995 table. For example, steel is an input to the oil and gas sector. Suppose in 1995, that oil purchased 55 percent of the steel used in oil and gas. Then we assume that in 2001, oil purchased 55 percent of the steel used in oil and gas.

### 4.3.6 Regional IO Tables and Trade Flows of the Regions

We constructed input-output tables of the 88 regions that are based on data from the regions (described below) and the national input-output table. The input-output tables for our ten regional markets are aggregates of the input-output tables of the regions in their respective regional markets.

We assume that the technology of production is common across regions, so that the input-output coefficients from the national input-output table apply across all regions. As a first step, for each industrial sector, we took the national output from the national input-output table for 2001, and we used the data in Regions of Russia to allocate the shares of that output across the 88 regions. That is, from the Regions of Russia 2001, we have, by region, the value of total industrial output and industry shares of regional industrial output for the year 2000 (table 13.3); thousands of tons of oil recovery, including gas condensate, for the year 2000.
(table 13.13); extraction of natural gas (in millions of cubic meters for the year 2000, table 13.14); thousands of tons of mined coal for the year 2000 (table 13.15). This allows us to calculate the value of industry output by sector and region. For each industrial sector, we then proportionally scaled the value of region level output so that the sum of industrial output across all regions was equal to the value of national output of the sector from the national input-output table.

We infer regional demand (and supply) of services, assuming that intermediate and final demand for services share a common intensity of demand in all regions as in the national model. For example, if telecommunications costs are x percent of the costs of nonferrous metals production in the national model, we assume that telecommunications costs are x percent of nonferrous metals costs in each of the regions. Demand for telecommunications from non-ferrous metals will differ across regions, however, since the share of total output attributable to non-ferrous metals differs across regions.

We have total external exports and imports by region, as well as the commodity structure of external exports and imports by region for the year 2001 (tables 23.1 and 23.2). We also have unpublished data supplied to us by Rosstat on inter-region exports and imports by sector. That is, for each of over 250 key commodities, we have an 88 by 88 matrix of bilateral trade flows among the regions.

Supply and demand balance by region and by commodity requires adjustment of trade intensities. These adjustments assure that region exports and imports in aggregate are consistent with national import and export values, we have to adjust the region import and export intensities. We did this using a methodology that minimized the sum of squares of the difference between the original data on exports and imports and the adjusted exports and imports data, subject to the constraints of supply-demand balance and consistency with the national model data. Since we had greater confidence in the validity of the region output data than the inter-region trade flow matrix, in this optimization process, we fixed the output levels of the regions at the levels we had calculated above. We do not need to make any other adjustments, as the production technologies are assumed consistent across the regions. See appendix C of Rutherford and Tarr (2006) for the GAMS code that created the regional input-output tables.

Since in every step of the process, we calculated region shares of the national input-output table, the process yields a set of 88 regional input-output tables which portray a regional disaggregation of the national input-output table. That is, summing over all the 88 input-output tables will yield the national input-output table, including wholesale and retail distribution margins, investment demand and government expenditure. Crucially, we may aggregate the 88 regions into a set of non-overlapping subsets and any such aggregation will
yield a set of input-output tables that is fully consistent with the national input-output table. In particular, our ten region model is consistent with the national input-output table.

4.3.7 FDI Shares

The methodology is explained in detail in an appendix to Rutherford and Tarr (2006), but briefly, we first employed the NOBUS survey to obtain the shares of workers working in multinationals service sectors in each sector in each region. We used this as a proxy for the share of output in each service sector in each region. We also obtained information from (1) from the Russian service sector institutes mentioned above; (2) Regions of Russia (2003) by Rosstat; and (3) the “BEEPS” survey. Only the NOBUS survey provides data that allows us to estimate shares of multinational ownership by both region and sector. We thus start with our calculations based on the NOBUS information.

When found, however, that when we aggregate the NOBUS shares across regions or sectors, the other three sources of information show considerably higher foreign ownership shares than the NOBUS survey. We believe that the NOBUS survey estimates are too small, and adjust them. We adjusted our estimates from the NOBUS to be consistent with the estimates of the service sectors institutes. The service sector institute estimates are lower than those from the BEEPS or Regions of Russia, and thus involve less adjustment of the NOBUS data. We employed least squares adjustment of the NOBUS data so that the weighted average over all of Russia in each sector is consistent with the national estimates we received from the specialist service sector research institutes in Russia. This process will give as a structure of ownership based on the NOBUS survey, with the economy-wide average by sector determined by the national data. Results are presented in table 12b.

5. Results of Policy scenarios

5.1. Policy Scenarios

One of our principal interests is the quantification of economic and environmental impacts associated with Russia’s WTO accession. In our central WTO accession scenario without environmental abatement policies, we assume that: (i) barriers to foreign direct investment are eliminated or reduced (depending on the sector); (ii) following the work of Shepotylo and Tarr (2012), applied tariffs will fall according to the commitments of the Russian Federation as part of its WTO accession agreement; and (iii) in line with Rutherford and Tarr (2008; 2010), we postulate that better access to export markets for some industries will lead to improvement in terms of trade ranging from 0.5 percent (sectors: other industrial products, food industry, other goods and services) to 1.5 percent for sectors subject to more
intensive antidumping actions (sectors: ferrous metals, non-ferrous metals, chemical and petrochemical products. (See table 12a for details.)

We then reflect “green” policy initiatives in Russia by means of three scenarios that capture Russia’s objectives in international climate policy as well as domestic energy use. The three environmental regulation policies we evaluate to reduce carbon emissions by 20 percent are: (i) CO2, market based “cap and trade” regulation; (ii) CST, uniform emissions intensity standards; and (iii) EEF, uniform energy efficiency standards.

As mentioned in section 2, Russia is pursuing policies to reduce greenhouse gas emissions. Scenario CO2 imposes a 20 percent reduction of CO2 emissions in Russia from base-year emission levels to be achieved through a system of tradable emission rights (or equivalently a nation-wide CO2 tax). In the case of uniform emissions intensity standards (CST), we require that in all sectors and regions except for fossil fuels sectors (coal, crude oil and gas,) uniformly reduce the intensity of their carbon emissions per unit of the value of output produced. We solve for the uniform reduction in the intensity of carbon emissions such that a 20 percent reduction in carbon emissions is achieved. 19 In the case of uniform energy efficiency standards, we require that in all regions and sectors except electricity and fossil fuel production (crude oil, coal and natural gas) equi-proportionately reduce their use of gas, refined oil and electricity. We solve for the uniform reduction in the use of energy inputs such that a 20 percent reduction in carbon emissions is achieved.

As trade liberalization tends to raise incomes, the environmental Kuznets curve suggests that above a given level of income, with higher incomes often comes a demand for greater environmental regulation and the ability to adopt cleaner technologies. In fact, Antweiler et al., (2001) have shown in their empirical study of over 40 countries, trade liberalization has been associated with a cleaner environment due to stronger environmental regulations following trade liberalization. In a third set of scenarios, we assess the impacts of “overlapping” policy reforms where we simultaneously implement our central case WTO accession with each of our three carbon emission reduction policy initiatives (scenarios WTO_CO2, WTO_CST and WTO_EFF).

Below, we summarize the main features of our policy scenarios. In tables 13-20a we report results for our seven policy scenario. For all ten regions and for an overall average for Russia, we report aggregate results (welfare, emissions of our seven pollutants, decomposition of the CO2 change into the scale, composition and technique effects, changes

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19 We allow for a tolerance in the solution of up to one percentage point of carbon emissions. That is, carbon emissions are reduced by between 19 and 21 percent.
in exports, imports, employment, factor returns and real exchange rate). In these tables, we also report output changes for all sectors in all regions.
Key features of trade and environmental policy scenarios

| Scenario name | Trade reform | Environmental regulation |
|---------------|--------------|--------------------------|
| WTO           | WTO accession| None                     |
| CO2           | None         | 20% CO2 emission reduction through market based cap and trade regulation |
| CST           | None         | 20% CO2 emission reduction through emission intensity standards |
| EEF           | None         | 20% CO2 emission reduction through energy intensity standards |
| WTO\_CO2      | WTO accession| 20% CO2 emission reduction through cap and trade |
| WTO\_CST      | WTO accession| 20% CO2 emission reduction through emission intensity standards |
| WTO\_EFF      | WTO accession| 20% CO2 emission reduction through energy intensity standards |
5.2. WTO Accession Results

The aggregate results for each of our ten regions of our WTO simulation scenario without environmental abatement are presented in table 13. Due to the possibility of inter-fuel substitution and optimization of export sales in the energy sectors that were not allowed in Rutherford and Tarr (2010), the estimated welfare gains overall are 0.8 percent of consumption larger with the present model. It has been shown by Rutherford and Tarr (2008; 2010) that the source of the largest gains is the reduction in barriers against foreign investors in services—accounting for about 70 percent of the total gains. Consistent with the econometric evidence cited above, in our model new services providers increase the productivity of sectors that use services. Russian commitments to reduce barriers against multinational service providers will allow multinationals to obtain greater after tax returns on their investments in Russia and thus initially create positive profits. This will induce the multinationals to increase foreign direct investment to supply the Russian market until the additional entry restores a zero profit equilibrium. Although we find that there is some decline in the number of purely Russian owned businesses serving the services markets, on balance there will be additional service providers. Russian users of businesses services will then have improved access to the providers of services in areas like telecommunication, banking, insurance, transportation and other business services.

5.2.1 Explaining Differences across Regions

While the average gain in welfare from WTO accession as a percent of GDP for the whole country is 4.0 percent, we estimate that the three regions that gain the most are: Northwest (5.6 percent), St. Petersburg (5.2 percent) and Far East (4.8 percent). The principal explanation for the differences across regions is the ability of the different regions to benefit from a reduction in barriers against foreign direct investment. Some regions may attract FDI much more easily than others. A key parameter in our model is the initial share of multinational investment in each sector in each region. Multinational firms have widely different shares of the business services sectors in the different regions. A 10 percent expansion of multinational firms will be a much larger absolute amount in a region that has substantial FDI initially. Thus, larger initial shares of FDI in a region will lead to larger absolute increases in FDI in the region when the barriers against FDI are reduced.

In table 12b, we display our estimates of the shares of the industry captured by multinational firms. The three regions with the largest welfare gains are clearly the regions with the estimated largest shares of multinational investment (along with a fourth region, the
North region, which also gains substantially). All have estimated multinational shares of the service sector that are twice the national average in maritime services, rail services, truck services, air transportation services, telecommunications, science and financial services. On the other hand, we estimate that the Urals will gain only 3.3% of GDP, considerably less than the national average. But we see from table 12b that the Urals has relatively little FDI in the services sectors, as the Urals share of FDI ranges from about 50 to 70 percent of the national average depending on the sector.

5.2.2 Impact of WTO Accession on Carbon Emissions

In table 13, we report the impact of WTO accession on carbon emissions, where we show the decomposition of emissions into the scale, composition and technique effects based on the following methodology.

Let \( E \) = emissions, \( Y \) = the value of aggregate output, \( a_i \) = emissions per unit of the value of output, \( y_i \) = the value of output of sector \( i \) and \( \theta_i \) = the share of sector \( i \)'s output in the economy. With \( n \) sectors in the economy, aggregate emissions are:

\[
(1) \quad E = \sum_{i=1}^{n} a_i y_i
\]

\[
(2) \quad E = Y \sum_{i=1}^{n} a_i \theta_i \quad \text{where} \quad y_i = \theta_i Y
\]

It follows that, in the neighborhood of the equilibrium, the percentage change in emissions can be decomposed into:

\[
(3) \quad \frac{\Delta E}{E} = \frac{\Delta Y}{Y} + \frac{\sum_{i=1}^{n} a_i \Delta \theta_i}{\sum_{i=1}^{n} a_i \theta_i} + \frac{\sum_{i=1}^{n} \theta_i \Delta a_i}{\sum_{i=1}^{n} a_i \theta_i}
\]

The first term on the right side of equation 3 is the scale effect; the second term is the composition effect and the third term is the technique effect. In all of our scenarios, we show the percentage change in carbon emissions in total and due to each of these three effects for each of the ten regions of our Russia model and an overall average for the Russian economy.\(^{20}\)

Looking at the overall average, we see that WTO accession increases carbon emissions by 4.3 percent. The main reason for the increase in emissions is the increase in output, as the increased scale of output results in an increase in carbon emissions of 4.9

\(^{20}\) Although our decomposition is based on a methodology that is a local approximation to a discrete change, we find that the sum of our components are accurate to within 0.5 percent points of carbon dioxide emissions in all cases except WTO_CST, where the tolerance is 1.2 percentage points of carbon dioxide emissions.
percent. The composition effect also increases emissions in the case of Russia by 1.0 percent. While the composition effect is ambiguous in general, the reason is that it has an adverse environmental impact in Russia is that two of the relatively dirty industries, namely ferrous metals and chemicals and petrochemicals, are (along with non-ferrous metals) the sectors that expand the most.\textsuperscript{21} As shown in table 14, ferrous metals output expands in all nine of the regions in which it is produced. Output of chemicals and petrochemicals expand in all ten regions. We have also shown that overall (Jensen, Rutherford and Tarr, 2007), non-ferrous metals output expands the most of any sector in the model. The reason these sectors expand is that trade liberalization, in general, tends to benefit export intensive sectors, since export intensive sectors experience the benefit of the removal of the anti-export bias of trade protection realized through a depreciated real exchange rate. In the case of Russia, it is ferrous metals, non-ferrous metals and chemicals that intensively export (two of which intensively emit carbon dioxide), while the relatively cleaner sectors, such as food and light industry, which do little exporting, decline in most regions. The technique effect, however, works toward a cleaner environment, reducing carbon emissions by 1.6 percent. The technique effect in this scenario comes about primarily due to increased productivity with existing resources due to the Dixit-Stiglitz productivity externality from additional varieties of imperfectly produced goods and services and a shift toward a less fossil fuel intensive form of production.

5.3. Evaluating Alternate Policy Reforms to Reduce Carbon Emissions by 20 Percent

We emphasize that in all of our green policy scenarios, we do not calculate the benefits of a cleaner environment. Although this calculation is beyond scope of our analysis, we do not mean to infer that the net welfare change of these environmental policies is negative. Rather, we take a cleaner environment as an objective desired by the authorities, and assess different environmental regulations in terms of their direct economic costs, and by implication, political feasibility.

5.3.1 Market Based Carbon Emissions Trading (“Cap and Trade”)

In tables 15 and 15a we show the results of our estimates of a policy of using a system of tradable emission rights (or equivalently a nation-wide CO2 tax) to achieve a 20 percent carbon emission reduction. We find that it would cost 0.5 percent of GDP. From our

\textsuperscript{21} In our dataset, non-ferrous metals does not intensively emit carbon dioxide; see figure 7.
decomposition analysis, we see that the reduction in carbon emissions is accomplished primarily through the technique effect. Although there is a modest 1 percent reduction in emissions through output reduction and a shift to cleaner industries results in a 3.1 percent reduction in carbon emissions, the technique effect accounts for over 16 percent reduction in carbon emissions. Since there are no productivity gains in this scenario, unlike our WTO accession scenario, the technique effect derives from fuel switching toward fuels that emit fewer carbon emissions and a switch to a less fuel intensive form of production.

5.3.2. Carbon Emissions Intensity Standards

In tables 16 and 16a, we present our assessment of the impact of requiring a uniform reduction in the intensity of carbon emissions per unit of the value of output produced at the sector and regional level (coal, crude oil and gas production excluded). We find that requiring a 20 percent reduction in emissions intensity achieves the outcome of a 20 percent reduction in carbon emissions and does so at a cost of about 0.8 percent of GDP. Again, it is the technique effect which dominates the adjustment in carbon emissions, accounting for 17.1 percent reduction in carbon emissions. As expected, emission intensity standards are not as efficient as the market based emission trading system, but the additional costs of achieving the 20 percent carbon reduction are only 0.3 percent of GDP. The relatively small additional cost of this “command and control” regulation compared with a market based system can be attributed to the fact that “emissions intensity” is close to the target of a reduction in carbon emissions.

5.3.3 Energy Efficiency Standards

In tables 17 and 17a, we show the results of our assessment of the impact of uniform energy efficiency standards where we require that in all regions and sectors except electricity and fossil fuel production (crude oil, coal and natural gas) to equi-proportionately reduce their use of gas, refined oil and electricity to achieve a 20 percent reduction in carbon emissions. We find that a uniform requirement to cut use of fossil fuel use by 25 percent, results in a 20 percent reduction in carbon emissions. The cost in terms of loss in GDP, however, is a very substantial 2.7 percent of GDP, more than five times the cost of the emissions trading system to achieve the same carbon emissions reduction. The higher cost of achieving the carbon emission reduction is partly due to the lack of adjustments of a market based system; but our results show that even more important is the fact that, compared with emissions intensity standards, energy efficiency standards do not closely target the objective of lower carbon emissions.
On the positive side for energy efficiency standards is that they achieve a much greater reduction in non-CO2 emissions than carbon emissions trading or carbon emissions intensity standards. This is especially true regarding nitrogen oxide and particulate matter, where energy efficiency standards achieve a double digit percent reduction.

### 5.4 Combining WTO Accession with Policies to Reduce Carbon Emissions by 20 Percent

Given that many countries have complemented trade liberalization with policies to improve the environment, in this section we evaluate the impacts of Russia simultaneously acceding to the WTO and implementing one of our carbon reduction policies.

#### 5.4.1 WTO Accession Combined with Carbon Emissions Trading

In tables 18 and 18a, we show our results for combining WTO accession with a regulation to cut carbon emissions by 20 percent through carbon emissions trading. Although overall welfare gains fall compared with WTO accession independently, overall welfare gains as a percent of consumption remain high at 7.2 percent of consumption. Interestingly, while the composition effect of WTO accession alone increases carbon emissions due to an increase in the production of ferrous metals, chemicals and petro-chemicals, the composition effect is positive when combined with environmental regulation through emissions trading. We show in table 17a that in this combined scenario, the chemicals and petro-chemicals sector declines in eight of the ten regions and the ferrous metals sector declines in all sectors where it is produced. In addition, production of oil, gas and the pipeline sector decline in this scenario. The technique effect becomes even more important in this scenario, as it is responsible for a decline of 19.5 percent in total carbon emissions. In addition to switching away from fossil fuel use, the productivity gains of WTO accession allow production of output with fewer fossil fuels.

#### 5.4.2 WTO Accession Combined with Emission Intensity Standards

In tables 19 and 19a, we display our results for combining WTO accession with a regulation to cut carbon emissions by 20 percent by requiring all sectors (except for fossil fuels sectors) and regions to uniformly reduce the intensity of their carbon emissions per unit of the value of output produced. The welfare gain of 6.4 percent of consumption is substantial, but constitutes a reduction of 2.2 percent of consumption compared with WTO accession alone and a further reduction of 0.8 percent of consumption compared with
emissions trading combined with WTO accession. The switch to clean industries (the composition effect) is much weaker in this scenario than under emissions trading, since all sectors must reduce the intensity of their emissions uniformly, even if they start with fewer emissions per ruble of output. Then switching production to clean industries does not help achieve the regulatory target. Consequently, in this policy simulation, the technique effect is the strongest of all seven of our core policy scenarios.

5.4.3 WTO Accession Combined with Energy Efficiency Standards

In tables 20 and 20a, we display the aggregate results for our ten regions of our final policy scenario in which we combine WTO accession with the regulatory requirement that all sectors except electricity and fossil fuel production (coal, natural gas and oil refining), uniformly reduce their use of gas, oil and electricity such that carbon emissions are reduced by 20 percent. With this environmental policy, the welfare gains fall very substantially to 0.6 percent of consumption. Thus, judged on the basis of carbon emissions alone, this policy is by far the most costly. In table 21, however, we can see that energy efficiency standards to achieve carbon emissions reduction are considerably more effective at achieving a reduction in emissions other than carbon dioxide. In fact, energy efficiency standards are more effective at reducing all six non-CO2 emissions.

6. Sensitivity Analysis

6.1 Results with Constant Returns to Scale and Perfect Competition

As we mentioned above, most models that assess the impact of trade on the environment assume constant returns to scale and perfect competition, and exclude foreign direct investment and productivity impacts. In this sub-section, we investigate the impact of our more innovative and empirically accurate modeling framework by executing our seven basic scenarios in a model with constant returns to scale and perfect competition. In table 22, we show the aggregate results for the overall economy of all seven scenarios in a constant returns to scale model. Table 22 is directly comparable to table 21, where the latter is based on our central model with increasing returns to scale and FDI in services.

Examining WTO accession alone, with constant returns to scale, the estimated welfare gains are much smaller; at 0.5 percent of GDP, they are within the range of the “Harberger constant.”22 At the same time, the negative impact on emissions of all seven pollutants is considerably smaller in the CRTS model. The reason is that the smaller welfare

22 The Harberger constant is the loose characterization that the welfare gains from trade reform in constant returns to scale models is less than 1 percent of GDP.
gains are associated with smaller output expansion, which results in lesser emission of pollutants. In the case of CO2 emissions, our decomposition analysis shows that the negative scale effect on CO2 emissions, which is the primary culprit in the increase in CO2 emissions with IRTS, is much smaller in the CRTS model.

A key result of our analysis with our central model is reversed with the CRTS model. We found that with IRTS, WTO accession is expected to expand incomes by more than enough to pay for the cost of environmental abatement policies, even if the least efficient policy of environmental regulation is used. With CRTS, simultaneous application of WTO accession and environmental regulation yields net benefits only if the market based cap and trade system is employed, and a substantial loss if the least efficient environmental policy is employed. When simultaneously applied with WTO accession, energy efficiency standards, which is the least efficient of our three environmental policies for CO2 reduction, yields a net welfare loss of 1.6 percent of GDP.

6.2 Piecemeal Sensitivity Analysis

In tables 23a—23g, we present our estimates of the impact on emissions of our seven pollutants and welfare as a percent of GDP of varying the value of key parameters. In these scenarios, we retain the central value of all parameters except the parameter in question. We show results for each region and an overall economy average. As far as welfare is concerned, the gains to the economy generally increase with an increase in elasticities, since higher elasticities imply that the economy is able to more easily shift to sectors or products that are cheaper after trade and FDI liberalization. There are two parameters in the table that have a strong impact on the results: the elasticity of substitution between value-added and business services (esubs) and the elasticity of multinational firm supply (etaf). A liberalization of the barriers to FDI will result in a reduction in the cost of business services, both from the direct effect of lowering the costs of doing business for multinational service providers and from the indirect effect that additional varieties of business services allow users to purchase a quality adjusted unit of services at less cost. When the elasticity of substitution between value-added and business services is high (esubs = 2 in table 23a), users have the greater potential to substitute the cheaper business services and this increases productivity. The elasticity of multinational and Russian firm supply (etaf, etad) is primarily dependent on the sector specific factor for each firm type (foreign or domestic). When etaf is high, a reduction in the barriers to foreign direct investment results in a larger expansion in the number of

23 An increase in the elasticity of substitution between varieties reduces the welfare gain. This is because when varieties are good substitutes, additional varieties are worth less to firms and consumers.
multinational firms supplying the Russian market, and hence more gains from additional varieties of business services. In addition, the share of the services market captured by multinationals has a strong effect, since a liberalization results in a larger number of new varieties introduced.

In tables 23b through 23g, we show the sensitivity of emissions to the parameters. In general, emissions of pollutants are more sensitive to the parameter specification than economic welfare. Carbon dioxide, sulphur dioxide, volatile organic components and especially hydrocarbons are especially sensitive to the parameter esubs. This shows that the scale and composition effects significantly dominate the technique effect. Higher values of esubs allow greater use on newer technologies (technically new varieties), which reduces pollution through the technique effect. But higher values of esubs mean more output expansion, and this (along with the shift to dirty industries we have noted) dominates, especially for most of the non-CO2 pollutants.

7. Conclusions

To gain insights into the pending trade-offs between trade and FDI liberalization and pollution in Russia, we developed a ten-region, 30 sector model of the Russian economy. Our model contains foreign direct investment, imperfectly competitive sectors and endogenous productivity effects triggered by WTO accession. We incorporated environmental emissions data in Russia for seven pollutants which are tracked for all 30 sectors in each of the ten Russian regions of our model.

We find that WTO accession alone will increase environmental pollution in Russia. Our decomposition shows that the negative effect on the environment of the composition effect (especially the relative expansion of dirty industries) and the expansion of output (scale effect) dominate the positive impact on the environment of the technique effect (which includes importing new, more efficient technologies, processes and services).

Given the adverse impact on the environment of WTO accession, and that part of the income increase from WTO accession might be used to pay for environmental abatement, we assess the costs of three types of environmental regulations to reduce carbon dioxide emissions by 20 percent: market based “cap and trade”; emission intensity standards; and energy efficiency standards. In a third set of scenarios, we assess the impacts of “overlapping” policy reforms where we simultaneously implement our central case scenario of WTO accession with each of our three carbon emission reduction policy initiatives.

We find that the welfare gains of WTO accession are large enough to pay for the costs of any of the three environment abatement policies, while leaving a net welfare gain. In
order to assist regulators in the design of policies that would minimize opposition to environmental regulation, we have assessed the relative costs of three alternate policies that achieve a 20 percent reduction in carbon dioxide emissions. We find that the market based “cap and trade” regulation is the least costly of the three policies, followed by emission intensity standards (which is reasonably efficient). Energy efficiency policies are significantly more costly at achieving the same level of carbon dioxide reduction compared with cap and trade and emissions intensity standards.

In our sensitivity analysis, we find that there are drastic differences in the economic and environmental impacts between model simulations without and with the endogenous productivity effects of our model with increasing returns to scale and foreign direct investment. In particular, with a CRTS model, the welfare gains are insufficient to finance the costs of the least efficient environmental regulation.

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### Tables

#### Table 1. List of Sectors

| Code | Description                                      |
|------|--------------------------------------------------|
| RLW  | Railway transportation                           |
| TRK  | Truck transportation                             |
| PIP  | Pipelines transportation                         |
| MAR  | Maritime transportation                          |
| AIR  | Air transportation                               |
| TRO  | Other transportation                             |
| TMS  | Telecommunications                               |
| SCI  | Science & science servicing                      |
| FIN  | Financial services                               |
| FME  | Ferrous metallurgy                               |
| NFM  | Non-ferrous metallurgy                           |
| CHM  | Chemical & oil-chemical industry                 |
| MWO  | Mechanical engineering & metal-working           |
| TPP  | Timber & woodworking & pulp & paper industry    |
| CNM  | Construction materials industry                  |
| FOO  | Food industry                                    |
| OTI  | Other industries                                 |
| HEA  | Public services, culture and arts                |
| AGR  | Agriculture & forestry                           |
| COL  | Coalmining                                       |
| HOU  | Housing and communal services                    |
| CON  | Construction                                     |
| ELE  | Electric industry                                |
| GAS  | Gas                                              |
| CRU  | Crude oil extraction                             |
| OIL  | Oil refining and processing                      |
| OTH  | Other goods-producing sectors                    |
| PST  | Post                                             |
| TRD  | Wholesale and retail trade                       |
| CLI  | Textiles and apparel                             |

1. **Sectors where foreign direct investment from new multinational services providers is possible**

2. **Sectors where new foreign firms may provide new goods from abroad**

3. **Competitive sectors subject to constant returns to scale**
Table 2. List of Russian Regional Markets and Oblasts

| Russian regional “markets” | Oblasts (plus Republics, Territories, Federal Cities, Autonomous Regions, Autonomous Districts) |
|----------------------------|---------------------------------------------------------------------------------------------------|
| msc Moscow (msk,mos)      | 1. ady Adygeya, The Republic of                                                                  |
| stp Saint-Petersburg (len,spb) | 2. agi Aginsky Buryatsky Autonomous District                                                      |
| tmn Tumenskaya (tum,kha,yam) | 3. alt Altaiy krai                                                                               |
| vgd Northwest (vol,klg,nov,psk) | 4. alr Altay Republic                                                                            |
| nor North (kpa,nen,krl,kom,arh,mur) | 5. amu Amurskaya                                                                                |
| cen Central (bel,bry,vla,iva,kal,kos,kr,lp,rya,smo,tam,tve,tul,yar) | 6. arh Arkhangelskaya                                                                            |
| sou South (sar,ady,dag,ing,kab,krl,kar,sev,kdk,sta,ast,vlg,ros) | 7. ast Astrakhanskaya                                                                            |
| url Urals (mar,mor,tat,udm,chi,kir,niz,pen,ulo,ore,sam,bs,per,krg,sve,cli) | 8. bas Bashkortostan, The Republic of                                                             |
| sib Siberia (air,bur,tyv,hak,alt,kem,uns,tom,oms,ive,tai,ust,kra,sah,kam,mag,kor,chu) | 9. bel Belgorodskaya                                                                             |
| far Far East (agi,cli,hab,amu,sa,pri,eao) | 10. bry Bryanskaya                                                                               |
|                            | 11. bur Buryatia, The Republic of                                                                 |
|                            | 12. chr Chechnya (sou), The Republic of                                                            |
|                            | 13. chl Chelyabinskaya                                                                           |
|                            | 14. chi Chitinskaya                                                                              |
|                            | 15. chu Chukotsky Autonomous District                                                              |
|                            | 16. chv Chuvashia, The Republic of                                                                 |
|                            | 17. dag Dagestan, The Republic of                                                                  |
|                            | 18. eve Evenkiysky Autonomous District                                                              |
|                            | 19. ing Ingushetia, The Republic of                                                                 |
|                            | 20. irk Irkutskaya                                                                               |
|                            | 21. iva Ivanovskaya                                                                              |
|                            | 22. eao Jewish Autonomous Region                                                                  |
|                            | 23. kab Kabardino Balkaria, The Republic of                                                        |
|                            | 24. klg Kaliningradskaya                                                                         |
|                            | 25. kal Kaluzhskaya                                                                              |
|                            | 26. kfr Kalymykiia, The Republic of                                                                |
|                            | 27. kam Kamschatkia                                                                              |
|                            | 28. kar Karachaevo Cherkessia, The Republic of                                                      |
|                            | 29. krl Karelia, The Republic of                                                                   |
|                            | 30. kem Kemerovskaya                                                                             |
|                            | 31. hab Khabarovskiy krai                                                                         |
|                            | 32. hak Khakasia, The Republic of                                                                  |
|                            | 33. kha Khanty-Mansiyski Autonomous District                                                       |
|                            | 34. kir Kirovskaya                                                                               |
|                            | 35. kom Komi, The Republic of                                                                     |
|                            | 36. kpa Komi-Permıyatski Autonomous District                                                        |
|                            | 37. kor Koryakskiy Autonomous District                                                              |
|                            | 38. kos Kostromskaya                                                                             |
|                            | 39. kdk Krasnodarskiy krai                                                                        |
|                            | 40. kra Krasnoyarskiy krai                                                                        |
|                            | 41. krg Kurganskaya                                                                              |
|                            | 42. krs Kurskaya                                                                                 |
|                            | 43. len Leningradskaya                                                                            |
|                            | 44. lip Lipetskaya                                                                               |
|                            | 45. mag Maganskaya                                                                               |
|                            | 46. mar Mari El, The Republic of                                                                   |
|                            | 47. mor Mordovia, The Republic of                                                                   |
|                            | 48. mos Moskovskaya                                                                              |
|                            | 49. msk Moscow city                                                                               |
|                            | 50. mur Murmanskaya                                                                              |
|                            | 51. nen Nenetsky Autonomous District                                                                |
|                            | 52. niz Nizhegorodskaya                                                                          |
|                            | 53. sev North Osetia, The Republic of                                                               |
|                            | 54. nov Novgorodskaya                                                                             |
|                            | 55. nvs Novosibirskaya                                                                           |
|                            | 56. ons Omskaya                                                                                  |
|                            | 57. ore Orenburgskaya                                                                            |
|                            | 58. orl Orlovskaya                                                                               |
|                            | 59. pen Penzenskaya                                                                               |
|                            | 60. per Permskaya                                                                                |
|                            | 61. pri Primorskiy krai                                                                            |
|                            | 62. psk Pskovskaya                                                                               |
|                            | 63. ros Rostovskaya                                                                               |
|                            | 64. rya Ryazanskaya                                                                               |
|                            | 65. spb Saint Petersburg City                                                                     |
|                            | 66. sah Sakha, The Republic of                                                                     |
|                            | 67. sao Sakhalinskaya                                                                             |
|                            | 68. sam Samarskaya                                                                               |
|                            | 69. sar Saratovskaya                                                                              |
|                            | 70. smo Smolenskaya                                                                               |
|                            | 71. sta Stavropolskiy krai                                                                         |
|                            | 72. sve Sverdlovskaya                                                                             |
|                            | 73. tai Tamyrsky (Dolgan-Nenetsky) Autonomous                                                      |
|                            | 74. tam Tambovskaya                                                                               |
|                            | 75. tat Tatranst, The Republic of                                                                   |
|                            | 76. tom Tomskaya                                                                                 |
|                            | 77. tul Tulsksy                                                                                   |
|                            | 78. tum Tumenskaya                                                                               |
|                            | 79. tve Tverskaya                                                                                |
|                            | 80. tyv Tyva, The Republic of                                                                      |
|                            | 81. udm Udmurtia, The Republic of                                                                   |
|                            | 82. ulo Ulyanovskaya                                                                              |
|                            | 83. ust Ust-ordinsky Buryatsky Autonomous District                                                  |
|                            | 84. vla Vladimirskaya                                                                             |
|                            | 85. vlg Volgogradskaya                                                                           |
|                            | 86. vol Volgodskaya                                                                               |
|                            | 87. vor Voronezhskaya                                                                             |
|                            | 88. yam Yamalo-Nenetsky Autonomous District                                                        |
|                            | 89. yar Yaroslavskaya                                                                             |

* No data.
Table 3. Value Added in 2000 by Russian Regional Market and by Sector (in billions of 2001 rubles)\textsuperscript{a/b}

| Sector \textsuperscript{b}/ | Central | Far East | North | Siberia | South | Urals | Moscow | St. Petersb. | Tumen | North-west | Sector total |
|---------------------------|---------|----------|-------|---------|-------|-------|--------|-------------|--------|------------|------------|
| MAR                       | 4.7     | 1.3      | 1.4   | 7.2     | 4.1   | 14.7  | 4.0    | 1.7         | 6.9    | 1.0        | 47.1       |
| AGR                       | 110.2   | 17.5     | 7.4   | 84.8    | 125.2 | 155.3 | 15.2   | 11.8        | 8.2    | 15.1       | 550.7      |
| AIR                       | 3.6     | 1.3      | 1.0   | 5.3     | 4.5   | 10.0  | 14.9   | 1.6         | 2.5    | 0.6        | 45.2       |
| CHM                       | 13.9    | 0.3      | 1.6   | 10.6    | 9.3   | 35.6  | 7.7    | 2.0         | 0.1    | 4.2        | 85.4       |
| CNM                       | 10.3    | 1.1      | 0.7   | 4.6     | 6.7   | 12.2  | 8.8    | 2.4         | 0.8    | 0.7        | 48.2       |
| COL                       | 0.1     | 5.2      | 3.2   | 32.6    | 1.7   | 1.2   |        |             |        |            | 43.9       |
| CON                       | 76.4    | 7.1      | 6.1   | 54.7    | 105.2 | 151.6 | 138.6  | 29.7        | 24.1   | 11.4       | 605.0      |
| CRU                       | 4.5     | 16.9     | 9.9   | 37.7    | 97.5  |       |        |             |        | 282.9      | 450.3      |
| ELE                       | 26.7    | 7.8      | 7.1   | 34.7    | 22.9  | 62.9  | 42.9   | 10.5        | 19.1   | 5.8        | 240.4      |
| FIN                       | 43.5    | 16.4     | 14.3  | 60.7    | 44.0  | 106.8 | 115.7  | 20.8        | 47.0   | 9.0        | 478.0      |
| FME                       | 19.0    | 0.5      | 1.6   | 9.0     | 3.9   | 33.8  | 2.3    | 1.1         | 11.3   |           | 82.5       |
| FOO                       | 24.9    | 9.2      | 3.7   | 17.4    | 24.0  | 28.1  | 33.9   | 17.7        | 0.5    | 4.7        | 164.2      |
| GAS                       | 0.2     | 0.4      | 0.5   | 1.5     | 2.8   |       |        |             |        | 52.2       | 57.5       |
| HEA                       | 42.3    | 17.5     | 14.6  | 58.8    | 45.0  | 100.6 | 126.3  | 21.8        | 40.6   | 8.9        | 476.4      |
| HOU                       | 22.1    | 8.8      | 6.7   | 29.1    | 24.8  | 50.9  | 68.0   | 11.2        | 13.7   | 4.6        | 239.8      |
| MWO                       | 38.7    | 11.2     | 2.6   | 19.4    | 18.0  | 101.8 | 45.4   | 18.9        | 3.0    | 3.6        | 262.7      |
| NFM                       | 2.5     | 8.1      | 9.3   | 113.2   | 4.8   | 46.0  | 7.1    | 4.4         | 0.2    |           | 195.5      |
| OIL                       | 12.2    | 4.7      | 1.5   | 17.4    | 10.1  | 39.2  | 4.4    | 7.2         | 3.9    |           | 100.6      |
| OTH                       | 7.7     | 2.0      | 2.2   | 8.8     | 4.9   | 18.4  | 6.3    | 3.3         | 7.4    | 1.9        | 62.8       |
| OTI                       | 13.6    | 0.6      | 0.7   | 2.5     | 4.0   | 9.2   | 9.9    | 2.6         | 0.1    | 0.9        | 44.0       |
| PIP                       | 1.5     | 0.5      | 0.5   | 2.0     | 1.7   | 5.4   | 1.2    | 0.7         | 5.2    | 0.2        | 18.7       |
| PST                       | 2.7     | 1.0      | 0.8   | 3.5     | 2.9   | 6.3   | 6.8    | 1.3         | 2.8    | 0.6        | 28.7       |
| RLW                       | 23.5    | 6.9      | 6.3   | 30.2    | 20.5  | 53.8  | 34.5   | 9.4         | 16.1   | 6.2        | 207.3      |
| SCI                       | 8.8     | 3.2      | 2.4   | 10.4    | 7.8   | 22.6  | 16.5   | 4.1         | 9.8    | 1.5        | 87.0       |
| TMS                       | 7.6     | 2.8      | 2.2   | 10.1    | 8.3   | 18.7  | 21.1   | 3.6         | 7.4    | 1.5        | 83.3       |
| TPP                       | 6.8     | 4.4      | 15.1  | 13.1    | 2.6   | 13.0  | 6.8    | 7.3         | 0.6    | 4.2        | 73.9       |
| TRD                       | 205.4   | 78.2     | 67.0  | 300.6   | 223.3 | 535.3 | 456.6  | 101.6       | 386.8  | 48.2       | 2,402.9    |
| TRK                       | 10.2    | 3.5      | 3.1   | 13.6    | 11.3  | 24.6  | 23.0   | 4.7         | 12.9   | 2.2        | 109.2      |
| TRO                       | 4.5     | 1.5      | 1.3   | 5.7     | 5.1   | 11.2  | 10.7   | 2.0         | 5.7    | 0.9        | 48.7       |
| CLI                       | 3.8     | 1.6      | 1.2   | 5.0     | 4.4   | 8.6   | 12.9   | 2.0         | 1.9    | 0.8        | 42.3       |

\textsuperscript{a} Value added defined here does not include taxes.

\textsuperscript{b} Sector codes are in Table 1, oblasts in the markets are listed in Table 2.

Source: Regions of Russia, Roskomstat, and authors' calculations.
## Table 4. Value-Added by Sector as a percent of the Value-Added of the Regional Market

| Sector | Central | Far East | North | Siberia | South | Urals | Moscow | St. Petersb. | Tumen | North-west |
|--------|---------|---------|-------|---------|-------|-------|--------|--------------|-------|-----------|
| MAR    | 0.6     | 0.6     | 0.7   | 0.7     | 0.5   | 0.8   | 0.3    | 0.6          | 0.7   | 0.6       |
| AGR    | 14.8    | 7.6     | 3.7   | 8.7     | 15.8  | 8.7   | 1.2    | 3.9          | 0.9   | 10.0      |
| AIR    | 0.5     | 0.6     | 0.5   | 0.5     | 0.6   | 0.6   | 1.2    | 0.5          | 0.3   | 0.4       |
| CHM    | 1.9     | 0.1     | 0.8   | 1.1     | 1.2   | 2.0   | 0.6    | 0.7          | 0.0   | 2.8       |
| CNM    | 1.4     | 0.5     | 0.4   | 0.5     | 0.8   | 0.7   | 0.7    | 0.8          | 0.1   | 0.4       |
| COL    | 0.0     | 2.3     | 1.6   | 3.3     | 0.2   | 0.1   | 0.1    | 0.1          | 0.1   | 0.1       |
| CON    | 10.2    | 3.1     | 3.0   | 5.6     | 13.3  | 8.5   | 11.2   | 9.7          | 2.5   | 7.6       |
| CRU    | 1.9     | 8.3     | 1.0   | 4.8     | 5.5   | 29.4  | 0.7    | 29.4         | 0.7   | 29.4      |
| ELE    | 3.6     | 3.4     | 3.5   | 3.6     | 2.9   | 3.5   | 3.5    | 3.5          | 2.0   | 3.9       |
| FIN    | 5.8     | 7.2     | 7.0   | 6.2     | 5.6   | 6.0   | 9.3    | 6.8          | 4.9   | 5.9       |
| FME    | 2.5     | 0.2     | 0.8   | 0.9     | 0.5   | 1.9   | 0.2    | 0.4          | 0.4   | 0.4       |
| FOO    | 3.3     | 4.0     | 1.8   | 1.8     | 3.0   | 1.6   | 2.7    | 5.8          | 0.1   | 3.1       |
| GAS    | 0.1     | 0.2     | 0.0   | 0.2     | 0.2   | 0.2   | 0.2    | 5.4          | 0.0   | 0.0       |
| HEA    | 5.7     | 7.6     | 7.2   | 6.0     | 5.7   | 5.7   | 10.2   | 7.1          | 4.2   | 5.9       |
| HOU    | 3.0     | 3.8     | 3.3   | 3.0     | 3.1   | 2.9   | 5.5    | 3.7          | 1.4   | 3.0       |
| MWO    | 5.2     | 4.9     | 1.3   | 2.0     | 2.3   | 5.7   | 3.7    | 6.2          | 0.3   | 2.4       |
| NFM    | 0.3     | 3.5     | 4.6   | 11.6    | 0.6   | 2.6   | 0.6    | 1.4          | 0.1   | 0.1       |
| OIL    | 1.6     | 2.1     | 0.8   | 1.8     | 1.3   | 2.2   | 0.4    | 2.4          | 0.4   | 0.4       |
| OTH    | 1.0     | 0.9     | 1.1   | 0.9     | 0.6   | 1.0   | 0.5    | 1.1          | 0.8   | 1.2       |
| OTI    | 1.8     | 0.2     | 0.3   | 0.3     | 0.5   | 0.5   | 0.8    | 0.8          | 0.0   | 0.6       |
| PIP    | 0.2     | 0.2     | 0.2   | 0.2     | 0.2   | 0.3   | 0.1    | 0.2          | 0.5   | 0.1       |
| PST    | 0.4     | 0.4     | 0.4   | 0.4     | 0.4   | 0.4   | 0.6    | 0.4          | 0.3   | 0.4       |
| RLW    | 3.1     | 3.0     | 3.1   | 3.1     | 2.6   | 3.0   | 2.8    | 3.1          | 1.7   | 4.1       |
| SCI    | 1.2     | 1.4     | 1.2   | 1.1     | 1.0   | 1.3   | 1.3    | 1.4          | 1.0   | 1.0       |
| TMS    | 1.0     | 1.2     | 1.1   | 1.0     | 1.0   | 1.1   | 1.7    | 1.2          | 0.8   | 1.0       |
| TPP    | 0.9     | 1.9     | 7.5   | 1.3     | 0.3   | 0.7   | 0.5    | 2.4          | 0.1   | 2.8       |
| TRD    | 27.5    | 34.2    | 33.0  | 30.8    | 28.3  | 30.1  | 36.8   | 33.3         | 40.2  | 31.9      |
| TRK    | 1.4     | 1.5     | 1.5   | 1.4     | 1.4   | 1.4   | 1.9    | 1.5          | 1.3   | 1.5       |
| TRO    | 0.6     | 0.7     | 0.7   | 0.6     | 0.6   | 0.6   | 0.9    | 0.7          | 0.6   | 0.6       |
| CLI    | 0.5     | 0.7     | 0.6   | 0.5     | 0.6   | 0.5   | 1.0    | 0.7          | 0.2   | 0.5       |

Total 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0

See Table 1 for sector codes.

Source: Regions of Russia, Roskomstat.
| Good | Central | Far East | North | Siberia | South | Urals | Moscow | St. Petersb. | Tumen | North-west | Sector Total |
|------|---------|---------|-------|---------|-------|-------|--------|------------|-------|-----------|-------------|
| MAR  | 10.0    | 2.8     | 2.9   | 15.2    | 8.8   | 31.3  | 8.5    | 3.7        | 14.7  | 2.0       | 100.0       |
| AGR  | 20.0    | 3.2     | 1.3   | 15.4    | 22.7  | 28.2  | 2.8    | 2.1        | 1.5   | 2.7       | 100.0       |
| AIR  | 7.9     | 2.8     | 2.1   | 11.6    | 10.0  | 22.1  | 32.9   | 3.6        | 5.5   | 1.4       | 100.0       |
| CHM  | 16.3    | 0.4     | 1.8   | 12.4    | 10.9  | 41.6  | 9.1    | 2.4        | 0.1   | 4.9       | 100.0       |
| CNM  | 21.3    | 2.3     | 1.5   | 9.6     | 13.9  | 25.2  | 18.2   | 4.9        | 1.6   | 1.4       | 100.0       |
| COL  | 0.3     | 11.8    | 7.3   | 74.2    | 3.8   | 2.7   |        |            |       |           | 100.0       |
| CON  | 12.6    | 1.2     | 1.0   | 9.0     | 17.4  | 25.1  | 22.9   | 4.9        | 4.0   | 1.9       | 100.0       |
| CRU  | 1.0     | 3.7     | 2.2   | 8.4     | 21.7  |       |        |            |       | 62.8      | 100.0       |
| ELE  | 11.1    | 3.2     | 2.9   | 14.4    | 9.5   | 26.2  | 17.9   | 4.4        | 7.9   | 2.4       | 100.0       |
| FIN  | 9.1     | 3.4     | 3.0   | 12.7    | 9.2   | 22.3  | 24.2   | 4.4        | 9.8   | 1.9       | 100.0       |
| FME  | 23.0    | 0.6     | 1.9   | 10.9    | 4.8   | 40.9  | 2.8    | 1.4        |       | 13.7      | 100.0       |
| FOO  | 15.2    | 5.6     | 2.2   | 10.6    | 14.6  | 17.1  | 20.6   | 10.8       | 0.3   | 2.8       | 100.0       |
| GAS  | 0.3     | 0.7     | 0.8   | 2.5     | 4.8   |       |        |            |       | 90.8      | 100.0       |
| HEA  | 8.9     | 3.7     | 3.1   | 12.3    | 9.4   | 21.1  | 26.5   | 4.6        | 8.5   | 1.9       | 100.0       |
| HOU  | 9.2     | 3.7     | 2.8   | 12.1    | 10.3  | 21.2  | 28.4   | 4.7        | 5.7   | 1.9       | 100.0       |
| MWO  | 14.7    | 4.3     | 1.0   | 7.4     | 6.8   | 38.8  | 17.3   | 7.2        | 1.1   | 1.4       | 100.0       |
| NFM  | 1.3     | 4.1     | 4.7   | 57.9    | 2.5   | 23.6  | 3.6    | 2.2        |       | 0.1       | 100.0       |
| OIL  | 12.1    | 4.7     | 1.5   | 17.3    | 10.0  | 38.9  | 4.4    | 7.2        | 3.9   |           | 100.0       |
| OTH  | 12.3    | 3.2     | 3.6   | 14.0    | 7.8   | 29.3  | 10.0   | 5.2        | 11.7  | 3.0       | 100.0       |
| OTI  | 30.8    | 1.3     | 1.6   | 5.7     | 9.1   | 20.9  | 22.5   | 5.8        | 0.2   | 2.1       | 100.0       |
| PIP  | 7.8     | 2.7     | 2.5   | 10.5    | 8.9   | 28.9  | 6.4    | 3.6        | 27.7  | 1.0       | 100.0       |
| PST  | 9.3     | 3.5     | 2.8   | 12.2    | 10.1  | 22.0  | 23.9   | 4.5        | 9.9   | 1.9       | 100.0       |
| RLW  | 11.3    | 3.3     | 3.0   | 14.6    | 9.9   | 25.9  | 16.6   | 4.5        | 7.8   | 3.0       | 100.0       |
| SCI  | 10.1    | 3.6     | 2.8   | 11.9    | 8.9   | 26.0  | 18.9   | 4.7        | 11.3  | 1.7       | 100.0       |
| TMS  | 9.1     | 3.3     | 2.7   | 12.1    | 9.9   | 22.4  | 25.3   | 4.3        | 8.9   | 1.8       | 100.0       |
| TPP  | 9.3     | 5.9     | 20.5  | 17.8    | 3.5   | 17.6  | 9.2    | 9.8        | 0.8   | 5.7       | 100.0       |
| TRD  | 8.5     | 3.3     | 2.8   | 12.5    | 9.3   | 22.3  | 19.0   | 4.2        | 16.1  | 2.0       | 100.0       |
| TRK  | 9.3     | 3.2     | 2.8   | 12.5    | 10.4  | 22.6  | 21.1   | 1.3        | 11.8  | 2.0       | 100.0       |
| TRO  | 9.2     | 3.1     | 2.7   | 11.7    | 10.5  | 23.0  | 21.9   | 4.2        | 11.8  | 1.9       | 100.0       |
| CLI  | 9.0     | 3.7     | 2.8   | 11.7    | 10.5  | 20.4  | 30.6   | 4.7        | 4.6   | 1.9       | 100.0       |
| Total| 329.2   | 99.4    | 96.2  | 453.3   | 284.4 | 734.1 | 465.5  | 340.9      | 68.7  | 3000.0    |             |

Source: Regions of Russia and authors calculations.
Table 6: Exports by Product and by Regional Market  (in billions of 2001 rubles)

| Good | Central | Far East | North | Siberia | South | Urals | Moscow | St. Petersb. | Tumen | North-west |
|------|---------|----------|-------|---------|-------|-------|--------|-------------|-------|-----------|
| MAR  | 4.9     | 1.7      | 1.7   | 7.1     | 4.5   | 13.7  | 4.3    | 2.2         | 6.9   | 1.2       |
| AGR  | 3.1     | 0.5      | 0.2   | 2.4     | 3.5   | 4.4   | 0.4    | 0.3         | 0.2   | 0.4       |
| AIR  | 5.6     | 2.4      | 1.8   | 7.6     | 6.8   | 13.2  | 18.9   | 3.0         | 4.4   | 1.2       |
| CHM  | 27.5    | 0.5      | 2.0   | 33.2    | 18.2  | 92.0  | 13.7   | 5.0         | 0.3   | 15.2      |
| CNM  | 1.8     | 0.2      | 0.1   | 1.7     | 1.2   | 3.4   | 1.6    | 0.6         | 0.2   | 0.2       |
| COL  | 0.1     | 4.2      | 2.6   | 26.4    | 1.3   | 0.9   |        |             |       |           |
| CON  | 4.0     | 0.4      | 0.3   | 2.9     | 5.6   | 8.0   | 7.3    | 1.6         | 1.3   | 0.6       |
| CRU  | 7.1     | 27.0     | 15.8  | 60.3    | 156.1 | 452.8 | 1.6    |             |       |           |
| ELE  | 1.1     | 0.3      | 0.3   | 1.4     | 1.0   | 2.6   | 1.8    | 0.4         | 0.8   | 0.2       |
| FIN  | 0.7     | 0.3      | 0.2   | 0.9     | 0.7   | 1.6   | 1.8    | 0.3         | 0.7   | 0.1       |
| FME  | 50.5    | 1.1      | 3.7   | 22.4    | 11.1  | 83.8  | 7.1    | 48.7        | 28.3  |           |
| FOO  | 8.7     | 9.7      | 2.5   | 12.6    | 23.1  | 10.1  | 27.0   | 9.2         | 0.1   | 3.6       |
| GAS  | 1.4     | 3.1      | 3.6   | 11.5    | 21.8  |        |        |             |       | 410.7     |
| HEA  | 0.3     | 0.1      | 0.1   | 0.4     | 0.3   | 0.6   | 0.8    | 0.1         | 0.2   | 0.1       |
| HOU  | 0.3     | 0.1      | 0.1   | 0.4     | 0.3   | 0.6   | 0.8    | 0.1         | 0.2   | 0.1       |
| MWO  | 22.8    | 14.2     | 1.9   | 43.0    | 23.3  | 97.0  | 95.5   | 30.4        | 1.9   | 5.0       |
| NFM  | 4.6     | 15.1     | 18.4  | 203.1   | 11.1  | 101.6 | 17.2   | 11.3        | 0.6   |           |
| OIL  | 35.5    | 13.7     | 4.5   | 50.9    | 29.5  | 114.4 | 12.8   | 21.1        | 11.5  |           |
| OTH  | 1.7     | 0.4      | 0.5   | 1.9     | 1.1   | 4.0   | 1.4    | 0.7         | 1.6   | 0.4       |
| OTI  | 7.2     | 0.3      | 0.4   | 1.3     | 2.1   | 4.9   | 5.3    | 1.4         | 0.0   | 0.5       |
| PST  | 0.3     | 0.1      | 0.1   | 0.5     | 0.4   | 0.8   | 0.9    | 0.2         | 0.4   | 0.1       |
| RLW  | 0.9     | 0.3      | 0.2   | 1.1     | 0.8   | 2.0   | 1.3    | 0.3         | 0.6   | 0.2       |
| SCI  | 0.6     | 0.2      | 0.2   | 0.7     | 0.5   | 1.6   | 1.1    | 0.3         | 0.7   | 0.1       |
| TMS  | 0.9     | 0.3      | 0.3   | 1.2     | 1.0   | 2.1   | 2.4    | 0.4         | 0.9   | 0.2       |
| TPP  | 3.1     | 17.1     | 29.2  | 35.1    | 1.7   | 13.3  | 2.1    | 12.7        | 0.4   | 8.1       |
| TRD  | 2.0     | 0.8      | 0.7   | 3.0     | 2.2   | 5.3   | 4.5    | 1.0         | 3.9   | 0.5       |
| TRK  | 0.4     | 0.1      | 0.1   | 0.5     | 0.4   | 0.9   | 0.9    | 0.2         | 0.5   | 0.1       |
| TRO  | 0.5     | 0.2      | 0.2   | 0.7     | 0.6   | 1.3   | 1.2    | 0.2         | 0.7   | 0.1       |
| CLI  | 2.6     | 1.1      | 0.8   | 3.4     | 3.1   | 6.0   | 9.0    | 1.4         | 1.3   | 0.5       |

See Tables 1 and 2 for sector and region definitions.

Source: Roskomstat unpublished surveys and authors’ calculations.
Table 7. Sector Exports as a Percent of Total Exports of the Regional Market

| Good | Central | Far East | North | Siberia | South | Urals | Moscow | St. Petersb. | Tumen | North-west |
|------|---------|----------|-------|---------|-------|-------|--------|-------------|-------|------------|
| MAR  | 3       | 2        | 2     | 1       | 2     | 2     | 2      | 2           | 1     | 2          |
| AGR  | 2       | 1        | 0     | 0       | 2     | 1     | 0      | 0           | 0     | 1          |
| AIR  | 3       | 3        | 2     | 2       | 3     | 2     | 8      | 3           | 0     | 2          |
| CHM  | 14      | 1        | 2     | 7       | 8     | 12    | 6      | 5           | 0     | 22         |
| CNM  | 1       | 0        | 0     | 0       | 1     | 0     | 1      | 1           | 0     | 0          |
| COL  | 0       | 4        | 3     | 5       | 1     | 0     |        |             |       |            |
| CON  | 2       | 0        | 0     | 1       | 2     | 1     | 3      | 1           | 0     | 1          |
| CRU  | 8       | 26       | 3     | 27      | 20    | 50    | 2      |             |       |            |
| ELE  | 1       | 0        | 0     | 0       | 0     | 0     | 1      | 0           | 0     | 0          |
| FIN  | 0       | 0        | 0     | 0       | 0     | 0     | 1      | 0           | 0     | 0          |
| FME  | 26      | 1        | 4     | 5       | 5     | 11    | 3      | 4           | 41    |            |
| FOO  | 5       | 10       | 2     | 3       | 10    | 1     | 11     | 8           | 0     | 5          |
| GAS  | 2       | 3        | 1     | 5       | 3     |       |        |             | 45    | 0          |
| HEA  | 0       | 0        | 0     | 0       | 0     | 0     | 0      | 0           | 0     | 0          |
| HOU  | 0       | 0        | 0     | 0       | 0     | 0     | 0      | 0           | 0     | 0          |
| MWO  | 12      | 15       | 2     | 9       | 10    | 13    | 40     | 28          | 0     | 7          |
| NFM  | 2       | 16       | 18    | 42      | 5     | 13    | 7      | 10          |       | 1          |
| OIL  | 19      | 15       | 4     | 10      | 13    | 15    | 5      | 19          | 1     |            |
| OTH  | 1       | 0        | 0     | 0       | 0     | 1     | 1      | 1           | 0     | 1          |
| OTI  | 4       | 0        | 0     | 0       | 1     | 1     | 2      | 1           | 0     | 1          |
| PST  | 0       | 0        | 0     | 0       | 0     | 0     | 0      | 0           | 0     | 0          |
| RLW  | 0       | 0        | 0     | 0       | 0     | 1     | 0      | 0           | 0     | 0          |
| SCI  | 0       | 0        | 0     | 0       | 0     | 0     | 0      | 0           | 0     | 0          |
| TMS  | 0       | 0        | 0     | 0       | 0     | 1     | 0      | 0           | 0     | 0          |
| TPP  | 2       | 18       | 28    | 7       | 1     | 2     | 1      | 12          | 0     | 12         |
| TRD  | 1       | 1        | 1     | 1       | 1     | 1     | 2      | 1           | 0     | 1          |
| TRK  | 0       | 0        | 0     | 0       | 0     | 0     | 0      | 0           | 0     | 0          |
| TRO  | 0       | 0        | 0     | 0       | 0     | 0     | 1      | 0           | 0     | 0          |
| CLI  | 1       | 1        | 1     | 1       | 1     | 1     | 4      | 1           | 0     | 1          |
| Total| 100     | 100      | 100   | 100     | 100   | 100   | 100    | 100         | 100   | 100        |

See Tables 1 and 2 for sector and region definitions.

Source: Roskomstat unpublished surveys and authors' calculations.
Table 8. Sector Export Intensities by Regional Market: Exports of the Sector as a Percent of Production of the Sector (in percent)

| Good | Central | Far East | North | Siberia | South | Urals | Moscow | St. Petersb. | Tumen | Northwest |
|------|---------|---------|-------|---------|-------|-------|--------|-------------|-------|-----------|
| MAR  | 53      | 57      | 57    | 51      | 53    | 50    | 54     | 57          | 51    | 57        |
| AGR  | 1       | 1       | 1     | 1       | 1     | 1     | 1      | 1           | 1     | 1         |
| AIR  | 46      | 48      | 48    | 44      | 45    | 43    | 43     | 48          | 47    | 48        |
| CHM  | 27      | 21      | 17    | 48      | 27    | 37    | 24     | 35          | 40    | 57        |
| CNM  | 3       | 3       | 3     | 6       | 3     | 5     | 3      | 4           | 4     | 7         |
| COL  | 23      | 23      | 23    | 23      | 23    | 23    | 23     | 23          |       |           |
| CON  | 3       | 3       | 3     | 3       | 3     | 3     | 3      | 3           | 3     | 3         |
| CRU  | 56      | 56      | 56    | 56      | 56    | 56    | 56     | 56          | 56    | 56        |
| ELE  | 2       | 2       | 2     | 2       | 2     | 2     | 2      | 2           | 2     | 2         |
| FIN  | 1       | 1       | 1     | 1       | 1     | 1     | 1      | 1           | 1     | 1         |
| FME  | 1       | 1       | 1     | 1       | 1     | 1     | 1      | 1           | 1     | 1         |
| FOO  | 40      | 35      | 34    | 37      | 43    | 37    | 48     | 75          | 37    |           |
| GAS  | 4       | 12      | 8     | 8       | 11    | 4     | 9      | 6           | 3     | 9         |
| HEA  | 364     | 534     | 474   | 545     | 488   | 477   | 397    | 459         | 357   | 510       |

See Tables 1 and 2 for sector and region definitions.

Source: Roskomstat unpublished surveys and authors’ calculations.
Table 9: Imports by Product and by Regional Market (in x 2001 rubles)

| Good | Central | Far East | North | Siberia | South | Urals | Moscow | St. Petersb. | Tumen | Northwest |
|------|---------|----------|-------|---------|-------|-------|---------|-------------|-------|-----------|
| AGR  | 4.6     | 1.4      | 0.8   | 4.3     | 5.0   | 7.6   | 7.9     | 2.0         | 1.3   | 0.8       |
| AIR  | 0.3     | 0.1      | 0.1   | 0.4     | 0.3   | 0.6   | 0.9     | 0.1         | 0.2   | 0.1       |
| CHM  | 12.5    | 4.0      | 2.8   | 18.8    | 9.7   | 25.5  | 47.9    | 8.9         | 4.9   | 3.6       |
| CNM  | 2.7     | 0.5      | 0.4   | 3.3     | 2.8   | 4.6   | 11.6    | 2.2         | 0.8   | 0.7       |
| COL  | 0.6     | 0.2      | 0.2   | 1.3     | 0.4   | 1.2   | 0.6     | 0.2         | 0.2   | 0.2       |
| CON  | 8.0     | 4.0      | 3.4   | 10.2    | 10.0  | 20.4  | 15.3    | 4.7         | 16.4  | 1.7       |
| CRU  | 1.5     | 0.6      | 0.2   | 2.2     | 1.4   | 5.1   | 0.6     | 0.9         | 1.1   | 0.0       |
| ELE  | 0.3     | 0.1      | 0.1   | 0.4     | 0.3   | 0.8   | 0.5     | 0.1         | 0.2   | 0.1       |
| ETR  | 0.6     | 0.5      | 2.2   | 1.6     | 3.7   | 4.2   | 0.8     | 1.7         | 0.3   |           |
| FOOA | 9.5     | 1.2      | 0.8   | 3.1     | 7.8   | 11.7  | 13.4    | 4.3         | 2.9   | 2.8       |
| FOOB | 19.1    | 7.2      | 3.0   | 14.4    | 17.9  | 25.3  | 79.1    | 36.2        | 4.2   | 7.7       |
| GAS  | 0.1     | 0.0      | 0.0   | 0.1     | 0.1   | 0.3   | 0.2     | 0.0         | 0.2   | 0.0       |
| HEA  | 0.9     | 0.4      | 0.3   | 1.3     | 1.0   | 2.3   | 2.8     | 0.5         | 0.9   | 0.2       |
| HOU  | 3.5     | 1.4      | 1.1   | 4.6     | 3.9   | 8.0   | 10.7    | 1.8         | 2.2   | 0.7       |
| MWO  | 35.8    | 14.3     | 8.2   | 18.0    | 31.1  | 60.3  | 198.5   | 49.6        | 20.1  | 10.9      |
| NFM  | 3.9     | 2.1      | 1.5   | 13.2    | 4.7   | 10.9  | 9.2     | 3.5         | 2.2   | 1.2       |
| OIL  | 4.1     | 1.1      | 1.0   | 4.5     | 4.0   | 9.0   | 6.4     | 1.6         | 3.3   | 0.8       |
| OTH  | 1.7     | 0.6      | 0.5   | 2.2     | 1.7   | 4.1   | 3.7     | 0.8         | 2.0   | 0.4       |
| OTI  | 1.2     | 0.3      | 0.2   | 1.1     | 1.1   | 2.1   | 1.5     | 0.4         | 0.6   | 0.2       |
| PST  | 0.1     | 0.0      | 0.0   | 0.1     | 0.1   | 0.2   | 0.2     | 0.0         | 0.1   | 0.0       |
| RLW  | 0.1     | 0.0      | 0.0   | 0.2     | 0.1   | 0.3   | 0.3     | 0.1         | 0.2   | 0.0       |
| SCI  | 0.0     | 0.0      | 0.0   | 0.0     | 0.0   | 0.1   | 0.1     | 0.0         | 0.0   | 0.0       |
| TMS  | 0.8     | 0.3      | 0.2   | 1.0     | 0.8   | 1.8   | 2.0     | 0.4         | 0.7   | 0.2       |
| TPP  | 2.7     | 0.6      | 1.1   | 0.7     | 3.6   | 2.0   | 22.1    | 7.3         | 0.1   | 2.8       |
| TRD  | 1.0     | 0.4      | 0.3   | 1.5     | 1.1   | 2.6   | 2.4     | 0.5         | 1.5   | 0.2       |
| TRK  | 0.4     | 0.1      | 0.1   | 0.5     | 0.4   | 0.9   | 0.9     | 0.2         | 0.5   | 0.1       |
| TRO  | 0.1     | 0.0      | 0.0   | 0.2     | 0.2   | 0.3   | 0.3     | 0.1         | 0.2   | 0.0       |
| CLI  | 25      | 10       | 8     | 32      | 29    | 56    | 84      | 13          | 13    | 5         |
| Total| 142     | 52       | 35    | 142     | 140   | 268   | 528     | 140         | 81    | 41        |

See Tables 1 and 2 for sector and region definitions.

Source: Roskomstat unpublished surveys and authors' calculations.
Table 10. Sector Imports as a Percent of Total Imports of the Regional Market

| Good | Central | Far East | North | Siberia | South | Urals | Moscow | St. Petersb. | Tumen | North-west |
|------|---------|----------|-------|---------|-------|-------|--------|-------------|-------|------------|
| AGR  | 3       | 3        | 2     | 3       | 4     | 3     | 1      | 1           | 2    | 2          |
| AIR  | 0       | 0        | 0     | 0       | 0     | 0     | 0      | 0           | 0    | 0          |
| CHM  | 9       | 8        | 8     | 13      | 7     | 10    | 9      | 6           | 6    | 9          |
| CNM  | 2       | 1        | 1     | 2       | 2     | 2     | 2      | 2           | 1    | 2          |
| COL  | 0       | 0        | 1     | 1       | 0     | 0     | 0      | 0           | 0    | 1          |
| CON  | 6       | 8        | 10    | 7       | 7     | 8     | 3      | 3           | 20   | 4          |
| CRU  | 1       | 1        | 1     | 2       | 1     | 2     | 0      | 1           | 1    | 0          |
| ELE  | 0       | 0        | 0     | 0       | 0     | 0     | 0      | 0           | 0    | 0          |
| FIN  | 1       | 1        | 2     | 2       | 1     | 1     | 1      | 1           | 2    | 1          |
| FME  | 7       | 2        | 2     | 6       | 4     | 3     | 3      | 4           | 7    | 4          |
| FOO  | 13      | 14       | 9     | 10      | 13    | 9     | 15     | 26          | 5    | 19         |
| GAS  | 0       | 0        | 0     | 0       | 0     | 0     | 0      | 0           | 0    | 0          |
| HEA  | 1       | 1        | 1     | 1       | 1     | 1     | 1      | 0           | 1    | 0          |
| HOU  | 2       | 3        | 3     | 3       | 3     | 3     | 2      | 1           | 3    | 2          |
| MWO  | 25      | 28       | 23    | 13      | 22    | 23    | 38     | 35          | 25   | 27         |
| NFM  | 3       | 4        | 4     | 9       | 3     | 4     | 2      | 2           | 3    | 3          |
| OIL  | 3       | 2        | 3     | 3       | 3     | 3     | 3      | 1           | 1    | 4          |
| OTH  | 1       | 1        | 1     | 2       | 1     | 2     | 1      | 1           | 2    | 1          |
| OTI  | 1       | 1        | 1     | 1       | 1     | 1     | 0      | 0           | 1    | 0          |
| PST  | 0       | 0        | 0     | 0       | 0     | 0     | 0      | 0           | 0    | 0          |
| RLW  | 0       | 0        | 0     | 0       | 0     | 0     | 0      | 0           | 0    | 0          |
| SCI  | 0       | 0        | 0     | 0       | 0     | 0     | 0      | 0           | 0    | 0          |
| TMS  | 1       | 1        | 1     | 1       | 1     | 1     | 1      | 0           | 0    | 1          |
| TPP  | 2       | 1        | 3     | 1       | 3     | 1     | 4      | 5           | 0    | 7          |
| TRD  | 1       | 1        | 1     | 1       | 1     | 0     | 0      | 0           | 0    | 2          |
| TRK  | 0       | 0        | 0     | 0       | 0     | 0     | 0      | 0           | 0    | 1          |
| TRO  | 0       | 0        | 0     | 0       | 0     | 0     | 0      | 0           | 0    | 0          |
| CLI  | 17      | 20       | 22    | 23      | 21    | 21    | 16     | 9           | 15   | 13         |
| Total| 142     | 52       | 35    | 142     | 140   | 268   | 528    | 140         | 81   | 41         |

See Tables 1 and 2 for sector and region definitions.

Source: Roskomstat unpublished surveys and authors' calculations.
Table 11. Sector Import Intensities by Regional Market: Regional Imports of the Sector as a Percent of Regional Consumption of the Product

| Good | Central | Far East | North | Siberia | South | Urals | Moscow | St. Petersb. | Tumen | North-west |
|------|---------|----------|-------|---------|-------|-------|--------|-------------|-------|-----------|
| AGR  | 4       | 4        | 4     | 4       | 4     | 4     | 4      | 4           | 4     | 4         |
| AIR  | 3       | 3        | 3     | 3       | 3     | 3     | 3      | 3           | 3     | 3         |
| CHM  | 35      | 36       | 30    | 47      | 29    | 33    | 74     | 58          | 19    | 57        |
| CNM  | 13      | 16       | 13    | 18      | 10    | 11    | 29     | 25          | 8     | 20        |
| COL  | 7       | 7        | 7     | 7       | 7     | 7     | 7      | 7           | 7     | 7         |
| CON  | 8       | 8        | 8     | 8       | 8     | 8     | 8      | 8           | 8     | 8         |
| CRU  | 5       | 5        | 5     | 5       | 5     | 5     | 5      | 5           | 5     | 5         |
| ELE  | 1       | 1        | 1     | 1       | 1     | 1     | 1      | 1           | 1     | 1         |
| FIN  | 1       | 1        | 1     | 1       | 1     | 1     | 1      | 1           | 1     | 1         |
| FME  | 32      | 17       | 19    | 14      | 36    | 17    | 38     | 37          | 25    | 75        |
| FOO  | 25      | 23       | 13    | 15      | 20    | 15    | 31     | 94          | 10    | 50        |
| GAS  | 2       | 2        | 2     | 2       | 2     | 2     | 2      | 2           | 2     | 2         |
| HEA  | 1       | 1        | 1     | 1       | 1     | 1     | 1      | 1           | 1     | 1         |
| HOU  | 8       | 8        | 8     | 8       | 8     | 8     | 8      | 8           | 8     | 8         |
| MWO  | 36      | 37       | 24    | 15      | 27    | 26    | 98     | 100         | 16    | 53        |
| NFM  | 16      | 40       | 41    | 96      | 35    | 23    | 39     | 41          | 23    | 25        |
| OIL  | 8       | 8        | 8     | 8       | 8     | 8     | 8      | 8           | 8     | 8         |
| OTH  | 19      | 19       | 19    | 19      | 19    | 19    | 19     | 19          | 19    | 19        |
| OTI  | 7       | 6        | 6     | 6       | 6     | 6     | 7      | 7           | 6     | 6         |
| PST  | 2       | 2        | 2     | 2       | 2     | 2     | 2      | 2           | 2     | 2         |
| RLW  | 0       | 0        | 0     | 0       | 0     | 0     | 0      | 0           | 0     | 1         |
| SCI  | 0       | 0        | 0     | 0       | 0     | 0     | 0      | 0           | 0     | 0         |
| TMS  | 6       | 6        | 6     | 6       | 6     | 6     | 6      | 6           | 6     | 6         |
| TPP  | 13      | 11       | 28    | 4       | 19    | 5     | 60     | 83          | 1     | 78        |
| TRD  | 0       | 0        | 0     | 0       | 0     | 0     | 0      | 0           | 0     | 0         |
| TRK  | 2       | 2        | 2     | 2       | 2     | 2     | 2      | 2           | 2     | 2         |
| TRO  | 1       | 1        | 1     | 1       | 1     | 1     | 1      | 1           | 1     | 1         |
| CLI  | 73      | 73       | 73    | 73      | 73    | 73    | 73     | 73          | 73    | 73        |
| Total| 142     | 52       | 35    | 142     | 140   | 268   | 528    | 140         | 81    | 41        |

See Tables 1 and 2 for sector and region definitions.

Source: Roskomstat unpublished surveys and authors' calculations.
|                                      | Tariff rates | Estimated change in world market price | Equivalent % barriers to FDI |
|--------------------------------------|--------------|----------------------------------------|-----------------------------|
|                                      | 2011-pre WTO accession | 2020-final commitments | Export tax rates |
| Electric industry                    | 0.0          | 0.0                                    | 0.0                        |
| Oil extraction                       | 1.7          | 1                                      | 7.9                        |
| Oil processing                       | 5.1          | 4.9                                    | 4.6                        |
| Gas                                  | 4.7          | 5                                      | 18.8                       |
| Coalmining                           | 4.4          | 4.4                                    | 0.0                        |
| Ferrous metallurgy                   | 8.6          | 5.9                                    | 0.4                        |
| Non-ferrous metallurgy               | 10           | 7.4                                    | 5.3                        |
| Chemical & oil-chemical industry     | 7.4          | 5.2                                    | 1.6                        |
| Mechanical engineering & metal-working| 8.9         | 5.7                                    | 0.0                        |
| Timber & woodworking & pulp & paper industry | 14.3    | 8.2                                    | 6.9                        |
| Construction materials industry      | 12.7         | 9.9                                    | 1.6                        |
| Textiles and Apparel                 | 12.3         | 8.2                                    | 4.1                        |
| Food industry                        | 18.2         | 13.6                                   | 3.1                        |
| Other industries                     | 10.4         | 7.4                                    | 0.0                        |
| Agriculture & forestry               | 7.7          | 5.7                                    | 0.6                        |
| Other goods-producing sectors        | 14.2         | 10.7                                   | 0.0                        |
| Telecommunications                   |              |                                        | 33.0                       |
| Science & science servicing (market) |              |                                        | 33.0                       |
| Financial services                   |              |                                        | 36.0                       |
| Railway transportation               |              |                                        | 33.0                       |
| Truck transportation                 |              |                                        | 33.0                       |
| Pipelines transportation             |              |                                        | 33.0                       |
| Maritime transportation              |              |                                        | 95.0                       |
| Air transportation                   |              |                                        | 90.0                       |
| Other transportation                 |              |                                        | 33.0                       |

Source: Shepotylo and Tarr (2014) for tariff rates; Kimura et al. (2004a,b,c) for barriers to FDI; Roskomstat for export tax rates; authors’ estimates for change in world market prices.
### Table 12b. Shares of Business Services Sectors in the Regions of Russia Captured by Multinational Firms (ad-valorem in %) -- by sector

| Region       | Maritime | Rail | Truck | Pipeline | Air  | Other Transp. | Telecom | Science | Financial |
|--------------|----------|------|-------|----------|------|---------------|---------|---------|-----------|
| Moscow       | 0.47     | 0.02 | 0.03  | 0.06     | 0.11 | 0.02          | 0.08    | 0.07    | 0.13      |
| St. Petersburg| 0.70     | 0.06 | 0.10  | 0.06     | 0.50 | 0.08          | 0.30    | 0.20    | 0.18      |
| Tumen        | 0.29     | 0.04 | 0.05  | 0.01     | 0.46 | 0.04          | 0.20    | 0.12    | 0.08      |
| Northwest    | 0.70     | 0.06 | 0.10  | 0.06     | 0.50 | 0.08          | 0.30    | 0.20    | 0.20      |
| North        | 0.70     | 0.06 | 0.10  | 0.06     | 0.50 | 0.08          | 0.30    | 0.20    | 0.20      |
| Central      | 0.41     | 0.03 | 0.07  | 0.05     | 0.35 | 0.05          | 0.20    | 0.09    | 0.09      |
| South        | 0.46     | 0.04 | 0.06  | 0.05     | 0.30 | 0.05          | 0.19    | 0.10    | 0.09      |
| Urals        | 0.15     | 0.02 | 0.03  | 0.02     | 0.16 | 0.03          | 0.09    | 0.07    | 0.04      |
| Siberia      | 0.28     | 0.02 | 0.05  | 0.03     | 0.26 | 0.04          | 0.15    | 0.09    | 0.07      |
| Far East     | 0.70     | 0.06 | 0.10  | 0.06     | 0.50 | 0.08          | 0.30    | 0.20    | 0.20      |
| National average | 0.35 | 0.03 | 0.05  | 0.03     | 0.25 | 0.04          | 0.15    | 0.10    | 0.10      |
Table 12c. Base-Year Pollution Intensities by Sector for non-CO2 Pollutants (in grams per ruble)

| sector | Sulphur Dioxide | Hydro-carbons | Carbon Monoxide | Nitrogen Oxide | Particulate Matter | Organic Components |
|--------|-----------------|---------------|-----------------|----------------|--------------------|--------------------|
| NFM    | 4.3             | 0.0           | 1.4             | 0.2            | 0.5                | 0.0                |
| ELE    | 2.8             | 0.0           | 0.4             | 1.8            | 2.3                | 0.0                |
| FME industry average | 1.9 | 0.0 | 1.1 | 0.1 | 0.3 | 0.0 |
| OIL    | 0.3             | 0.1           | 0.2             | 0.2            | 0.7                | 1.2                |
| CRU    | 0.2             | 1.4           | 3.8             | 0.2            | 0.3                | 0.2                |
| CHM    | 0.2             | 0.1           | 0.5             | 0.2            | 0.3                | 0.2                |
| CNM    | 0.1             | 0.0           | 0.6             | 0.3            | 1.0                | 0.0                |
| CLI    | 0.1             | 0.0           | 0.2             | 0.1            | 0.2                | 0.0                |
| HOU    | 0.1             | 0.0           | 0.1             | 0.0            | 0.0                | 0.0                |
| COL    | 0.1             | 3.7           | 0.1             | 0.1            | 0.3                | 0.0                |
| MAR    | 0.1             | 1.5           | 0.3             | 0.2            | 0.2                | 0.1                |
| RLW    | 0.1             | 1.3           | 0.3             | 0.1            | 0.2                | 0.1                |
| TRK    | 0.1             | 1.2           | 0.3             | 0.1            | 0.2                | 0.1                |
| AIR    | 0.1             | 1.1           | 0.2             | 0.1            | 0.2                | 0.1                |
| TRO    | 0.1             | 1.2           | 0.3             | 0.1            | 0.2                | 0.1                |
| PIP    | 0.1             | 1.5           | 0.3             | 0.2            | 0.2                | 0.1                |
| GAS    | 0.0             | 0.2           | 0.3             | 0.0            | 0.0                | 0.1                |
| FOO    | 0.0             | 0.0           | 0.1             | 0.0            | 0.1                | 0.0                |
| MWO    | 0.0             | 0.0           | 0.2             | 0.1            | 0.2                | 0.0                |
| TPP    | 0.0             | 0.0           | 0.1             | 0.0            | 0.1                | 0.0                |
| AGR    | 0.0             | 0.0           | 0.1             | 0.0            | 0.1                | 0.0                |
| OTH    | 0.0             | 0.0           | 0.0             | 0.0            | 0.0                | 0.0                |
| OTI    | 0.0             | 0.0           | 0.0             | 0.0            | 0.0                | 0.0                |

Source: Authors’ calculations based on the SUST_RUS database. See the appendix for details.
Table 13. Impact of WTO Accession on Regional Markets, including decomposition of CO2 emissions (Results are Percentage Change from Base Year)

|                        | Overall average | Moscow | St. Peters. | Tumen | North-west | North | Central | South | Urals | Siberia | East |
|------------------------|-----------------|--------|-------------|-------|------------|-------|---------|-------|-------|---------|------|
| Aggregate welfare      |                 |        |             |       |            |       |         |       |       |         |      |
| Welfare (EV as % of consumption) | 8.6  7.7      | 11.5  13.7 | 12.0  10.7  | 8.8  9.2  7.1  8.3  10.7 |
| Welfare (EV as % of GDP)   | 4.0  4.2      | 5.2   | 2.9        | 5.6  4.4  4.1  4.4  3.2  3.9  4.8 |
| Carbon Dioxide Emissions and Decomposition |         |        |             |       |            |       |         |       |       |         |      |
| CO2 price (ruble per ton of CO2)   | 0.0  0.0      | 0.0 | 0.0       | 0.0  0.0  0.0  0.0  0.0  0.0  0.0 |
| CO2 emissions, decomposed into: |           |        |             |       |            |       |         |       |       |         |      |
| Output effect (% of CO2) | 4.9  4.9 | 7.0  5.1 | 7.4  6.5  | 5.0  5.4  3.7  4.8  6.7 |
| Composition effect (% of CO2) | 1.0  -0.9  | 4.4  0.1 | 2.7  0.4  | 2.6  0.7  1.0  1.3  0.4 |
| Technique effect (% of CO2)  | -1.6  -1.5  | -2.7 | -1.4       | -2.0  -1.6  -1.5  -1.6  -1.3  -1.5  -2.1 |
| Non-Carbon Dioxide Emissions |         |        |             |       |            |       |         |       |       |         |      |
| Sulphur Dioxide         | 6.2  4.5 | 28.8  3.5 | 10.1  7.7  | 11.2 10.6  9.2  4.1  4.7 |
| Nitrogen Oxide          | 2.8  1.7 | 4.6  2.8 | 6.8  3.7 | 3.0  3.6  2.4  2.8  2.9 |
| Hydrocarbons            | 1.7  -2.0 | 4.5  1.9 | 4.8  4.1 | 2.6  1.8  -0.1  2.7  8.6 |
| Particulate Matter      | 3.0  1.5 | 5.9  2.8 | 5.0  4.0 | 2.6  2.9  3.1  2.9  2.5 |
| Volatile Organic Components | 2.7  3.8 | 1.8  2.8 | 13.3 2.9 | 6.2  3.5  1.8  3.0  4.5 |
| Carbon Monoxide         | 4.5  9.9 | 13.6 2.7 | 9.8  4.8 | 17.0 5.8  4.4  3.4  3.5 |
| Aggregate trade         |               |        |             |       |            |       |         |       |       |         |      |
| Regional terms of trade (% change) | 2.9  16.3  | 17.9  16.2 | 17.8 16.9  16.3 15.8 15.2 15.1 17.0 |
| Regional exports (% change) | 3.0  3.3  | 3.8  2.9 | 3.6  3.7 | 3.1  2.7  2.6  2.8  2.9 |
| Real exchange rate (% change) | 1.8  1.9 | 2.7  2.2 | 2.2  2.2 | 2.1  2.1  1.2  1.4  2.5 |
| International exports (% change) | 8.1  11.1 | 17.6 2.6 | 17.9 7.5 | 19.5 8.6  8.7  7.4  9.5 |
| Return to primary factors (% change) |             |        |             |       |            |       |         |       |       |         |      |
| Unskilled labor         | 3.7  3.9 | 6.0  3.5 | 5.6  5.0 | 3.7  4.5  2.3  3.6  5.6 |
| Skilled labor           | 3.7  2.5 | 6.2  4.8 | 6.1  5.5 | 4.2  4.3  2.2  3.8  6.2 |
| National capital        | 3.8  3.9 | 4.6  4.1 | 4.2  4.2 | 4.0  4.0  3.1  3.3  4.4 |
| Regional mobile capital | 5.8  6.0 | 9.5  4.3 | 9.5  7.1 | 6.5  6.0  4.9  5.5  7.5 |
| Crude oil resources     | 4.4  5.1 | 3.7  4.9 | 4.6  4.6  2.5  2.7  5.5 |
| Natural gas resources   | 7.0  8.1 | -10.1 -3.3 | -2.0 | -5.2 -6.1 -3.6 |
| Coal resources          | 9.7  12.4 | 10.9 | 11.2 8.8 | 9.0 12.5 |
| Specific capital in domestic firms | -29.9 -22.5 | -47.7 -20.8 | -24.5 -16.9 | -24.1 -16.3 -19.3 -26.3 |
| Specific capital in multinational firms | 60.2 47.7  | 215.9 79.1 | 140.9 114.3 | 125.9 138.8 159.5 113.0 |
| Factor adjustments      |               |        |             |       |            |       |         |       |       |         |      |
| Unskilled labor (% changing sectors) | 2.0  1.9  | 3.1  1.9 | 3.8  2.0 | 2.1  1.5  2.0  1.9  2.3 |
| Skilled labor (% changing sector) | 2.6  2.6  | 3.9  2.7 | 4.1  2.9 | 2.7  2.1  2.3  2.5  3.3 |

Source: Authors' estimates
Table 14. Impact of WTO Accession on Output by Sector and Regional Market.
(Results are Percentage Change from Base Year)

| Good | Central | Siberia | South | North | Urals | Far East | Moscow | St. Pete. | Tumen | Northwest |
|------|---------|---------|-------|-------|-------|----------|--------|-----------|-------|-----------|
| FME  | 26.6    | 13.1    | 37.4  | 24.7  | 13.7  | 23.3     | 38.5   | 293.0     | 12.0  |           |
| CHM  | 8.6     | 20.9    | 11.2  | 3.3   | 12.4  | 5.2      | 6.8    | 47.6      | 25.5  |           |
| TMS  | 13.7    | 8.6     | 13.2  | 20.3  | 0.4   | 21.5     | 0.7    | 21.3      | 10.3  | 21.9      |
| TRK  | 10.1    | 6.8     | 8.8   | 11.5  | 4.3   | 13.6     | 5.1    | 14.5      | 5.4   | 15.2      |
| COL  | 7.8     | 6.4     | 8.0   | 8.8   | 6.7   | 8.6      |        |           |       |           |
| TRD  | 6.7     | 4.7     | 4.9   | 5.3   | 4.2   | 6.1      | 5.0    | 7.8       | 3.0   | 9.3       |
| NFM  | 5.8     | 3.6     | 20.2  | 8.1   | 14.5  | 4.6      | 22.6   | -6.6      | -22.3 |           |
| PST  | 3.9     | 3.1     | 4.0   | 4.5   | 2.4   | 4.9      | 2.8    | 4.2       | 4.2   | 4.7       |
| OIL  | 4.9     | 0.6     | 5.4   | 5.1   | 0.4   | 6.2      | 1.8    | 1.3       | 8.7   |           |
| ELE  | 3.3     | 3.0     | 3.5   | 3.4   | 2.7   | 3.2      | 2.0    | 4.1       | 3.6   | 5.7       |
| HOU  | 2.1     | 2.2     | 2.8   | 3.1   | 1.5   | 3.1      | 2.2    | 2.6       | 3.2   | 2.9       |
| RLW  | 3.7     | 0.8     | 1.9   | 1.9   | 1.4   | 2.1      | 0.4    | 6.1       | 0.5   | 4.3       |
| CRU  | 1.5     | 2.5     | 2.8   | 1.5   | 3.0   |          |        |           | 2.7   | 1.9       |
| SCI  | 1.7     | 2.0     | 0.5   | 1.8   | 0.1   | 4.5      | 1.1    | 7.5       | -4.3  | 6.8       |
| HEA  | 1.4     | 1.3     | 1.7   | 1.5   | 1.2   | 1.7      | 1.5    | 1.7       | 1.2   | 1.7       |
| CLI  | 1.0     | -0.4    | 1.1   | 1.2   | 0.3   | 1.2      | 0.0    | -1.9      | 6.0   | -2.9      |
| MWD  | -4.1    | 0.9     | 1.3   | -0.3  | -4.3  | 2.3      | 8.4    | 2.1       | 2.8   | -5.4      |
| CON  | 0.4     | -0.9    | 0.8   | -0.2  | 0.3   | -0.4     | 1.8    | -1.8      | 3.4   | -3.6      |
| OTI  | -0.9    | -2.6    | 0.1   | -0.1  | -1.2  | -1.4     | 2.6    | 0.5       | 2.6   | -2.0      |
| AIR  | -0.8    | -3.7    | -0.9  | 2.8   | -3.1  | 2.7      | -1.6   | -0.3      | 2.9   | -0.6      |
| TPP  | -6.2    | -5.0    | -9.4  | 0.6   | -1.9  | 17.1     | -11.3  | -7.2      | 16.3  | -9.2      |
| AGR  | -1.4    | -1.1    | -0.2  | -1.7  | 0.5   | -2.5     | -0.8   | -6.7      | 6.4   | -8.6      |
| GAS  | -3.0    | -1.3    | -1.8  | -2.5  | -2.0  |          |        |           | 2.9   | -5.0      |
| PIP  | -1.3    | -2.8    | -2.1  | -3.3  | -1.9  | -2.3     | -3.7   | -3.3      | 0.1   | 0.5       |
| CNM  | -2.5    | -4.8    | -1.2  | -1.3  | -2.7  | -1.9     | -4.5   | -5.9      | 6.2   | -7.8      |
| OTH  | -2.0    | -6.5    | -3.0  | -4.9  | -1.2  | -6.5     | 0.1    | -8.7      | 3.7   | -13.0     |
| FIN  | -5.5    | -6.1    | -5.4  | -5.8  | -6.3  | -5.3     | -5.6   | -4.9      | -7.5  | -4.1      |
| TRO  | -4.3    | -9.5    | -6.3  | -1.3  | -15.1 | 0.6      | -18.1  | 1.0       | -13.2 | 1.6       |
| FOO  | -8.4    | -6.8    | -6.1  | -3.8  | -6.4  | -7.1     | -11.0  | -8.4      | 4.5   | -11.6     |
| MAR  | -6.4    | -11.4   | -8.0  | -4.9  | -6.9  | -4.3     | -9.2   | -5.8      | -6.1  | -7.6      |

See table 1 for sector codes.

Source: Author’s estimates.
Table 15: Impact of “Cap and Trade” Market Based Emission Control System to Reduce Carbon Emissions by 20 Percent on Regional Markets, with decomposition of carbon emission effects. (Results are Percentage Change from Base Year.)

| Overall average | Moscow | St. Petersburg | Tumen | North-West | North-East | South | Ural | Siberia | East |
|-----------------|--------|---------------|-------|------------|------------|-------|------|---------|-------|
| Aggregate welfare |       |               |       |            |            |       |      |         |       |
| Welfare (EV as % of consumption) | -1.1 | -1.8 | -1.4 | -0.2 | 0.5 | -1.2 | -0.1 | -1.3 | -0.5 | -0.6 | -0.6 | -1.7 |
| Welfare (EV as % of GDP) | -0.5 | -1.0 | -0.6 | 0.0 | 0.0 | -0.5 | -0.1 | -0.6 | -0.2 | -0.3 | -0.8 |

Carbon Dioxide Emissions and Decomposition

|                      | Overall average | Moscow | St. Petersburg | Tumen | North-West | North-East | South | Ural | Siberia | East |
|----------------------|-----------------|--------|---------------|-------|------------|------------|-------|------|---------|-------|
| CO2 price (ruble per ton of CO2) | 96.0 | 96.0 | 96.0 | 96.0 | 96.0 | 96.0 | 96.0 | 96.0 | 96.0 | 96.0 |
| CO2 emissions, decomposed into: |       |       |       |       |       |       |       |       |       |       |
| Output effect (% of CO2) | -20.0 | -18.3 | -19.9 | -21.9 | -21.7 | -19.8 | -20.3 | -18.3 | -20.5 | -20.8 |
| Composition effect (% of CO2) | -3.1 | -0.1 | -8.9 | -4.3 | -2.5 | -2.4 | -1.2 | -2.5 | -4.7 | -2.3 |
| Technique effect (% of CO2) | -16.3 | -17.5 | -17.5 | -10.5 | -17.3 | -15.6 | -17.6 | -16.3 | -17.6 | -16.0 |

Non-Carbon Dioxide Emissions

|                      | Overall average | Moscow | St. Petersburg | Tumen | North-West | North-East | South | Ural | Siberia | East |
|----------------------|-----------------|--------|---------------|-------|------------|------------|-------|------|---------|-------|
| Sulphur Dioxide | -0.1 | -2.7 | -0.2 | -5.2 | -12.9 | -0.2 | -9.1 | -5.3 | -3.6 | 2.1 | 0.7 |
| Nitrogen Oxide | -3.3 | -3.9 | -2.9 | -3.6 | -5.0 | -3.1 | -3.9 | -4.1 | -3.3 | -2.3 | -3.0 |
| Hydrocarbons | -4.2 | -2.4 | -2.4 | -2.1 | -3.2 | -5.8 | -3.5 | -2.8 | -2.1 | -10.6 | -19.1 |
| Particulate Matter | -2.9 | -4.0 | -3.6 | -2.7 | -4.4 | -2.7 | -3.8 | -4.1 | -3.5 | -1.6 | -2.2 |
| Volatile Organic Components | -1.5 | -3.8 | -1.5 | -1.6 | -0.4 | -1.2 | 1.2 | -1.4 | -1.4 | -2.9 | -0.6 |
| Carbon Monoxide | -1.7 | -1.0 | -0.9 | -1.8 | -12.8 | -0.6 | -13.0 | -2.4 | -2.3 | 1.1 | -0.1 |

Aggregate trade

|                      | Overall average | Moscow | St. Petersburg | Tumen | North-West | North-East | South | Ural | Siberia | East |
|----------------------|-----------------|--------|---------------|-------|------------|------------|-------|------|---------|-------|
| Regional terms of trade (% change) | -0.1 | 1.5 | 1.3 | 0.5 | 0.8 | 1.4 | 1.3 | 1.3 | 1.2 | 1.7 | 1.5 |
| Regional exports (% change) | -1.2 | -1.3 | -1.8 | -1.0 | -1.4 | -0.6 | -0.9 | -0.8 | -1.8 | -1.5 |
| Real exchange rate (% change) | 0.4 | 0.4 | 0.3 | -0.3 | 0.9 | 0.3 | 0.8 | 0.4 | 0.5 | 0.3 | 0.2 |
| International exports (% change) | 0.4 | 3.6 | 0.3 | 1.1 | -3.9 | 1.2 | -5.5 | 1.3 | 0.2 | -0.1 | 2.4 |

Return to primary factors (% change)

|                      | Overall average | Moscow | St. Petersburg | Tumen | North-West | North-East | South | Ural | Siberia | East |
|----------------------|-----------------|--------|---------------|-------|------------|------------|-------|------|---------|-------|
| Unskilled labor | -1.7 | -1.4 | -1.6 | -2.1 | -0.7 | -1.9 | -1.3 | -1.8 | -1.9 | -2.1 | -1.9 |
| Skilled labor | -2.6 | -1.4 | -1.6 | -4.9 | -2.1 | -3.2 | -1.9 | -2.2 | -2.1 | -4.4 | -3.4 |
| National capital | -1.7 | -1.7 | -1.9 | -2.4 | -1.3 | -1.9 | -1.4 | -1.8 | -1.6 | -1.9 | -2.0 |
| Regional mobile capital | -1.8 | -2.1 | -2.0 | -0.2 | -2.9 | -1.6 | -2.4 | -1.8 | -1.9 | -1.5 | -1.5 |
| Crude oil resources | -0.6 | -1.3 | 1.4 | 0.1 | 0.5 | 0.7 | 0.1 | 0.7 | 0.1 | -0.1 |
| Natural gas resources | -32.9 | -34.6 | -2.2 | -19.2 | -16.2 | -13.6 | -19.5 | -20.7 |
| Coal resources | -13.6 | -12.9 | -11.0 | -12.1 | -13.4 | -13.8 | -13.3 |
| Specific capital in domestic firms | -0.4 | -0.6 | -1.3 | -1.4 | -1.2 | -0.9 | -1.2 | -1.8 | -0.5 | -0.9 |
| Specific capital in multinational firms | 0.1 | 0.9 | 3.8 | 0.7 | 1.8 | 2.4 | 2.6 | 3.9 | 3.7 | 2.1 |

Factor adjustments

|                      | Overall average | Moscow | St. Petersburg | Tumen | North-West | North-East | South | Ural | Siberia | East |
|----------------------|-----------------|--------|---------------|-------|------------|------------|-------|------|---------|-------|
| Unskilled labor (% changing sectors) | 0.9 | 0.6 | 0.6 | 1.2 | 2.0 | 0.8 | 1.0 | 0.5 | 0.9 | 1.3 | 1.0 |
| Skilled labor (% changing sector) | 1.5 | 0.6 | 0.8 | 2.1 | 2.5 | 1.8 | 1.3 | 0.7 | 1.2 | 3.3 | 2.2 |

Source: Authors' estimates
Table 15a. Impact of 20 Percent CO2 Reduction through Market Based Cap and Trade on Output by Sector and Regional Market. (Results are Percentage Change from Base Year)

| Good | Central | Siberia | South | North | Urals | Far East | Moscow | St. Pete. | Tumen | Northwest |
|------|---------|---------|-------|-------|-------|----------|--------|-----------|--------|-----------|
| NFM  | 18.3    | 8.1     | 15.2  | 9.2   | 19.3  | 6.9      | 26.4   | 25.6      | 202.6  | 5.6       |
| MAR  | 4.5     | 2.4     | 3.0   | 2.1   | 3.2   | 3.5      | 4.3    | 2.8       | -2.7   | 3.7       |
| OTH  | 5.0     | 3.0     | 1.9   | 1.1   | 3.0   | 1.4      | 0.7    | 0.0       | -4.4   | 6.4       |
| TPP  | -0.4    | 1.6     | -1.6  | -0.7  | -0.4  | 14.3     | -1.7   | 0.3       | -4.9   | 10.6      |
| FOO  | 3.3     | 1.0     | 2.1   | 0.3   | 1.5   | 1.2      | 2.8    | 1.1       | -3.3   | 6.0       |
| OIL  | 5.3     | 0.5     | 1.2   | 0.9   | 2.6   | 0.3      | 1.2    | 0.3       | -4.9   |           |
| PST  | 1.0     | 0.6     | 0.7   | 0.6   | 0.9   | 0.4      | 0.6    | 0.4       | 0.2    | 1.6       |
| TMS  | 0.6     | 0.4     | 0.3   | 0.2   | 0.5   | 0.0      | 0.2    | 0.0       | 0.1    | 1.0       |
| CLI  | 1.9     | 0.1     | 0.0   | -0.4  | 1.1   | -0.9     | 0.3    | 0.0       | -3.6   | 3.2       |
| AGR  | 0.0     | 0.0     | -0.4  | -0.4  | -0.4  | -0.2     | -0.4   | -0.3      | -0.1   | 0.1       |
| HEA  | -0.3    | -0.2    | -0.3  | -0.2  | -0.2  | -0.2     | -0.3   | -0.3      | -0.6   | -0.5      |
| FIN  | 0.1     | 0.0     | -0.3  | -0.6  | -1.0  | -0.6     | -1.1   | -0.6      | -4.1   | 2.6       |
| CON  | 0.9     | 0.3     | -0.6  | -1.0  | -0.6  | -1.1     | -0.2   | -1.0      | -4.1   | 2.6       |
| CRU  | -0.6    | -0.5    | -0.6  | -0.5  | -0.7  | -1.3     | -0.1   |           |        |           |
| SCI  | -1.2    | -1.0    | -1.1  | -0.9  | -1.5  | -1.7     | -0.3   | -0.8      | -2.3   | -0.5      |
| TRD  | -2.9    | -1.4    | -0.8  | -0.7  | -1.2  | -0.7     | -1.5   | -1.6      | -1.9   | -3.1      |
| TRO  | -1.5    | -2.3    | -1.6  | -1.7  | -1.7  | -1.6     | -1.7   | -1.9      | -1.9   | -1.7      |
| OLI  | 0.3     | -2.7    | -1.1  | -1.9  | -0.7  | -0.7     | -2.9   | -0.2      | -1.3   | -7.3      |
| MNO  | -0.7    | -5.7    | -1.9  | -3.6  | -2.8  | -5.4     | -5.5   | 2.8       | -1.2   | -7.1      |
| TRK  | -3.3    | -2.8    | -2.5  | -2.3  | -2.8  | -2.0     | -3.1   | -2.9      | -0.9   | -3.0      |
| HOU  | -2.1    | -2.9    | -3.1  | -3.1  | -2.6  | -3.5     | -3.4   | -2.9      | -2.7   | -1.7      |
| RLW  | -3.9    | -4.8    | -2.3  | -3.1  | -3.9  | -2.1     | -1.3   | -2.1      | -2.1   | -5.4      |
| AIR  | -1.2    | -2.6    | -3.4  | -1.7  | -1.7  | -1.6     | -3.2   | -5.0      | -6.8   | -0.4      |
| ELE  | -4.0    | -3.8    | -4.1  | -3.8  | -4.1  | -3.8     | -3.8   | -3.4      | -5.7   | -4.5      |
| CNM  | -2.3    | -6.3    | -3.5  | -5.4  | -3.7  | -6.0     | -5.9   | -5.8      | -7.5   | -1.7      |
| PIP  | -9.3    | -8.7    | -6.8  | -7.5  | -6.0  | -7.0     | -17.9  | -7.9      | -3.9   | -23.8     |
| CHM  | -6.7    | -18.1   | -10.1 | -10.5 | -11.0 | -11.3    | -9.8   | -12.6     | -23.0  | -0.6      |
| GAS  | -13.1   | -11.7   | -13.0 | -10.5 | -10.5 | -13.7    | -9.8   | -12.6     | -23.0  | -0.6      |
| COL  | -17.7   | -19.3   | -18.4 | -18.8 | -19.5 | -19.1    | -20.7  | -5.7      |        |           |
| FME  | -21.1   | -22.5   | -26.2 | -22.7 | -21.6 | -21.7    | -28.4  | -54.2     | -18.0  |           |

See table 1 for sector codes.

Source: Authors' estimates.
Table 16: Impact on the Regions of Russia of Emission Intensity Standards to Reduce Carbon Emissions by 20 Percent, with decomposition of carbon emission effects. (Results are Percentage Change from Base Year unless otherwise indicated.)

| Overall average | Moscow | St. Peters. | Tumen | North-west | North | Central | South | Urals | Siberia | Far East |
|-----------------|--------|-------------|-------|-----------|-------|---------|-------|-------|---------|---------|
| Aggregate welfare |        |             |       |           |       |         |       |       |         |         |
| Welfare (EV as % of consumption) | -1.7 | -1.5 | -1.6 | -6.9 | -1.4 | -2.0 | -1.2 | -1.6 | -1.4 | -1.6 | -1.9 |
| Welfare (EV as % of GDP) | -0.8 | -0.8 | -0.7 | -1.5 | -0.6 | -0.8 | -0.6 | -0.8 | -0.6 | -0.7 | -0.9 |
| Carbon Dioxide Emissions and Decomposition |        |             |       |           |       |         |       |       |         |         |
| CO2 price (ruble per ton of CO2) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CO2 emissions, decomposed into: | -20.0 | -19.4 | -20.1 | -24.1 | -21.0 | -18.5 | -20.6 | -19.8 | -20.4 | -17.2 | -17.7 |
| Output effect (% of CO2) | -1.8 | -1.5 | -1.5 | -4.2 | -1.7 | -1.8 | -1.5 | -1.7 | -1.6 | -1.5 | -1.6 |
| Composition effect (% of CO2) | -1.0 | 1.5 | 1.3 | -13.4 | 1.0 | -0.1 | 1.1 | 0.7 | 0.6 | -0.7 | -0.2 |
| Technique effect (% of CO2) | -17.1 | -19.4 | -19.9 | -5.6 | -20.4 | -16.7 | -20.3 | -18.8 | -19.5 | -15.1 | -15.9 |
| Non-Carbon Dioxide Emissions |        |             |       |           |       |         |       |       |         |         |
| Sulphur Dioxide | 1.0 | 4.9 | 3.8 | -0.2 | -0.6 | 1.1 | 2.6 | 2.9 | 0.5 | 0.6 | 3.1 |
| Nitrogen Oxide | 2.0 | 5.0 | 2.9 | -1.6 | 5.0 | 2.5 | 5.7 | 3.6 | 1.2 | 1.6 | 2.5 |
| Hydrocarbons | -3.6 | -5.9 | -5.6 | -2.6 | -5.3 | -4.3 | -5.4 | -4.3 | -3.1 | -4.9 | -6.2 |
| Particulate Matter | 1.1 | 4.9 | 4.1 | -1.4 | 6.8 | 2.6 | 5.5 | 4.9 | 0.8 | 0.7 | 0.8 |
| Volatile Organic Components | -1.4 | -1.3 | -1.7 | -1.6 | 0.7 | -1.0 | -0.6 | -1.6 | -1.1 | -1.0 | -0.7 |
| Carbon Monoxide | -1.2 | 1.2 | -0.6 | -1.7 | -2.9 | -0.7 | -2.1 | -1.3 | -1.4 | -0.3 | 0.2 |
| Aggregate trade |        |             |       |           |       |         |       |       |         |         |
| Regional terms of trade (% change) | -0.6 | 2.5 | 2.4 | 0.9 | 2.4 | 2.3 | 2.6 | 2.4 | 2.4 | 2.5 | 2.4 |
| Regional exports (% change) | -1.3 | -1.2 | -1.3 | -2.3 | -1.3 | -1.2 | -1.2 | -1.2 | -1.0 | -1.3 | -1.3 |
| Real exchange rate (% change) | -0.3 | -0.2 | -0.3 | -1.1 | -0.3 | -0.4 | -0.3 | -0.4 | -0.3 | -0.3 | -0.3 |
| International exports (% change) | -0.4 | -2.9 | -2.1 | 1.8 | -2.7 | -0.4 | -3.4 | -0.4 | -0.7 | -0.6 | -0.9 |
| Return to primary factors (% change) |        |             |       |           |       |         |       |       |         |         |
| Unskilled labor | 0.0 | 0.3 | 0.2 | -0.8 | 0.2 | -0.2 | 0.2 | -0.1 | -0.1 | -0.1 | -0.1 |
| Skilled labor | 0.3 | 1.2 | 0.9 | -2.7 | 1.0 | 0.0 | 1.0 | 0.7 | 0.7 | -0.2 | 0.0 |
| National capital | -1.1 | -1.0 | -1.0 | -1.8 | -1.0 | -1.1 | -1.0 | -1.1 | -1.1 | -1.1 | -1.0 |
| Regional mobile capital | -0.7 | -1.0 | -1.0 | 0.7 | -1.1 | -0.8 | -0.9 | -0.7 | -0.7 | -0.7 | -0.9 |
| Crude oil resources | -2.4 | -2.9 | -1.8 | -1.3 | -1.5 | -1.4 | -1.2 | -1.5 | -0.9 | -0.8 | -0.8 |
| Natural gas resources | -42.7 | -44.3 | -25.2 | -28.9 | -28.0 | -27.6 | -27.0 | -24.9 | -7.9 | -7.7 | -7.7 |
| Coal resources | -7.9 | -8.1 | -8.3 | -8.6 | -8.8 | -7.9 | -7.9 | -7.7 | -7.9 | -7.7 | -7.7 |
| Specific capital in domestic firms | -0.9 | -1.0 | -1.8 | -1.4 | -1.3 | -1.2 | -1.5 | -1.5 | -0.9 | -0.8 | -0.8 |
| Specific capital in multinational firms | -0.8 | -0.9 | -2.2 | -1.1 | -1.1 | -0.7 | -0.5 | -0.4 | -0.7 | -1.0 | -1.0 |
| Factor adjustments |        |             |       |           |       |         |       |       |         |         |
| Unskilled labor (% changing sectors) | 0.7 | 0.7 | 0.7 | 1.1 | 0.8 | 0.6 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| Skilled labor (% changing sector) | 1.1 | 0.9 | 0.9 | 2.1 | 1.0 | 1.0 | 0.9 | 0.9 | 0.9 | 1.2 | 1.2 |

Source: Authors' estimates
Table 16a. Impact of 20 Percent CO2 Reduction through Emissions Intensity Standards on Output by Sector and Regional Market. (Results are Percentage Change from Base Year)

|        | Good | Central | Siberia | South | North | Urals | Far East | Moscow | St. Pete. | Tumen | Northwest |
|--------|------|---------|---------|-------|-------|-------|----------|--------|-----------|-------|-----------|
| ELE    | 6.3  | 4.8     | 5.5     | 4.9   | 5.3   | 4.9   | 5.3      | 5.3   | 5.6       | -0.1  | 7.2       |
| NFM    | 0.9  | 0.6     | -1.7    | 0.7   | -0.7  | 2.6   | 4.2      | 4.4   | 11.0      |       |           |
| SCI    | 0.1  | 0.0     | -0.1    | 0.1   | -0.2  | 0.3   | 0.3      | 0.2   | -1.7      | 0.4   |           |
| FIN    | -0.1 | -0.1    | -0.2    | -0.2  | -0.1  | -0.2  | -0.2     | -0.2  | -0.7      | -0.1  |           |
| HEA    | -0.3 | -0.4    | -0.5    | -0.4  | -0.4  | -0.5  | -0.5     | -0.4  | -0.8      | -0.4  |           |
| CON    | -0.5 | -0.1    | -0.8    | -0.1  | -0.7  | 0.5   | -0.3     | -0.3  | -3.2      | -0.3  |           |
| CRU    | -0.5 | -0.8    | -0.6    | -0.7  | -0.4  |       |          | -1.2  | -1.0      |       |           |
| CNM    | -0.4 | -0.4    | -0.8    | -0.4  | -0.8  | 0.1   | -0.2     | 0.0   | -5.5      | -0.2  |           |
| TMS    | -1.1 | -0.9    | -1.1    | -0.9  | -1.0  | -0.9  | -1.1     | -1.0  | -1.4      | -1.2  |           |
| CHM    | 0.3  | 0.7     | -1.0    | -0.6  | -1.1  | 0.9   | 0.7      | 1.3   | -15.7     | 2.5   |           |
| HOU    | -0.7 | -0.9    | -1.0    | -1.2  | -0.9  | -1.0  | -0.9     | -0.8  | -3.7      | -0.9  |           |
| MMO    | -1.0 | -2.1    | -2.1    | -0.8  | -1.9  | 0.0   | -0.7     | -0.7  | -5.6      | -0.4  |           |
| AGR    | -0.7 | -1.3    | -1.7    | -1.2  | -1.5  | -0.7  | -0.5     | -0.6  | -7.3      | -0.2  |           |
| OTI    | -0.9 | -1.1    | -1.4    | -1.1  | -1.3  | -0.3  | -0.8     | -0.8  | -7.7      | -1.1  |           |
| PST    | -1.8 | -1.6    | -1.6    | -1.6  | -1.6  | -1.5  | -1.5     | -1.7  | -2.0      | -2.0  |           |
| TRO    | -1.6 | -1.5    | -1.7    | -1.7  | -1.5  | -1.7  | -1.7     | -1.6  | -2.2      | -1.7  |           |
| RLW    | -1.9 | -1.4    | -2.0    | -1.8  | -1.9  | -1.4  | -1.5     | -1.5  | -2.2      | -2.2  |           |
| FOO    | -1.0 | -1.4    | -1.9    | -1.7  | -1.4  | -1.1  | -0.9     | -1.0  | -7.7      | -1.1  |           |
| OIL    | -1.1 | -0.5    | -3.0    | -1.3  | -0.7  | -0.2  | -2.9     | -1.7  | -7.2      |       |           |
| OTH    | -2.4 | -1.1    | -2.7    | -0.6  | -2.4  | -0.5  | -2.3     | -2.1  | -5.8      | -1.9  |           |
| TRD    | -3.5 | -2.2    | -2.0    | -1.8  | -2.1  | -2.3  | -2.7     | -2.8  | 0.5       | -3.7  |           |
| CLI    | -1.9 | -1.9    | -2.3    | -2.2  | -2.1  | -2.0  | -1.7     | -2.0  | -6.8      | -1.9  |           |
| TPP    | -1.5 | -3.8    | -2.4    | -2.7  | -2.0  | -6.9  | -1.4     | -2.1  | -5.2      | -2.0  |           |
| TRK    | -3.5 | -3.0    | -2.9    | -3.0  | -3.0  | -3.3  | -3.5     | -3.4  | -1.2      | -3.8  |           |
| FME    | -4.3 | -3.5    | -6.6    | -3.6  | -4.9  | -1.1  | -4.1     | -10.4 | -3.5      |       |           |
| MAR    | -5.8 | -4.4    | -6.7    | -6.5  | -5.0  | -5.6  | -5.5     | -8.2  | -7.1      |       |           |
| COL    | -7.0 | -6.3    | -7.2    | -6.5  | -7.3  | -6.2  |          |       |           |       |           |
| PIP    | -12.7| -9.3    | -8.2    | -7.8  | -7.3  | -7.7  | -19.8    | -9.5  | -3.2      | -26.2 |           |
| GAS    | -11.1| -11.7   | -11.0   | -11.5 | -10.0 | -15.3 | -15.2    | -21.0 | -10.3     |       |           |
| AIR    | -17.9| -16.4   | -17.5   | -20.7 | -15.3 | -20.7 | -15.2    | -21.0 | -20.8     | -20.8 |           |

See table 1 for sector codes.
Source: Authors’ estimates.
Table 17: Impact on the Regions of Russia of Energy Efficiency Standards to Reduce Carbon Emissions by 20 Percent, with decomposition of carbon emission effects. (Results are Percentage Change from Base Year unless otherwise indicated.)

|                         | Overall average | Moscow | St. Peters. | Tumen | North-west | North | Central | South | Urals | Siberia | East |
|-------------------------|-----------------|--------|-------------|-------|-----------|-------|---------|-------|-------|---------|------|
| Aggregate welfare       |                 |        |             |       |           |       |         |       |       |         |      |
| Welfare (EV as % of consumption) | -5.9     | -5.5   | -5.9       | -13.2 | -5.5      | -6.8  | -5.2    | -5.9  | -5.6  | -5.5    | -6.5 |
| Welfare (EV as % of GDP) | -2.7           | -3.0   | -2.7       | -2.8  | -2.5      | -2.8  | -2.4    | -2.8  | -2.5  | -2.6    | -2.9 |
| Carbon Dioxide Emissions and Decomposition |                 |        |             |       |           |       |         |       |       |         |      |
| CO2 price (ruble per ton of CO2) | 0.0        | 0.0    | 0.0        | 0.0   | 0.0       | 0.0   | 0.0     | 0.0   | 0.0   | 0.0     | 0.0  |
| CO2 emissions, decomposed into: |             |        |             |       |           |       |         |       |       |         |      |
| Output effect (% of CO2)  | -6.1          | -5.5   | -6.2       | -7.4  | -6.1      | -6.5  | -6.1    | -6.1  | -6.4  | -5.8    | -6.1 |
| Composition effect (% of CO2) | -6.0         | -5.2   | -5.8       | -10.9 | -5.1      | -4.7  | -5.4    | -5.3  | -5.9  | -4.8    | -3.8 |
| Technique effect (% of CO2) | -8.2         | -10.1  | -10.3      | -1.9  | -7.1      | -7.5  | -9.6    | -9.9  | -9.1  | -6.9    | -7.9 |
| Non-Carbon Dioxide Emissions |                 |        |             |       |           |       |         |       |       |         |      |
| Sulphur Dioxide          | -6.9          | -18.1  | -11.1      | -17.3 | -11.5     | -6.9  | -18.7   | -18.3 | -10.7 | -3.8    | -5.6 |
| Nitrogen Oxide           | -16.1         | -20.5  | -17.8      | -10.9 | -21.6     | -17.0 | -23.7   | -19.6 | -15.1 | -13.6   | -15.6|
| Hydrocarbons             | -6.5          | -10.4  | -11.4      | -4.5  | -9.5      | -6.3  | -9.2    | -7.1  | -7.7  | -6.6    | -2.4 |
| Particulate Matter       | -12.5         | -20.2  | -19.1      | -7.6  | -24.4     | -14.8 | -22.9   | -21.5 | -13.0 | -9.8    | -10.2|
| Volatile Organic Components | -8.6         | -17.2  | -11.8      | -3.9  | -9.2      | -5.1  | -16.5   | -7.1  | -8.1  | -13.2   | -10.9|
| Carbon Monoxide          | -4.7          | -7.4   | -6.3       | -4.0  | -5.9      | -4.0  | -9.8    | -6.0  | -5.6  | -3.2    | -3.5 |
| Aggregate trade          |                 |        |             |       |           |       |         |       |       |         |      |
| Regional terms of trade (% change) | -1.5        | 19.9   | 19.3       | 16.5  | 19.4      | 18.8  | 19.5    | 19.7  | 19.4  | 19.6    | 19.4 |
| Regional exports (% change) | -7.5         | -6.3   | -8.5       | -7.3  | -7.3      | -7.6  | -7.9    | -6.5  | -8.3  | -8.2    | -8.0 |
| Real exchange rate (% change) | -0.2        | -0.1   | -0.3       | -1.4  | -0.1      | -0.5  | -0.1    | -0.3  | -0.2  | -0.3    | -0.3 |
| International exports (% change) | -1.2        | -6.2   | -4.6       | 3.3   | -8.8      | -0.9  | -9.1    | 0.3   | -0.9  | -3.2    | -2.0 |
| Return to primary factors (% change) |             |        |             |       |           |       |         |       |       |         |      |
| Unskilled labor          | 0.0           | 0.7    | 0.5        | -1.1  | 0.2       | -0.2  | 0.5     | -0.3  | 0.0   | -0.4    | 0.0  |
| Skilled labor            | -0.4          | 0.9    | 0.5        | -4.6  | 0.5       | -0.7  | 0.2     | -0.2  | -0.4  | -0.4    | -0.2 |
| National capital         | -3.4          | -3.2   | -3.5       | -4.5  | -3.3      | -3.6  | -3.2    | -3.5  | -3.3  | -3.4    | -3.4 |
| Regional mobile capital  | -3.1          | -3.8   | -3.8       | -0.8  | -3.9      | -3.2  | -3.7    | -3.1  | -3.2  | -3.1    | -3.5 |
| Crude oil resources      | -6.4          | -7.4   | -4.7       | -5.1  | -5.0      | -4.6  | -5.4    | -5.0  | -4.6  | -5.4    | -4.9 |
| Natural gas resources    | -32.0         | -34.8  | 3.5        | -6.6  | -5.2      | -2.3  | -5.7    | -1.1  | -2.8  | -3.3    | -2.8 |
| Coal resources           | -3.2          | -3.5   | -2.5       | -3.4  | -2.8      | -3.8  | -3.8    | -2.5  | -2.8  | -2.8    | -2.8 |
| Specific capital in domestic firms | -2.9        | -3.2   | -1.8       | -3.7  | -4.0      | -3.5  | -3.8    | -2.5  | -2.8  | -2.8    | -2.8 |
| Specific capital in multinational firms | -2.7        | -2.3   | 3.3        | -2.4  | 0.0       | -0.1  | 0.9     | 1.3   | 1.6   | 0.3     |      |
| Factor adjustments       |                 |        |             |       |           |       |         |       |       |         |      |
| Unskilled labor (% changing sectors) | 2.2          | 2.1    | 2.4        | 2.0   | 2.5       | 2.2   | 2.3     | 2.0   | 2.2   | 2.5     | 2.3  |
| Skilled labor (% changing sector) | 2.7          | 2.2    | 2.7        | 4.0   | 2.7       | 2.6   | 2.7     | 2.2   | 2.7   | 2.8     | 2.8  |

Source: Authors' estimates
### Table 17a. Impact of 20 Percent CO2 Reduction through Energy Intensity Standards on Output by Sector and Regional Market. (Results are Percentage Change from Base Year)

| Good | Central | Siberia | South | North | Urals | Far East | Moscow | St. Pete | Tumen | Northwest |
|------|---------|---------|-------|-------|-------|---------|--------|----------|--------|-----------|
| NFM  | 10.0    | 4.2     | 7.0   | 4.0   | 11.4  | 8.3     | 19.1   | 22.5     |        | 81.1      |
| SCI  | 1.1     | 0.7     | 0.3   | 0.5   | 0.6   | 0.8     | 1.0    | 1.0      | -1.8   | 1.2       |
| FIN  | -0.6    | -0.7    | -0.9  | -0.7  | -0.7  | -0.8    | -0.9   | -0.7     | -1.0   | -0.6      |
| TMS  | -1.5    | -2.0    | -1.8  | -1.7  | -1.3  | -2.0    | -2.2   | -1.9     | -0.7   | -1.8      |
| HEA  | -1.6    | -1.5    | -2.0  | -1.8  | -1.6  | -2.0    | -2.1   | -1.8     | -1.7   | -1.6      |
| CON  | -1.2    | -1.9    | -1.9  | -2.2  | -1.9  | -0.8    | -1.3   | -1.1     | -5.8   | -0.5      |
| GAS  | -1.2    | -1.0    | -1.5  | 0.3   | 0.9   |         |        | -15.5    | 2.8    |           |
| CRU  | -2.7    | -2.4    | -2.5  | -2.3  | -2.4  |         |        | -3.3     | -2.3   |           |
| COL  | -2.3    | -2.8    | -2.9  | -2.8  | -2.8  |         |        | -2.4     | -2.4   |           |
| FOO  | -1.6    | -3.0    | -2.8  | -4.3  | -2.9  | -1.8    | -1.2   | -2.5     | -12.7  | -1.0      |
| AGR  | -1.7    | -3.9    | -4.0  | -4.6  | -3.5  | -2.8    | -2.6   | -2.8     | -13.1  | -1.3      |
| PST  | -4.3    | -4.2    | -3.9  | -4.3  | -4.0  | -4.1    | -3.7   | -4.4     | -4.0   | -4.3      |
| OTI  | -3.3    | -5.0    | -3.9  | -5.2  | -4.0  | -3.8    | -3.4   | -3.8     | -9.7   | -3.1      |
| RLW  | -5.4    | -5.4    | -5.5  | -5.7  | -5.9  | -4.6    | -5.0   | -5.0     | -4.8   | -5.3      |
| OTH  | -4.7    | -5.2    | -4.6  | -6.1  | -5.0  | -4.5    | -6.3   | -6.6     | -10.8  | -3.7      |
| MNO  | -4.5    | -8.8    | -6.1  | -5.9  | -5.8  | -5.0    | -4.9   | -4.5     | -10.3  | -2.6      |
| HOU  | -5.5    | -5.7    | -6.2  | -6.5  | -5.9  | -6.3    | -6.0   | -5.9     | -8.2   | -5.6      |
| TRO  | -6.4    | -6.9    | -6.0  | -6.6  | -6.3  | -6.7    | -6.3   | -6.5     | -5.6   | -6.7      |
| TRD  | -9.0    | -6.9    | -5.6  | -5.6  | -6.2  | -6.6    | -6.8   | -7.8     | -1.5   | -8.4      |
| TPP  | -4.7    | -9.5    | -6.6  | -9.1  | -5.1  | -11.7   | -6.7   | -6.4     | -7.4   | -2.6      |
| CLI  | -5.7    | -6.1    | -6.5  | -7.8  | -6.2  | -6.8    | -5.8   | -6.7     | -13.5  | -5.5      |
| TRK  | -8.3    | -8.0    | -7.0  | -7.6  | -7.5  | -8.1    | -8.2   | -8.3     | -4.0   | -8.5      |
| MAR  | -7.8    | -8.0    | -7.8  | -8.5  | -8.5  | -7.9    | -9.6   | -5.3     | -5.3   | -6.4      |
| CNM  | -6.2    | -9.6    | -6.3  | -8.5  | -8.5  | -7.7    | -10.1  | -9.0     | -12.0  | -8.2      |
| FME  | -8.4    | -11.9   | -13.2 | -12.5 | -10.3 | -7.9    | -11.2  | -18.6    | -7.6   |           |
| PIP  | -17.0   | -15.6   | -9.0  | -5.2  | -10.5 | -12.4   | -17.8  | -14.8    | 1.0    | -18.9     |
| CHM  | -13.9   | -22.5   | -16.0 | -15.0 | -17.0 | -13.3   | -15.2  | -16.8    | -31.7  | -16.4     |
| OIL  | -17.9   | -20.5   | -19.0 | -19.6 | -18.7 | -17.9   | -18.8  | -16.0    | -28.0  |           |
| ELE  | -25.3   | -23.0   | -23.4 | -22.8 | -24.8 | -22.0   | -21.0  | -23.8    | -19.0  | -25.4     |
| AIR  | -25.4   | -23.9   | -25.0 | -31.2 | -21.4 | -31.2   | -21.9  | -31.3    | -29.8  | -30.4     |

See table 1 for sector codes.

Source: Authors’ estimates.
Table 18: Impact on the Regions of Russia of WTO Accession and Simultaneous “Cap and Trade” Market Based Emission Control System to Reduce Carbon Emissions by 20 Percent, with decomposition of carbon emission effects. (Results are Percentage Change from Base Year.)

| Overall average | Moscow | St. Petersburg | Tumen | North-west | North | Central | South | Urals | Siberia | East |
|----------------|--------|----------------|-------|------------|-------|---------|-------|-------|---------|------|
| **Aggregate welfare** | | | | | | | | | | |
| Welfare (EV as % of consumption) | 7.2 | 5.5 | 9.7 | 13.7 | 12.5 | 9.2 | 8.4 | 7.4 | 6.4 | 7.5 | 8.5 |
| Welfare (EV as % of GDP) | 3.3 | 3.0 | 4.4 | 2.9 | 5.8 | 3.8 | 3.9 | 3.5 | 2.9 | 3.5 | 3.8 |

**Carbon Dioxide Emissions and Decomposition**

| CO2 price (ruble per ton of CO2) | 112.4 | 112.4 | 112.4 | 112.4 | 112.4 | 112.4 | 112.4 | 112.4 | 112.4 | 112.4 |
| CO2 emissions, decomposed into: | | | | | | | | | | |
| Output effect (% of CO2) | 3.6 | 3.5 | 5.9 | 2.3 | 6.0 | 5.2 | 4.0 | 4.0 | 2.5 | 3.8 | 5.3 |
| Composition effect (% of CO2) | -3.6 | -1.0 | -0.7 | -11.4 | -2.7 | -3.4 | -1.3 | -1.5 | -3.0 | -5.2 | -2.9 |
| Technique effect (% of CO2) | -19.5 | -20.8 | -21.6 | -13.1 | -20.9 | -19.1 | -21.1 | -19.7 | -20.7 | -19.1 | -19.8 |

**Non-Carbon Dioxide Emissions**

| Sulphur Dioxide | 5.9 | 1.6 | 11.7 | -2.6 | -8.6 | 7.4 | -2.9 | 2.7 | 5.3 | 7.3 | 5.2 |
| Nitrogen Oxide | -1.3 | -2.9 | 0.3 | -1.4 | 1.3 | -0.1 | -1.9 | -1.6 | -1.7 | 0.0 | -1.0 |
| Hydrocarbons | -3.6 | -4.7 | 0.6 | -0.5 | 1.2 | -3.4 | -2.0 | -1.7 | -2.8 | -10.7 | -16.7 |
| Particulate Matter | -0.6 | -3.2 | -0.4 | -0.3 | 0.1 | 0.7 | -2.1 | -2.1 | -1.2 | 1.0 | -0.4 |
| Volatile Organic Components | 0.8 | -1.6 | 2.2 | 0.9 | 17.6 | 1.4 | 9.2 | 1.9 | -0.1 | -1.5 | 3.3 |
| Carbon Monoxide | 2.2 | 9.5 | 6.0 | 0.7 | -9.2 | 4.1 | -3.4 | 2.3 | 1.8 | 5.2 | 3.1 |

**Aggregate trade**

| Regional terms of trade (% change) | 2.8 | 14.0 | 15.5 | 12.6 | 14.6 | 14.5 | 13.7 | 13.4 | 12.4 | 13.0 | 14.6 |
| Regional exports (% change) | 1.4 | 1.5 | 2.3 | 0.9 | 2.4 | 1.9 | 2.5 | 1.6 | 1.4 | 0.4 | 2.1 |
| Real exchange rate (% change) | 2.4 | 2.5 | 3.3 | 1.9 | 3.5 | 2.6 | 3.2 | 2.6 | 1.9 | 1.7 | 2.6 |
| International exports (% change) | 8.2 | 16.0 | 13.6 | 3.9 | 12.7 | 9.0 | 10.0 | 9.6 | 8.9 | 7.2 | 13.1 |

**Return to primary factors (% change)**

| Unskilled labor | 1.6 | 2.2 | 4.4 | 1.0 | 4.8 | 2.7 | 2.2 | 2.3 | 0.0 | 1.0 | 3.2 |
| Skilled labor | 0.3 | 0.7 | 3.7 | -1.2 | 3.2 | 1.3 | 1.6 | 1.5 | -0.4 | -1.8 | 1.7 |
| National capital | 1.6 | 1.7 | 2.5 | 1.1 | 2.7 | 1.8 | 2.4 | 1.8 | 1.1 | 0.9 | 1.8 |
| Regional mobile capital | 3.6 | 3.4 | 6.3 | 4.2 | 5.8 | 5.2 | 3.4 | 3.7 | 2.4 | 3.7 | 5.7 |
| Crude oil resources | 3.8 | 3.6 | 5.8 | 5.3 | 5.5 | 3.4 | 2.9 | 5.3 | 33.4 | 34.1 | 33.6 |
| Natural gas resources | -33.4 | -34.1 | -28.4 | -30.6 | -23.9 | -26.3 | -34.1 | -33.6 | -9.2 | -8.5 | -4.7 | -6.2 | -9.9 | -10.0 | -7.0 |
| Coal resources | -9.2 | -8.5 | -4.7 | -6.2 | -9.9 | -10.0 | -7.0 | 3.6 | 3.4 | 2.9 | 5.3 |
| Specific capital in domestic firms | -29.9 | -21.5 | -48.5 | -21.9 | -25.5 | -17.4 | -25.0 | -18.2 | -18.6 | -27.1 |
| Specific capital in multinational firms | 59.3 | 48.4 | 217.4 | 77.4 | 139.6 | 113.4 | 125.9 | 139.0 | 159.2 | 113.6 |

**Factor adjustments**

| Unskilled labor (% changing sectors) | 2.1 | 1.8 | 2.1 | 2.5 | 2.8 | 2.3 | 1.8 | 1.4 | 2.4 | 2.6 | 3.2 |
| Skilled labor (% changing sector) | 2.9 | 2.4 | 2.6 | 3.1 | 3.3 | 3.4 | 2.3 | 1.9 | 2.7 | 4.4 | 4.4 |

Source: Authors' estimates
Table 18a. Impact on Output by Sector and Regional Market of WTO Accession and Simultaneous “Cap and Trade” to Reduce Carbon Emissions by 20 Percent. (Results are Percentage Change from Base Year)

| Good     | Central | Siberia | South | North | Urals | Far East | Moscow | St. Pete. | Tumen | Northwest |
|----------|---------|---------|-------|-------|-------|----------|--------|-----------|-------|-----------|
| NFM      | 37.2    | 15.6    | 50.8  | 22.3  | 47.9  | 13.5     | 69.1   | 48.1      |       | 192.6     |
| TMS      | 14.5    | 9.0     | 13.5  | 20.6  | 0.9   | 21.5     | -0.6   | 21.7      | 10.7  | 23.3      |
| TRK      | 5.4     | 3.3     | 5.5   | 8.5   | 0.6   | 11.2     | 1.3    | 10.0      | 4.6   | 11.0      |
| OIL      | 12.9    | 0.7     | 6.9   | 5.8   | 3.1   | 5.7      | 2.6    | 4.4       | 1.4   |           |
| PST      | 5.2     | 3.7     | 5.0   | 5.2   | 3.3   | 5.4      | 3.4    | 5.2       | 4.6   | 6.6       |
| TRD      | 2.6     | 2.8     | 3.7   | 4.4   | 2.5   | 5.5      | 3.1    | 5.0       | 4.2   | 5.5       |
| TPP      | -4.9    | -2.7    | -10.9 | 0.3   | -2.5  | 41.8     | -13.3  | -2.2      | 8.9   | 4.2       |
| CRU      | 0.9     | 2.1     | 2.2   | 1.0   | 2.1   |          |        |           | 1.3   | 2.0       |
| HEA      | 1.4     | 1.2     | 1.3   | 1.2   | 1.1   | 1.1      | 0.8    | 1.3       | 1.2   | 1.9       |
| CLI      | 4.3     | -0.2    | 1.6   | 1.0   | 1.8   | 0.1      | 0.5    | -0.3      | 1.4   | 1.2       |
| SCI      | 0.4     | 0.9     | -0.9  | 0.7   | -1.6  | 1.8      | 0.8    | 7.7       | -6.8  | 6.4       |
| CON      | 2.1     | -1.3    | 0.1   | -1.4  | -0.5  | -2.1     | 1.1    | -1.2      | -1.8  | -0.1      |
| Chemicals| 2.1     | -7.2    | -2.4  | -10.2 | -2.8  | -10.1    | -6.8   | -2.4      | -1.1  | 34.2      |
| HOU      | -0.4    | -1.3    | -0.9  | -0.6  | -1.5  | -1.1     | -1.9   | -0.6      | 0.1   | 0.8       |
| MNO      | -3.9    | -6.0    | -0.7  | -4.8  | -7.5  | -5.6     | 12.1   | 5.6       | -6.4  | 2.8       |
| AGR      | 3.1     | -2.0    | 0.3   | -3.5  | 1.7   | 4.5      | -0.2   | -4.8      | -1.8  | -3.1      |
| ELE      | -1.7    | -1.6    | -1.7  | -1.2  | -2.4  | -1.4     | -2.5   | -0.6      | -3.1  | 0.6       |
| OTH      | 5.7     | -3.0    | 0.0   | -3.6  | 2.5   | 5.4      | 0.8    | -6.2      | -1.8  | -5.7      |
| RLW      | -2.0    | -5.2    | -1.3  | -2.0  | -3.9  | -3.3     | -1.3   | 0.0       | -1.8  | -2.2      |
| OTI      | -0.1    | -6.2    | -1.2  | -3.8  | -2.3  | -5.4     | 2.3    | -0.5      | -6.0  | -1.6      |
| AIR      | -1.3    | -6.4    | -4.4  | -2.8  | -4.7  | -4.0     | -5.1   | -3.8      | -5.3  | -0.5      |
| FOO      | -3.4    | -5.3    | -2.7  | -3.1  | -4.2  | -5.5     | -7.3   | -5.1      | 0.9   | -4.2      |
| MAR      | -1.2    | -9.1    | -4.6  | -2.5  | -3.8  | -0.1     | -5.0   | -3.2      | -8.8  | -4.5      |
| FIN      | -6.1    | -6.4    | -5.8  | -6.2  | -6.7  | -5.7     | -6.0   | -5.5      | -8.2  | -5.0      |
| TRO      | -6.1    | -11.9   | -8.1  | -3.3  | -16.5 | -1.2     | -19.0  | -1.5      | -14.9 | -0.2      |
| CNM      | -4.7    | -12.4   | -5.6  | -8.2  | -7.5  | -9.9     | -11.7  | -10.8     | -4.0  | -9.1      |
| Pipelines| -10.9   | -12.7   | -9.6  | -11.5 | -8.8  | -10.2    | -23.0  | -11.1     | -4.2  | -25.4     |
| Ferrous Metals | -8.5 | -21.0 | -12.4 | -14.8 | -19.2 | -15.0    | -15.7  | -6.0      | -13.8 |
| Coal     | -15.2   | -18.3   | -16.1 | -16.2 | -18.6 | -16.7    |        |           |       |           |
| GAS      | -21.4   | -16.4   | -19.7 | -17.4 | -21.3 |          |        |           | -21.4 | -18.9     |

See table 1 for sector codes.
Source: Authors’ estimates.
Table 19: Impact on the Regions of Russia of WTO Accession and Simultaneous Emission Intensity Standards to Reduce Carbon Emissions by 20 Percent, with decomposition of carbon emission effects. (Results are Percentage Change from Base Year.)

|                       | Overall average | Moscow | St. Petersburg | Tumen | North-west | North | Central | South | Urals | Siberia | Far East |
|-----------------------|----------------|--------|----------------|-------|-----------|-------|---------|-------|-------|---------|----------|
| **Aggregate welfare** |                |        |                |       |           |       |         |       |       |         |          |
| Welfare (EV as % of consumption) | 6.4 | 5.8 | 9.4 | 5.2 | 10.1 | 8.1 | 7.1 | 7.1 | 5.3 | 6.3 | 8.2 |
| Welfare (EV as % of GDP) | 3.0 | 3.2 | 4.2 | 1.1 | 4.7 | 3.4 | 3.3 | 3.4 | 2.4 | 3.0 | 3.7 |
| **Carbon Dioxide Emissions and Decomposition** |                |        |                |       |           |       |         |       |       |         |          |
| CO2 price (ruble per ton of CO2) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CO2 emissions, decomposed into: |                |        |                |       |           |       |         |       |       |         |          |
| Output effect (% of CO2) | 2.7 | 3.1 | 5.0 | 0.0 | 5.2 | 4.2 | 3.1 | 3.2 | 1.8 | 2.9 | 4.6 |
| Composition effect (% of CO2) | -0.4 | 0.8 | 4.9 | -15.1 | 3.6 | 0.2 | 3.6 | 1.3 | 1.5 | 0.3 | 0.1 |
| Technique effect (% of CO2) | -20.3 | -23.0 | -24.4 | -7.0 | -24.6 | -20.0 | -23.9 | -22.3 | -22.5 | -18.0 | -19.6 |
| **Non-Carbon Dioxide Emissions** |                |        |                |       |           |       |         |       |       |         |          |
| Sulphur Dioxide | 7.1 | 10.2 | 28.0 | 3.1 | 7.8 | 9.1 | 13.2 | 13.1 | 9.4 | 4.9 | 8.9 |
| Nitrogen Oxide | 5.1 | 7.5 | 7.9 | 0.9 | 12.9 | 6.6 | 9.7 | 7.7 | 3.8 | 4.7 | 5.8 |
| Hydrocarbons | -2.6 | -8.9 | -2.5 | -1.1 | -1.4 | -1.2 | -4.0 | -3.4 | -3.7 | -3.3 | 0.8 |
| Particulate Matter | 4.3 | 7.1 | 10.2 | 1.1 | 13.2 | 7.0 | 9.0 | 8.6 | 4.0 | 3.7 | 3.5 |
| Volatile Organic Components | 1.1 | 2.3 | 0.4 | 0.9 | 15.8 | 1.7 | 5.9 | 1.7 | 0.6 | 1.7 | 3.6 |
| Carbon Monoxide | 3.0 | 11.4 | 10.8 | 0.8 | 4.6 | 4.1 | 12.9 | 4.0 | 2.7 | 3.1 | 4.0 |
| **Aggregate trade** |                |        |                |       |           |       |         |       |       |         |          |
| Regional terms of trade (% change) | 2.2 | 16.0 | 17.6 | 13.9 | 17.3 | 16.3 | 16.1 | 15.5 | 14.8 | 14.8 | 16.7 |
| Regional exports (% change) | 1.4 | 1.9 | 2.2 | 0.2 | 2.0 | 2.2 | 1.7 | 1.2 | 1.3 | 1.1 | 2.3 |
| Real exchange rate (% change) | 1.5 | 1.7 | 2.4 | 0.9 | 1.9 | 1.8 | 1.8 | 1.6 | 0.9 | 1.0 | 2.1 |
| International exports (% change) | 7.5 | 7.9 | 13.7 | 4.8 | 14.4 | 7.0 | 14.5 | 7.7 | 7.8 | 6.7 | 8.3 |
| **Return to primary factors (% change)** |                |        |                |       |           |       |         |       |       |         |          |
| Unskilled labor | 3.6 | 4.1 | 6.2 | 2.4 | 5.7 | 4.6 | 3.8 | 4.3 | 2.2 | 3.4 | 5.4 |
| Skilled labor | 3.9 | 3.7 | 7.1 | 1.3 | 7.1 | 5.2 | 5.2 | 5.0 | 2.9 | 3.4 | 5.9 |
| National capital | 2.4 | 2.8 | 3.3 | 1.8 | 2.9 | 2.7 | 2.7 | 2.5 | 1.8 | 1.9 | 3.0 |
| Regional mobile capital | 4.9 | 4.8 | 7.9 | 5.1 | 8.0 | 6.0 | 5.2 | 5.0 | 3.9 | 4.6 | 6.3 |
| Crude oil resources | 1.6 | 1.6 | 1.7 | 3.4 | 2.9 | 0.9 | 1.3 | 4.4 |       |       |       |
| Natural gas resources | -44.2 | -44.6 | -51.2 | -39.5 | -37.8 | -41.5 | -43.3 | -38.6 |       |       |       |
| Coal resources | -0.7 | 1.7 | 0.2 | -0.1 | -2.5 | -1.4 | 2.3 |       |       |       |       |
| Specific capital in domestic firms | -30.7 | -23.1 | -49.0 | -22.3 | -25.8 | -18.0 | -25.5 | -17.9 | -20.2 | -27.4 |       |
| Specific capital in multinational firms | 58.6 | 46.0 | 209.4 | 76.2 | 137.2 | 111.4 | 123.1 | 136.3 | 156.3 | 111.8 |       |
| **Factor adjustments** |                |        |                |       |           |       |         |       |       |         |          |
| Unskilled labor (% changing sectors) | 2.1 | 1.9 | 2.6 | 2.5 | 3.7 | 2.1 | 2.2 | 1.7 | 2.2 | 2.0 | 2.2 |
| Skilled labor (% changing sector) | 2.8 | 2.8 | 3.6 | 3.4 | 4.0 | 2.9 | 2.9 | 2.3 | 2.6 | 2.5 | 3.0 |

Source: Authors' estimates
Table 19a. Impact on Output by Sector and Regional Market of WTO Accession and Simultaneous Emissions Intensity Standards to Reduce Carbon Emissions by 20 Percent Impact. (Results are Percentage Change from Base Year)

| Good | Central | Siberia | South | North | Urals | Far East | Moscow | St. Pete. | Tumen | Northwest |
|------|---------|---------|-------|-------|-------|---------|--------|----------|--------|-----------|
| FME  | 18.1    | 6.6     | 23.3  | 17.2  | 5.7   | 19.9    | 28.5   | 210.6    | 5.7    |           |
| CHM  | 9.7     | 22.0    | 10.2  | 2.6   | 11.6  | 6.4     | 7.2    | 12.8     | 14.5   | 31.7      |
| TMS  | 12.1    | 7.3     | 11.7  | 18.8  | -0.8  | 20.0    | -2.0   | 19.8     | 8.5    | 20.0      |
| NFM  | 8.6     | 4.7     | 19.6  | 10.3  | 15.2  | 8.8     | 31.0   | 4.0      | -10.6  |           |
| ELE  | 10.7    | 8.6     | 9.9   | 9.1   | 8.7   | 9.1     | 8.0    | 10.7     | 3.3    | 14.5      |
| TRK  | 5.2     | 2.8     | 4.7   | 7.2   | 0.4   | 8.8     | 0.6    | 9.3      | 3.9    | 9.7       |
| TRD  | 2.4     | 2.0     | 2.3   | 2.9   | 1.6   | 3.3     | 1.8    | 4.0      | 3.6    | 4.7       |
| SCI  | 1.8     | 2.0     | 0.3   | 1.9   | -0.2  | 6.1     | 1.3    | 8.1      | -6.2   | 7.4       |
| PST  | 1.7     | 1.3     | 2.1   | 2.6   | 0.5   | 3.0     | 1.0    | 2.3      | 1.8    | 2.3       |
| CRU  | 0.9     | 1.6     | 2.1   | 0.7   | 2.5   |         |        | 1.4      | 0.7    |           |
| OIL  | 3.9     | -0.4    | 1.9   | 3.6   | -0.5  | 5.9     | -1.8   | 0.0      | -0.8   |           |
| HOU  | 1.2     | 0.9     | 1.5   | 1.6   | 0.4   | 1.8     | 1.1    | 1.6      | -1.1   | 1.8       |
| HEA  | 1.0     | 0.9     | 1.1   | 1.0   | 0.8   | 1.1     | 0.9    | 1.2      | 0.3    | 1.3       |
| RLM  | 1.0     | -1.0    | -0.6  | -0.3  | -1.0  | 0.3     | -1.3   | 3.2      | -2.0   | 1.4       |
| CON  | -0.1    | -1.1    | -0.2  | -0.3  | -0.5  | 0.1     | 1.3    | -1.9     | -0.5   | -4.0      |
| COL  | -0.9    | -1.7    | -1.0  | 0.6   | -2.5  | 0.8     |        |          |        |           |
| MNO  | -5.0    | -1.8    | -1.1  | -1.2  | -6.3  | 2.5     | 7.7    | 2.9      | -4.4   | -5.6      |
| OTI  | -1.8    | -4.1    | -1.5  | -1.4  | -2.7  | -1.8    | 1.6    | -0.4     | -6.4   | -3.3      |
| CLI  | -1.1    | -2.7    | -1.5  | -1.2  | -2.1  | -1.1    | -2.0   | -3.7     | -2.6   | -5.0      |
| AGR  | -2.1    | -2.7    | -2.1  | -3.0  | -1.2  | -3.4    | -1.4   | -6.8     | -2.8   | -8.9      |
| CNM  | -2.8    | -5.3    | -2.2  | -1.8  | -3.6  | -1.9    | -4.9   | -5.5     | -0.6   | -8.0      |
| TPP  | -7.8    | -9.2    | -12.0 | -2.7  | -4.2  | 7.3     | -12.9  | -8.6     | 9.0    | -11.2     |
| FIN  | -5.7    | -6.3    | -5.7  | -6.1  | -6.5  | -5.5    | -5.9   | -5.1     | -8.4   | -4.3      |
| OTH  | -4.4    | -7.7    | -5.8  | -5.5  | -3.9  | -7.0    | -2.6   | -10.3    | -3.6   | -14.9     |
| FOO  | -9.3    | -8.3    | -8.0  | -5.6  | -7.8  | -8.2    | -11.9  | -9.0     | -4.2   | -12.6     |
| TRO  | -6.3    | -11.3   | -8.3  | -3.4  | -16.9 | -1.5    | -19.9  | -1.2     | -15.6  | -0.5      |
| MAR  | -12.7   | -15.7   | -15.0 | -12.0 | -12.0 | -10.6   | -15.0  | -12.8    | -15.1  | -15.1     |
| PIP  | -15.0   | -13.0   | -11.0 | -11.7 | -9.9  | -10.5   | -24.8  | -13.6    | -3.3   | -28.4     |
| GAS  | -20.5   | -17.3   | -18.2 | -19.4 | -17.8 | -21.2   | -26.0  |          |        |           |
| AIR  | -21.7   | -22.0   | -21.5 | -22.6 | -20.5 | -22.6   | -19.5  | -24.0    | -23.3  | -23.9     |

See table 1 for sector codes.

Source: Authors’ estimates.
Table 20: Impact on the Regions of Russia of WTO Accession and Simultaneous Energy Efficiency Standards to Reduce Carbon Emissions by 20 Percent, with decomposition of carbon emission effects. (Results are Percentage Change from Base Year.)

| Overall average | Moscow | St. Peters. | Tumen | North-west | North | Central | South | Urals | Siberia | Far East |
|-----------------|--------|-------------|-------|------------|-------|---------|-------|-------|---------|----------|
| **Aggregate welfare** |        |             |       |            |       |         |       |       |         |          |
| Welfare (EV as % of consumption) | 0.6    | 0.3         | 3.3   | -3.2       | 4.2   | 0.7     | 1.5   | 1.0   | -0.6    | 0.9      | 1.8      |
| Welfare (EV as % of GDP) | 0.3    | 0.2         | 1.5   | -0.7       | 2.0   | 0.3     | 0.7   | 0.5   | -0.3    | 0.4      | 0.8      |
| **Carbon Dioxide Emissions and Decomposition** |        |             |       |            |       |         |       |       |         |          |
| CO2 price (ruble per ton of CO2) | -19.7  | -21.6       | -18.9 | -20.7      | -13.9 | -17.5   | -18.9 | -20.9 | -21.7   | -16.3    | -16.0    |
| CO2 emissions, decomposed into: |        |             |       |            |       |         |       |       |         |          |
| Output effect (% of CO2) | -3.0   | -2.1        | -1.1  | -4.2       | -0.8  | -2.6    | -2.9  | -2.5  | -4.4    | -2.7     | -1.3     |
| Composition effect (% of CO2) | -6.5   | -7.1        | -3.9  | -12.7      | -3.3  | -5.3    | -4.1  | -6.1  | -6.7    | -4.8     | -4.1     |
| Technique effect (% of CO2) | -10.6  | -12.9       | -14.0 | -3.0       | -9.9  | -9.9    | -12.3 | -12.7 | -11.3   | -9.2     | -10.7    |
| **Non-Carbon Dioxide Emissions** |        |             |       |            |       |         |       |       |         |          |
| Sulphur Dioxide | -1.3   | -15.5       | 9.2   | -16.6      | -4.1  | -1.6    | -12.0 | -11.7 | -2.0    | 0.5      | -0.4     |
| Nitrogen Oxide | -16.4  | -22.2       | -17.0 | -10.0      | -19.9 | -17.5   | -25.2 | -20.2 | -15.7   | -13.5    | -15.4    |
| Hydrocarbons | -6.4   | -14.8       | -10.2 | -3.4       | -7.5  | -4.3    | -9.0  | -7.1  | -9.6    | -5.6     | 5.6      |
| Particulate Matter | -12.0  | -22.1       | -18.1 | -6.2       | -24.6 | -14.4   | -24.7 | -22.8 | -12.6   | -8.8     | -9.5     |
| Volatile Organic Components | -5.8   | -19.1       | -11.9 | -1.8       | -2.0  | -4.0    | -14.2 | -5.4  | -8.6    | -14.6    | -7.5     |
| Carbon Monoxide | -1.2   | 2.9         | 3.1   | -1.9       | 2.4   | -1.1    | 2.6   | -1.9  | -2.1    | 0.1      | 0.0      |
| **Aggregate trade** |        |             |       |            |       |         |       |       |         |          |
| Regional terms of trade (% change) | 0.9    | 24.5        | 25.4  | 20.1       | 25.5  | 22.7    | 23.9  | 23.7  | 22.6    | 22.7     | 24.6     |
| Regional exports (% change) | -6.2   | -4.4        | -6.6  | -5.7       | -5.5  | -6.1    | -6.4  | -5.3  | -7.5    | -7.3     | -5.9     |
| Real exchange rate (% change) | 1.6    | 1.8         | 2.4   | 0.4        | 2.2   | 1.6     | 2.1   | 1.7   | 1.1     | 1.0      | 2.1      |
| International exports (% change) | 6.3    | 4.6         | 9.9   | 6.6        | 5.1   | 5.4     | 6.5   | 8.5   | 7.3     | 3.1      | 6.8      |
| **Return to primary factors (% change)** |        |             |       |            |       |         |       |       |         |          |
| Unskilled labor | 3.1    | 4.2         | 6.2   | 1.6        | 5.4   | 3.9     | 3.7   | 3.4   | 1.7     | 2.5      | 4.9      |
| Skilled labor | 2.5    | 3.0         | 6.0   | -1.7       | 6.1   | 3.9     | 3.8   | 3.5   | 1.2     | 2.8      | 5.1      |
| National capital | -0.8   | -5.5        | 0.0   | -1.9       | -0.1  | -0.7    | -0.2  | -0.6  | -1.2    | -1.3     | -0.3     |
| Regional mobile capital | 1.5    | 1.1         | 3.9   | 3.2        | 3.7   | 2.1     | 1.3   | 1.6   | 0.4     | 1.2      | 2.6      |
| Crude oil resources | -3.3   | -3.9        | -1.3  | -1.3       | -1.3  | 1.0     | -2.8  | -3.7  | -0.2    |          |          |
| Natural gas resources | -33.1  | -35.2       | -19.9 | -12.4      | -9.4  | -11.8   | -18.9 | -11.1 |          |          |          |
| Coal resources | 5.0    | 7.2         | 7.9   | 6.6        | 4.6   | 4.2     | 8.4   |       |          |          |          |
| Specific capital in domestic firms | -32.9  | -25.6       | -49.1 | -24.6      | -26.6 | -20.6   | -28.1 | -20.7 | -21.5   | -29.3    |          |
| Specific capital in multinational firms | 55.1   | 43.9        | 216.2 | 73.3       | 122.9 | 109.5   | 122.1 | 135.0 | 155.3   | 111.5    |          |
| **Factor adjustments** |        |             |       |            |       |         |       |       |         |          |
| Unskilled labor (% changing sectors) | 2.9    | 2.8         | 3.2   | 2.6        | 3.4   | 2.9     | 2.8   | 2.4   | 2.9     | 3.3      | 3.1      |
| Skilled labor (% changing sector) | 3.5    | 3.4         | 4.0   | 3.4        | 4.0   | 3.3     | 3.7   | 2.9   | 3.6     | 3.8      | 4.0      |

Source: Authors' estimates
Table 20a. Impact on Output by Sector and Regional Market of WTO Accession and Simultaneous Energy Intensity Standards to Reduce Carbon Emissions by 20 Percent Impact. (Results are Percentage Change from Base Year)

| Good | Central | Siberia | South | North | Urals | Far East | Moscow | St. Pete. | Tumen | Northwest |
|------|---------|---------|-------|-------|-------|----------|--------|----------|--------|-----------|
| NFM  | 25.4    | 11.4    | 39.1  | 13.1  | 38.8  | 17.6     | 63.6   | 32.3     | 85.9   |           |
| FME  | 12.6    | -7.1    | 10.8  | 0.5   | -3.1  | 7.5      | 15.0   | 170.0    | 2.2    |           |
| TMS  | 11.1    | 5.5     | 10.4  | 17.5  | -1.6  | 19.1     | -3.5   | 19.1     | 9.5    | 19.6      |
| COL  | 5.3     | 2.7     | 4.5   | 4.9   | 3.3   | 5.6      |        |          |        |           |
| SCI  | 2.6     | 2.6     | 0.4   | 7.2   | 0.4   | 6.4      | 2.0    | 9.0      | -6.6   | 8.2       |
| CRU  | -1.5    | 0.0     | -0.4  | -1.0  | 0.4   |          | -1.1   |          | -0.5   |           |
| HEA  | -0.6    | -0.6    | -0.8  | -0.9  | -0.8  | -1.2     | -0.7   | -0.8     | -0.3   |           |
| PST  | -1.3    | -2.1    | -0.6  | -1.1  | -2.4  | -0.2     | -1.6   | -1.0     | -0.7   | -0.6      |
| TRK  | -2.1    | -4.5    | -1.4  | -0.6  | -6.0  | 1.3      | -6.0   | 1.6      | 0.1    | 1.8       |
| CON  | -0.7    | -3.3    | -1.5  | -2.8  | -1.9  | -1.8     | 0.1    | -2.7     | -4.4   | -3.6      |
| TRD  | -4.8    | -4.1    | -2.3  | -2.3  | -3.7  | -2.2     | -3.5   | -2.4     | 1.4    | -1.9      |
| RLW  | -3.3    | -6.3    | -5.2  | -5.9  | -6.4  | -3.6     | -5.8   | -1.7     | -5.1   | -2.6      |
| HOU  | -5.2    | -5.4    | -5.4  | -6.0  | -6.2  | -5.2     | -5.8   | -5.2     | -7.1   | -4.5      |
| OTI  | -4.7    | -9.1    | -4.8  | -7.6  | -6.2  | -6.4     | -1.8   | -4.1     | -10.1  | -5.3      |
| AGR  | -2.9    | -6.0    | -4.7  | -6.3  | -3.6  | -6.1     | -4.1   | -9.3     | -11.1  | -9.0      |
| GAS  | -7.3    | -2.9    | -4.4  | -3.9  | -3.7  |          | -15.7  |          | -8.0   |           |
| FIN  | -6.4    | -7.1    | -6.6  | -7.6  | -7.2  | -6.5     | -6.9   | -6.1     | -8.8   | -5.0      |
| MWE  | -8.7    | -10.0   | -5.9  | -17.8 | -10.9 | -3.9     | 2.9    | -1.0     | -11.1  | -6.0      |
| CLI  | -5.4    | -7.7    | -6.7  | -8.3  | -6.9  | -7.3     | -6.9   | -9.4     | -11.9  | -8.6      |
| FOO  | -9.1    | -9.8    | -8.2  | -8.2  | -9.1  | -8.5     | -11.5  | -10.3    | -10.5  | -11.2     |
| OTH  | -6.0    | -12.2   | -7.3  | -11.4 | -6.3  | -11.2    | -7.2   | -14.8    | -10.6  | -15.4     |
| TEP  | -12.1   | -16.1   | -17.5 | -11.1 | -8.5  | -1.2     | -19.4  | -14.0    | 5.2    | -10.4     |
| TRO  | -12.0   | -17.4   | -13.4 | -10.0 | -21.8 | -7.8     | -24.5  | -7.4     | -19.4  | -7.0      |
| CNM  | -11.5   | -18.5   | -10.7 | -13.9 | -12.3 | -13.9    | -18.9  | -18.4    | -11.6  | -18.9     |
| MAR  | -13.7   | -19.4   | -15.8 | -14.4 | -13.7 | -13.9    | -17.2  | -16.2    | -12.6  | -13.3     |
| PIP  | -19.8   | -20.7   | -12.0 | -9.3  | -13.9 | -15.8    | -23.4  | -19.2    | 1.3    | -21.6     |
| CHM  | -13.2   | -20.5   | -15.0 | -20.2 | -16.0 | -15.9    | -17.8  | -17.1    | -22.4  | -3.6      |
| GES  | -14.8   | -24.0   | -16.8 | -18.1 | -21.6 | -14.9    | -20.2  | -16.1    | -27.0  |           |
| ELE  | -26.6   | -24.1   | -24.3 | -24.0 | -26.6 | -22.3    | -22.3  | -24.2    | -18.5  | -25.0     |
| AIR  | -32.5   | -32.1   | -31.9 | -37.8 | -29.0 | -37.4    | -28.6  | -38.0    | -35.9  | -37.0     |

See table 1 for sector codes.

Source: Authors’ estimates.
Table 21: Summary of Our Seven Policy Scenarios for Overall Impacts from our central model with FDI and IRTS (Results are Percentage Change from Base Year.)

|                              | WTO Accession plus | Carbon Reduction Policies Alone |
|------------------------------|-------------------|--------------------------------|
|                              | WTO accession     | carbon emissions | energy intensity | WTO accession | carbon emissions | energy intensity |
|                              | alone             | trading standards | standards        | alone         | trading standards | standards        |
| Aggregate welfare            |                   |                   |                  |               |                   |                  |
| Welfare (EV as % of consumption) | 8.6              | 7.2               | 6.4             | -1.1          | 1.7              | -5.9             |
| Welfare (EV as % of GDP)     | 4.0               | 3.3               | 3.0             | 0.3           | -0.5             | -2.7             |
| Carbon Dioxide Emissions and Decomposition | 112.4 | 96.0 |
| CO2 price (ruble per ton of CO2) | 4.3              | -20.0             | -19.2           | -20.0         | -20.0            | -19.8            |
| CO2 emissions, decomposed into: | 4.9              | 3.6               | 2.7             | -1.0          | -1.8             | -6.1             |
| Output effect (% of CO2)     | 1.0               | -3.6              | -0.4            | -3.1          | -1.0             | -6.0             |
| Composition effect (% of CO2) | -1.6             | -19.5             | -20.3           | -16.3         | -17.1            | -8.2             |
| Technique effect (% of CO2)  |                   |                   |                  |               |                   |                  |
| Non-Carbon Dioxide Emissions |                   |                   |                  |               |                   |                  |
| Sulphur Dioxide              | 6.2               | 5.9               | 7.1             | -1.3          | 1.0              | -6.9             |
| Nitrogen Oxide               | 2.8               | -1.3              | 5.1             | -16.4         | 2.0              | -16.1            |
| Hydrocarbons                 | 1.7               | -3.6              | -2.6            | -4.2          | -3.6             | -6.5             |
| Particulate Matter           | 3.0               | -0.6              | 4.3             | -2.9          | 1.1              | -12.5            |
| Volatile Organic Components  | 2.7               | 0.8               | 1.1             | -5.8          | -1.4             | -6.8             |
| Carbon Monoxide              | 4.5               | 2.2               | 3.0             | -1.7          | -1.2             | -4.7             |
| Aggregate trade              |                   |                   |                  |               |                   |                  |
| Regional terms of trade (% change) | 2.9              | 2.8               | 2.2             | 0.9           | -0.1             | -1.5             |
| Regional exports (% change)  | 3.0               | 1.4               | 1.4             | -6.2          | -1.2             | -7.5             |
| Real exchange rate (% change) | 1.8              | 2.4               | 1.5             | 1.6           | 0.4              | -0.3             |
| International exports (% change) | 8.1              | 8.2               | 7.5             | 6.3           | 0.4              | -1.2             |
| Return to primary factors (% change) |                |                   |                  |               |                   |                  |
| Unskilled labor              | 3.7               | 1.6               | 3.6             | 3.1           | 1.7              | 0.0              |
| Skilled labor                | 3.7               | 0.3               | 3.9             | 2.5           | 2.6              | 0.3              |
| National capital             | 3.8               | 1.6               | 2.4             | -0.8          | -1.7             | -1.1             |
| Regional mobile capital      | 5.8               | 3.6               | 4.9             | 1.5           | -1.8             | -0.7             |
| Crude oil resources          | 4.4               | 3.8               | 1.6             | -3.3          | -0.6             | -2.4             |
| Natural gas resources        | 7.0               | -33.4             | -44.2           | -33.1         | -32.9            | -42.7            |
| Coal resources               | 9.7               | -9.2              | -0.7            | 5.0           | -13.6            | -7.9             |
| Factor adjustments           |                   |                   |                  |               |                   |                  |
| Unskilled labor (% changing sectors) | 2.0              | 2.1               | 2.1             | 2.9           | 0.9              | 0.7              |
| Skilled labor (% changing sector) | 2.6              | 2.9               | 2.8             | 3.5           | 1.5              | 1.1              |

Source: Authors' estimates
Table 22: Sensitivity Analysis—Summary of Constant Returns to Scale Model Results of Our Seven Policy Scenarios. (Percentage Change from Base Year.)

|                           | WTO Accession plus | Carbon Reduction Policies Alone |
|---------------------------|-------------------|-------------------------------|
|                           | WTO accession     | carbon emissions trading      | emissions trading standards |
|                           | alone             | emissions intensity standards |                        |
| Aggregate welfare         |                   |                               |                            |
| Welfare (EV as % of consumption) | 1.1 | 0.7 | 0.0 | -3.5 |
| Welfare (EV as % of GDP)  | 0.5               | 0.3                           | 0.0                       | -1.6 | -0.2 | -0.4 | -1.9 |
| Carbon Dioxide Emissions and Decomposition | 107.8 | 103.4 | 1.0 | -20.0 | -20.4 | -20.2 | -20.0 | -19.9 | -19.9 |
| CO2 price (ruble per ton of CO2) | 1.1 | 0.4 | -0.4 | -4.7 | -0.7 | -1.4 | -5.3 |
| Composition effect (% of CO2) | 0.4 | -2.4 | -0.9 | -6.2 | -2.5 | -1.2 | -6.1 |
| Technique effect (% of CO2)  | -0.4 | -18.0 | -18.6 | -9.7 | -17.2 | -17.3 | -8.8 |
| Non-Carbon Dioxide Emissions | 1.1 | -1.4 | 2.4 | -12.5 | -2.5 | 1.2 | -12.9 |
| Sulphur Dioxide            | 4.6               | 4.5                           | 5.2                       | -4.7 | -0.4 | 0.6 | -8.9 |
| Nitrogen Oxide            | 0.9               | -2.1                          | 3.1                       | -16.5 | -2.9 | 2.1 | -16.4 |
| Hydrocarbons              | 0.1               | -4.5                          | -3.8                      | -7.1 | -4.3 | -3.6 | -6.7 |
| Particulate Matter        | 1.1               | -1.4                          | 2.4                       | -12.5 | -2.5 | 1.2 | -12.9 |
| Volatile Organic Components | 0.1 | -1.1 | -1.0 | -6.7 | -1.1 | -1.1 | -6.4 |
| Carbon Monoxide           | 1.9               | 0.5                           | 0.6                       | -3.6 | -1.4 | -1.2 | -5.2 |
| Aggregate trade           |                   |                               |                            |
| Regional terms of trade (% change) | 1.0 | 1.1 | 0.7 | 0.1 | 0.1 | -0.3 | -0.8 |
| Regional exports (% change) | 0.2 | -0.9 | -1.0 | -7.7 | -1.1 | -1.1 | -7.4 |
| Real exchange rate (% change) | 0.2 | 0.7 | 0.0 | 0.4 | 0.4 | -0.2 | 0.2 |
| International exports (% change) | 2.1 | 2.0 | 1.7 | -0.1 | -0.1 | -0.4 | -2.0 |
| Return to primary factors (% change) | 1.2 | -0.3 | 1.7 | 2.7 | -1.5 | 0.5 | 1.5 |
| Unskilled labor           | 1.2               | -0.3                          | 1.7                       | 2.7 | -1.5 | 0.5 | 1.5 |
| Skilled labor             | 1.6               | -0.9                          | 2.4                       | 2.5 | -2.4 | 0.8 | 0.9 |
| National capital          | 1.4               | -0.1                          | 0.7                       | -1.2 | -1.5 | -0.7 | -2.4 |
| Regional mobile capital   | 1.9               | 0.2                           | 1.6                       | -0.3 | -1.6 | -0.2 | -1.9 |
| Crude oil resources       | 0.2               | -0.1                          | -1.6                      | -5.8 | -0.3 | -1.7 | -5.7 |
| Natural gas resources     | 0.4               | -35.4                         | -45.9                     | -35.2 | -33.8 | -43.0 | -32.8 |
| Coal resources            | 0.6               | -12.2                         | -7.6                      | -0.5 | -12.2 | -7.3 | -0.9 |
| Factor adjustments        |                   |                               |                            |
| Unskilled labor (% changing sectors) | 0.8 | 0.9 | 1.2 | 2.5 | 0.7 | 0.7 | 2.3 |
| Skilled labor (% changing sector) | 0.9 | 1.4 | 1.5 | 3.0 | 1.3 | 1.0 | 2.7 |

Source: Authors’ estimates
### Table 23a. Piecemeal Sensitivity Analysis -- Welfare Impacts as a percent of GDP by Region from WTO Accession (percentage change from base year)

| Parameter being changed | Overall | Far | St. | North | Siberia | South | Urals | Moscow | Peters. | Tumen | Northwest |
|-------------------------|---------|-----|-----|-------|---------|-------|-------|--------|---------|-------|-----------|
| Central Results for reference | 4.0 | 4.1 | 4.8 | 4.4 | 3.9 | 4.4 | 3.2 | 4.2 | 5.2 | 2.9 | 5.6 |
| $esubc = 0.5$ | 3.6 | 3.7 | 4.4 | 4.1 | 3.6 | 4.0 | 3.0 | 3.9 | 4.3 | 2.7 | 5.2 |
| $esubc = 1.5$ | 4.1 | 4.2 | 4.9 | 4.6 | 4.0 | 4.5 | 3.3 | 4.4 | 5.4 | 2.9 | 5.7 |
| $esub = 2$ | 3.9 | 4.1 | 5.1 | 4.6 | 3.7 | 4.3 | 2.9 | 4.2 | 5.8 | 2.7 | 6.1 |
| $esub = 4$ | 3.8 | 3.9 | 4.5 | 4.2 | 3.8 | 4.2 | 3.2 | 4.1 | 4.8 | 2.8 | 5.2 |
| $esubs = 0.5$ | 3.1 | 3.2 | 3.7 | 3.4 | 3.1 | 3.5 | 2.5 | 3.4 | 4.1 | 2.2 | 4.4 |
| $esubs = 2.0$ | 5.3 | 5.6 | 6.5 | 6.1 | 5.3 | 5.8 | 4.3 | 5.6 | 6.2 | 4.0 | 7.6 |
| $esubva = 0.5$ | 4.0 | 3.9 | 4.9 | 4.2 | 3.9 | 4.4 | 3.1 | 4.3 | 5.1 | 2.9 | 5.3 |
| $esubva = 1.5$ | 4.0 | 4.1 | 4.7 | 4.4 | 3.9 | 4.3 | 3.2 | 4.2 | 5.2 | 2.9 | 5.7 |
| $etad = 10$ | 4.1 | 4.1 | 5.1 | 4.6 | 3.9 | 4.5 | 3.2 | 4.5 | 5.5 | 2.8 | 5.7 |
| $etad = 5$ | 3.8 | 4.1 | 4.4 | 4.2 | 3.9 | 4.2 | 3.2 | 3.8 | 4.8 | 2.9 | 5.5 |
| $etadx = 3$ | 3.9 | 4.0 | 4.7 | 4.1 | 3.9 | 4.3 | 3.2 | 4.1 | 5.1 | 3.0 | 5.5 |
| $etadx = 7$ | 4.0 | 4.1 | 4.8 | 4.4 | 3.9 | 4.4 | 3.2 | 4.3 | 5.3 | 2.8 | 5.6 |
| $etaf = 12.5$ | 3.4 | 3.5 | 4.3 | 3.9 | 3.3 | 3.8 | 2.7 | 3.7 | 4.7 | 2.4 | 5.0 |
| $etaf = 17.5$ | 4.5 | 4.6 | 5.2 | 4.9 | 4.4 | 4.9 | 3.7 | 4.7 | 5.6 | 3.3 | 6.1 |
| $sigmadm = 4$ | 3.9 | 4.0 | 4.6 | 4.3 | 3.9 | 4.2 | 3.2 | 4.1 | 4.9 | 2.9 | 5.3 |
| $sigmadm = 2$ | 3.9 | 4.0 | 5.0 | 4.5 | 3.7 | 4.3 | 2.9 | 4.1 | 5.6 | 2.6 | 5.9 |

Source: Authors' calculations.

Notes:

a. The piecemeal sensitivity analysis employs central values for all parameters (see below) other than the tested parameter.
b. Hicksian equivalent variation as a percent of the value of consumption in the benchmark equilibrium.

| Parameter | Central value | Definitions of the parameter (see figures, especially figure 5) |
|-----------|---------------|---------------------------------------------------------------|
| $esubc$ | 1.25 | Elasticity of substitution in consumer demand for more precise elasticity structure. |
| $esubs$ | 1.25 | Elasticity of substitution between value-added and business services |
| $sigmadm$ | 3 | "Armington" elasticity of substitution between imports and domestic goods |
| $etaf$ | 15 | Elasticity of multinational service firm supply with respect to price of output |
| $etad$ | 7.5 | Elasticity of Russian service firm supply with respect to price of output |
| $esub$ | 3 | Elasticity of substitution between firm varieties in imperfectly competitive sectors |
| $esubva$ | 1 | Elasticity of substitution between primary factors of production in value added |
| $etadx$ | 5 | Elasticity of transformation (domestic output versus exports) |
## Table 23b. Piecemeal Sensitivity Analysis – Carbone Dioxide Emissions by Region from WTO Accession (percentage change from base year)

| Parameter being changed | Overall average | Central | East | North | Siberia | South | Urals | Moscow | St. Peters | Tumen | Northwest |
|-------------------------|----------------|---------|------|-------|---------|-------|-------|--------|-----------|-------|-----------|
| Central Results for reference | 4.3 | 6.1 | 4.9 | 5.2 | 4.6 | 4.4 | 3.3 | 2.4 | 8.9 | 3.7 | 8.2 |
| esubc = 0.5 | 4.3 | 5.9 | 5.0 | 5.2 | 4.6 | 4.3 | 3.3 | 2.6 | 9.3 | 3.7 | 8.0 |
| esubc = 1.5 | 4.3 | 6.2 | 4.9 | 5.2 | 4.6 | 4.5 | 3.3 | 2.3 | 8.9 | 3.7 | 8.2 |
| esub = 2 | 3.6 | 5.3 | 4.8 | 5.0 | 3.6 | 3.8 | 2.6 | 1.8 | 7.9 | 3.2 | 8.2 |
| esub = 4 | 4.4 | 6.3 | 4.7 | 5.1 | 4.9 | 4.5 | 3.6 | 2.5 | 9.0 | 3.7 | 8.0 |
| esubs = 0.5 | 3.0 | 4.8 | 3.0 | 3.3 | 3.3 | 3.1 | 2.5 | 1.4 | 6.2 | 2.2 | 6.0 |
| esubs = 2.0 | 6.3 | 8.4 | 8.1 | 8.4 | 6.6 | 6.5 | 4.6 | 3.9 | 10.8 | 6.0 | 12.1 |
| esubva = 0.5 | 4.3 | 6.0 | 5.0 | 4.7 | 4.8 | 4.5 | 3.4 | 2.3 | 8.4 | 3.6 | 7.8 |
| esubva = 1.5 | 4.3 | 6.2 | 4.9 | 5.2 | 4.5 | 4.4 | 3.3 | 2.4 | 9.1 | 3.7 | 8.3 |
| etad = 10 | 4.1 | 6.1 | 4.7 | 4.9 | 4.3 | 4.2 | 3.0 | 2.2 | 9.6 | 3.5 | 7.8 |
| etad = 5 | 4.6 | 6.3 | 5.2 | 5.7 | 5.0 | 4.8 | 3.9 | 2.7 | 8.2 | 4.0 | 8.8 |
| etadx = 3 | 3.9 | 5.6 | 4.8 | 4.3 | 4.3 | 4.0 | 2.9 | 2.3 | 7.7 | 3.6 | 7.5 |
| etadx = 7 | 4.6 | 6.6 | 5.1 | 5.5 | 5.0 | 4.8 | 3.7 | 2.4 | 10.2 | 3.7 | 8.7 |
| etaf = 12.5 | 3.6 | 5.3 | 4.2 | 4.4 | 3.6 | 3.7 | 2.6 | 1.9 | 7.6 | 3.1 | 7.3 |
| etaf = 17.5 | 5.0 | 6.9 | 5.4 | 5.8 | 5.5 | 5.0 | 4.0 | 2.8 | 10.0 | 4.2 | 8.9 |
| sigmadm = 4 | 4.5 | 6.4 | 4.8 | 5.2 | 4.9 | 4.5 | 3.6 | 2.5 | 9.2 | 3.7 | 8.4 |
| sigmadm = 2 | 3.7 | 5.4 | 4.7 | 4.9 | 3.7 | 3.8 | 2.6 | 1.9 | 7.8 | 3.3 | 7.8 |

Source: Authors' calculations.

Notes:

a. The piecemeal sensitivity analysis employs central values for all parameters (see below) other than the tested parameter.

| Parameter | Central value | Definitions of the parameter (see figures, especially figure 5) |
|-----------|---------------|---------------------------------------------------------------|
| esubc     | 1.25          | Elasticity of substitution in consumer demand                 |
| esubs     | 1.25          | Elasticity of substitution between value-added and business services |
| sigmadm   | 3             | "Armington" elasticity of substitution between imports and domestic goods |
| etaf      | 15            | Elasticity of multinational service firm supply with respect to price of output |
| etad      | 7.5           | Elasticity of Russian service firm supply with respect to price of output |
| esub      | 3             | Elasticity of substitution between firm varieties in imperfectly competitive sectors |
| esubva    | 1             | Elasticity of substitution between primary factors of production in value added |
| etadx     | 5             | Elasticity of transformation (domestic output versus exports)    |
Table 23c. Piecemeal Sensitivity Analysis – Sulphur Dioxide Emissions by Region from WTO Accession (percentage change from base year)

| Parameter being changed | Overall Average | Central | Far East | North | Siberia | South | Urals | Moscow | St. Peters. | Tumen | Northwest |
|-------------------------|----------------|---------|---------|-------|---------|-------|-------|--------|------------|-------|---------|
| Central Results for reference | 6.2 | 11.2 | 4.7 | 7.7 | 4.1 | 10.6 | 9.2 | 4.5 | 28.8 | 3.5 | 10.1 |
| esubc = 0.5 | 6.5 | 11.0 | 5.1 | 8.0 | 4.1 | 10.5 | 9.2 | 5.2 | 35.5 | 3.5 | 10.0 |
| esubc = 1.5 | 6.2 | 11.2 | 4.6 | 7.6 | 4.1 | 10.6 | 9.2 | 4.3 | 28.7 | 3.5 | 10.1 |
| esub = 2 | 5.2 | 8.8 | 4.2 | 6.4 | 3.6 | 7.9 | 7.2 | 2.9 | 20.9 | 3.1 | 9.7 |
| esub = 4 | 6.7 | 11.9 | 5.1 | 8.5 | 4.4 | 11.7 | 10.2 | 5.3 | 31.9 | 3.5 | 10.1 |
| esubs = 0.5 | 5.7 | 9.7 | 4.5 | 6.9 | 3.8 | 9.5 | 8.9 | 3.8 | 25.5 | 2.3 | 8.0 |
| esubs = 2.0 | 7.0 | 13.7 | 5.3 | 9.0 | 4.5 | 12.5 | 9.7 | 5.8 | 31.3 | 5.4 | 13.8 |
| esubva = 0.5 | 5.8 | 10.9 | 4.1 | 5.4 | 3.7 | 10.6 | 8.9 | 4.2 | 26.4 | 3.5 | 9.7 |
| esubva = 1.5 | 6.4 | 11.3 | 5.0 | 7.9 | 4.2 | 10.6 | 9.4 | 4.7 | 29.9 | 3.5 | 10.2 |
| etad = 10 | 6.7 | 11.8 | 4.8 | 8.1 | 4.4 | 11.3 | 10.0 | 5.0 | 33.7 | 3.3 | 9.5 |
| etad = 5 | 5.7 | 10.6 | 4.8 | 7.3 | 3.7 | 9.8 | 8.4 | 3.9 | 23.0 | 3.7 | 11.2 |
| etad = 3 | 5.8 | 9.8 | 4.3 | 5.7 | 4.0 | 9.4 | 8.6 | 4.6 | 24.9 | 3.6 | 8.5 |
| etad = 7 | 6.6 | 12.4 | 5.2 | 8.0 | 4.1 | 11.7 | 9.8 | 4.6 | 33.6 | 3.4 | 11.6 |
| etaf = 12.5 | 6.1 | 9.9 | 5.4 | 7.7 | 4.3 | 9.6 | 8.7 | 4.1 | 25.4 | 2.9 | 8.9 |
| etaf = 17.5 | 6.3 | 12.3 | 4.2 | 7.6 | 3.8 | 11.4 | 9.8 | 4.9 | 32.0 | 4.0 | 11.0 |
| sigmadm = 4 | 6.7 | 11.8 | 5.1 | 8.1 | 4.4 | 11.4 | 10.0 | 5.1 | 32.1 | 3.5 | 10.5 |
| sigmadm = 2 | 5.4 | 9.4 | 4.3 | 6.9 | 3.8 | 8.5 | 7.8 | 3.4 | 22.2 | 3.1 | 9.4 |

Source: Authors’ calculations.

Notes:

a. The piecemeal sensitivity analysis employs central values for all parameters (see below) other than the tested parameter.

Parameter | Central Value | Definitions of the parameter (see figures, especially figure 5)
--- | --- | ---
esubc | 1.25 | Elasticity of substitution in consumer demand
esubs | 1.25 | Elasticity of substitution between value-added and business services
sigmadm | 3 | "Armington" elasticity of substitution between imports and domestic goods
etaf | 15 | Elasticity of multinational service firm supply with respect to price of output
etad | 7.5 | Elasticity of Russian service firm supply with respect to price of output
esub | 3 | Elasticity of substitution between firm varieties in imperfectly competitive sectors
esubs | 1 | Elasticity of substitution between primary factors of production in value added
etad | 5 | Elasticity of transformation (domestic output versus exports)
Table 23d. Piecemeal Sensitivity Analysis – Nitrogen Oxide Emissions by Region from WTO Accession (percentage change from base year)

| Parameter being changed | Overall average | Central | East | North | Siberia | South | Urals | Moscow | St. Peters. | Tumen | Northwest |
|-------------------------|----------------|---------|------|-------|---------|-------|-------|--------|------------|-------|-----------|
|                         |                | Central | East | North | Siberia | South | Urals | Moscow | St. Peters. | Tumen | Northwest |
| Central Results for reference | 2.8 | 3.0 | 2.9 | 3.7 | 2.8 | 3.6 | 2.4 | 1.7 | 4.6 | 2.8 | 6.8 |
| $e_{subc} = 0.5$       | 2.8 | 3.0 | 3.0 | 3.8 | 2.8 | 3.6 | 2.4 | 2.2 | 3.4 | 2.8 | 6.8 |
| $e_{subc} = 1.5$       | 2.8 | 3.0 | 2.9 | 3.7 | 2.8 | 3.6 | 2.4 | 1.5 | 4.6 | 2.8 | 6.8 |
| $e_{sub} = 2$          | 2.4 | 2.6 | 3.1 | 3.6 | 2.4 | 3.1 | 1.8 | 1.2 | 4.6 | 2.6 | 6.7 |
| $e_{sub} = 4$          | 2.9 | 3.0 | 2.7 | 3.7 | 2.9 | 3.7 | 2.6 | 1.8 | 4.5 | 2.8 | 6.7 |
| $e_{subs} = 0.5$       | 1.5 | 1.7 | 0.8 | 1.8 | 1.7 | 2.1 | 1.4 | 0.7 | 2.1 | 1.6 | 4.5 |
| $e_{subs} = 2.0$       | 4.8 | 5.2 | 6.5 | 7.0 | 4.7 | 6.0 | 4.0 | 3.3 | 6.9 | 4.8 | 11.1 |
| $e_{subva} = 0.5$      | 2.8 | 3.0 | 2.9 | 2.6 | 2.8 | 3.7 | 2.5 | 1.7 | 4.5 | 2.9 | 6.6 |
| $e_{subva} = 1.5$      | 2.8 | 3.0 | 2.9 | 3.7 | 2.8 | 3.6 | 2.4 | 1.7 | 4.7 | 2.8 | 6.9 |
| $etad = 10$            | 2.7 | 3.0 | 2.6 | 3.5 | 2.8 | 3.5 | 2.3 | 1.8 | 4.8 | 2.6 | 6.9 |
| $etad = 5$             | 3.0 | 3.0 | 3.3 | 4.0 | 2.9 | 3.8 | 2.7 | 1.6 | 4.6 | 3.2 | 6.9 |
| $etadx = 3$            | 2.7 | 2.9 | 2.8 | 2.5 | 2.8 | 3.4 | 2.4 | 1.8 | 4.5 | 2.9 | 6.7 |
| $etadx = 7$            | 2.9 | 3.0 | 3.0 | 3.8 | 2.9 | 3.8 | 2.5 | 1.7 | 4.8 | 2.8 | 6.9 |
| $etaf = 12.5$          | 2.4 | 2.5 | 2.7 | 3.4 | 2.5 | 3.1 | 2.0 | 1.4 | 4.1 | 2.4 | 6.2 |
| $etaf = 17.5$          | 3.2 | 3.4 | 3.0 | 4.0 | 3.1 | 4.0 | 2.9 | 2.0 | 5.1 | 3.2 | 7.3 |
| $sigmadm = 4$          | 2.9 | 3.1 | 2.8 | 3.7 | 3.0 | 3.7 | 2.6 | 1.8 | 4.7 | 2.9 | 7.2 |
| $sigmadm = 2$          | 2.4 | 2.5 | 2.9 | 3.6 | 2.4 | 3.1 | 1.8 | 1.3 | 4.4 | 2.6 | 6.3 |

Source: Authors’ calculations.

Notes:

a. The piecemeal sensitivity analysis employs central values for all parameters (see below) other than the tested parameter.

| Parameter | Central value | Definitions of the parameter (see figures, especially figure 5) |
|-----------|--------------|---------------------------------------------------------------|
| $e_{subc}$| 1.25         | Elasticity of substitution in consumer demand                |
| $e_{subbs}$| 1.25         | Elasticity of substitution between value-added and business services |
| $sigmadm$ | 3            | "Armington" elasticity of substitution between imports and domestic goods |
| $etaf$    | 15           | Elasticity of multinational service firm supply with respect to price of output |
| $etad$    | 7.5          | Elasticity of Russian service firm supply with respect to price of output |
| $esub$    | 3            | Elasticity of substitution between firm varieties in imperfectly competitive sectors |
| $esubva$  | 1            | Elasticity of substitution between primary factors of production in value added |
| $etadx$   | 5            | Elasticity of transformation (domestic output versus exports)  |
Table 23e. Piecemeal Sensitivity Analysis – Hydrocarbon Emissions by Region from WTO Accession (percentage change from base year)

| Parameter being changed | Overall average | Central | East | North | Siberia | South | Urals | Moscow | St. Petersburg | Tumen | Northwest |
|-------------------------|----------------|---------|------|-------|---------|-------|-------|--------|---------------|-------|-----------|
| **Central Results for reference** | | 1.7 | 2.6 | 8.6 | 4.1 | 2.7 | 1.8 | -0.1 | -2.0 | 4.5 | 1.9 | 4.8 |
| **esubc = 0.5** | 1.2 | 1.1 | 9.1 | 3.3 | 2.3 | 0.6 | -0.6 | -3.4 | 2.8 | 1.8 | 3.3 |
| **esubc = 1.5** | 1.9 | 3.1 | 8.5 | 4.4 | 2.9 | 2.2 | 0.1 | -1.5 | 5.3 | 2.0 | 5.4 |
| **esub = 2** | 1.8 | 2.9 | 7.4 | 4.2 | 2.3 | 2.1 | 0.4 | 0.4 | 5.0 | 1.8 | 5.3 |
| **esub = 4** | 1.6 | 2.4 | 8.8 | 4.1 | 2.8 | 1.6 | -0.4 | -3.1 | 4.3 | 1.9 | 4.7 |
| **esubs = 0.5** | -0.5 | -2.1 | 7.5 | 0.9 | 0.4 | -1.6 | -2.2 | -5.7 | -2.1 | 0.7 | -1.1 |
| **esubs = 2.0** | 5.2 | 10.5 | 10.1 | 9.5 | 6.5 | 7.3 | 3.1 | 3.9 | 11.2 | 3.9 | 15.8 |
| **esubva = 0.5** | 1.9 | 2.8 | 8.8 | 3.7 | 3.1 | 2.0 | 0.1 | -1.5 | 4.6 | 2.0 | 5.0 |
| **esubva = 1.5** | 1.6 | 2.5 | 8.5 | 4.0 | 2.6 | 1.7 | -0.2 | -2.2 | 4.4 | 1.9 | 4.8 |
| **etad = 10** | 1.2 | 1.6 | 8.8 | 3.5 | 2.3 | 0.9 | -0.6 | -2.7 | 3.5 | 1.6 | 3.9 |
| **etad = 5** | 2.4 | 4.1 | 8.5 | 5.0 | 3.4 | 3.0 | 0.6 | -0.8 | 6.1 | 2.4 | 6.4 |
| **etadx = 3** | 1.7 | 2.4 | 8.3 | 3.6 | 2.7 | 1.9 | 0.0 | -1.8 | 4.5 | 2.0 | 5.0 |
| **etadx = 7** | 1.7 | 2.6 | 9.1 | 4.1 | 2.8 | 1.6 | -0.2 | -2.3 | 4.3 | 1.9 | 4.5 |
| **etaf = 12.5** | 1.3 | 2.1 | 7.4 | 3.4 | 1.9 | 1.3 | -0.2 | -1.6 | 3.7 | 1.6 | 4.3 |
| **etaf = 17.5** | 2.1 | 3.0 | 9.7 | 4.7 | 3.5 | 2.1 | 0.0 | -2.4 | 5.2 | 2.2 | 5.3 |
| **sigmadm = 4** | 1.6 | 2.5 | 8.9 | 4.1 | 2.7 | 1.6 | -0.4 | -3.1 | 4.4 | 1.9 | 5.1 |
| **sigmadm = 2** | 1.8 | 2.9 | 7.5 | 4.1 | 2.4 | 2.1 | 0.4 | 0.1 | 4.7 | 1.8 | 4.8 |

Source: Authors’ calculations.

Notes:

a. The piecemeal sensitivity analysis employs central values for all parameters (see below) other than the tested parameter.

| Parameter | Central value for more precise elasticity structure | Definitions of the parameter (see figures, especially figure 5) |
|-----------|-----------------------------------------------|---------------------------------------------------------|
| esubc     | 1.25 Elasticity of substitution in consumer demand |
| esubs     | 1.25 Elasticity of substitution between value-added and business services |
| sigmadm   | 3 "Armington" elasticity of substitution between imports and domestic goods |
| etaf      | 15 Elasticity of multinational service firm supply with respect to price of output |
| etad      | 7.5 Elasticity of Russian service firm supply with respect to price of output |
| esub      | 3 Elasticity of substitution between firm varieties in imperfectly competitive sectors |
| esubva    | 1 Elasticity of substitution between primary factors of production in value added |
| etadx     | 5 Elasticity of transformation (domestic output versus exports) |
Table 23f. Piecemeal Sensitivity Analysis – Particulate Matter Emissions by Region from WTO Accession (percentage change from base year)

| Parameter being changed | Overall | Central | Far | East | North | Siberia | South | Urals | Moscow | St. Petersburg | Tumen | Northwest |
|-------------------------|---------|---------|-----|------|-------|---------|-------|-------|---------|--------------|-------|-----------|
|                         | average | Central | East | North | Siberia | South | Urals | Moscow | St. Petersburg | Tumen | Northwest |
| Central Results for reference | 3.0 | 2.6 | 2.5 | 4.0 | 2.9 | 2.9 | 3.1 | 1.5 | 5.9 | 2.8 | 5.0 |
| esubc = 0.5 | 3.0 | 2.7 | 2.6 | 4.2 | 2.9 | 3.1 | 3.1 | 2.0 | 6.2 | 2.8 | 5.1 |
| esubc = 1.5 | 3.0 | 2.6 | 2.5 | 3.9 | 2.9 | 2.9 | 3.2 | 1.3 | 5.8 | 2.8 | 4.9 |
| esub = 2 | 2.6 | 2.6 | 2.5 | 3.7 | 2.5 | 2.5 | 2.3 | 1.0 | 5.1 | 2.4 | 5.0 |
| esub = 4 | 3.1 | 2.6 | 2.3 | 4.1 | 3.0 | 3.0 | 3.4 | 1.6 | 6.0 | 2.9 | 4.8 |
| esubs = 0.5 | 2.0 | 1.4 | 0.7 | 2.7 | 1.9 | 1.7 | 2.3 | 0.5 | 3.8 | 2.0 | 3.0 |
| esubs = 2.0 | 4.6 | 4.7 | 5.8 | 6.2 | 4.4 | 4.9 | 4.5 | 3.1 | 7.7 | 4.1 | 8.6 |
| esubva = 0.5 | 3.0 | 2.6 | 2.5 | 2.9 | 2.8 | 3.0 | 3.2 | 1.5 | 5.6 | 2.8 | 4.8 |
| esubva = 1.5 | 3.0 | 2.6 | 2.5 | 4.0 | 2.9 | 2.9 | 3.1 | 1.5 | 6.0 | 2.8 | 5.0 |
| etad = 10 | 3.0 | 2.7 | 2.3 | 4.0 | 2.9 | 2.9 | 3.1 | 1.6 | 6.4 | 2.7 | 5.0 |
| etad = 5 | 3.1 | 2.6 | 3.0 | 4.1 | 2.9 | 3.1 | 3.3 | 1.4 | 5.3 | 3.0 | 5.1 |
| etadx = 3 | 2.9 | 2.6 | 2.5 | 2.9 | 2.8 | 2.8 | 3.1 | 1.6 | 5.5 | 2.9 | 5.0 |
| etadx = 7 | 3.1 | 2.6 | 2.6 | 4.1 | 2.9 | 3.1 | 3.3 | 1.4 | 6.4 | 2.8 | 5.0 |
| etaf = 12.5 | 2.6 | 2.2 | 2.4 | 3.7 | 2.6 | 2.5 | 2.7 | 1.2 | 5.1 | 2.4 | 4.5 |
| etaf = 17.5 | 3.3 | 3.0 | 2.6 | 4.2 | 3.1 | 3.3 | 3.6 | 1.8 | 6.5 | 3.2 | 5.4 |
| sigmadm = 4 | 3.2 | 2.7 | 2.4 | 4.1 | 3.1 | 3.0 | 3.5 | 1.6 | 6.2 | 2.9 | 5.3 |
| sigmadm = 2 | 2.5 | 2.2 | 2.7 | 3.8 | 2.5 | 2.5 | 2.4 | 1.1 | 5.0 | 2.5 | 4.6 |

Source: Authors’ calculations.

Notes:
- The piecemeal sensitivity analysis employs central values for all parameters (see below) other than the tested parameter.

| Parameter | Central value | Definitions of the parameter (see figures, especially figure 5) |
|-----------|--------------|---------------------------------------------------------------|
| esubc     | 1.25         | Elasticity of substitution in consumer demand                 |
| esubs     | 1.25         | Elasticity of substitution between value-added and business services |
| sigmadm   | 3            | "Armington" elasticity of substitution between imports and domestic goods |
| etaf      | 15           | Elasticity of multinational service firm supply with respect to price of output |
| etad      | 7.5          | Elasticity of Russian service firm supply with respect to price of output |
| esub      | 3            | Elasticity of substitution between firm varieties in imperfectly competitive sectors |
| esubva    | 1            | Elasticity of substitution between primary factors of production in value added |
| etadx     | 5            | Elasticity of transformation (domestic output versus exports) |

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Table 23g. Piecemeal Sensitivity Analysis –Volatile Organic Components Emissions by Region from WTO Accession (percentage change from base year)

| Parameter being changed | Overall | Far | East | North | Siberia | South | Urals | Moscow | Peters | Tumen | Northwest |
|-------------------------|---------|-----|------|-------|---------|-------|-------|--------|--------|-------|-----------|
|                         | Central | East | North | Siberia | South | Urals | Moscow | Peters | Tumen | Northwest |
| Central Results for reference | 2.7 | 6.2 | 4.5 | 2.9 | 3.0 | 3.5 | 1.8 | 3.8 | 1.8 | 2.8 | 13.3 |
| esubc = 0.5 | 2.5 | 5.7 | 4.1 | 2.7 | 2.6 | 3.3 | 1.7 | 3.8 | 0.0 | 2.8 | 12.9 |
| esubc = 1.5 | 2.7 | 6.3 | 4.6 | 2.9 | 3.1 | 3.6 | 1.9 | 3.8 | 0.0 | 2.8 | 13.5 |
| esub = 2 | 2.2 | 5.7 | 4.7 | 2.9 | 2.3 | 3.0 | 1.2 | 2.0 | 2.7 | 2.3 | 12.1 |
| esub = 4 | 2.8 | 6.2 | 4.3 | 2.8 | 3.1 | 3.6 | 2.0 | 4.6 | 1.4 | 2.9 | 14.0 |
| esubs = 0.5 | 1.9 | 4.9 | 2.9 | 1.8 | 1.2 | 2.6 | 1.0 | 3.1 | -0.7 | 2.4 | 11.8 |
| esubs = 2.0 | 3.8 | 8.4 | 7.1 | 4.6 | 5.7 | 5.1 | 3.1 | 4.9 | 3.9 | 3.3 | 16.4 |
| esubva = 0.5 | 2.7 | 5.8 | 4.4 | 2.2 | 3.1 | 3.7 | 2.0 | 3.1 | 1.8 | 2.8 | 12.8 |
| esubva = 1.5 | 2.6 | 6.3 | 4.5 | 2.8 | 2.9 | 3.5 | 1.8 | 4.1 | 1.8 | 2.8 | 13.6 |
| etad = 10 | 2.5 | 6.3 | 4.2 | 2.6 | 2.6 | 3.4 | 1.7 | 3.2 | 1.1 | 2.7 | 15.4 |
| etad = 5 | 2.8 | 5.8 | 4.8 | 3.1 | 3.5 | 3.8 | 2.0 | 4.5 | 2.7 | 2.8 | 10.9 |
| etadx = 3 | 2.7 | 6.3 | 4.1 | 2.3 | 2.7 | 3.6 | 1.9 | 3.3 | 2.4 | 2.9 | 14.3 |
| etadx = 7 | 2.6 | 6.0 | 4.8 | 2.8 | 3.3 | 3.5 | 1.8 | 4.4 | 1.1 | 2.7 | 12.6 |
| etaf = 12.5 | 2.1 | 5.5 | 4.0 | 2.4 | 2.0 | 3.0 | 1.3 | 2.9 | 1.6 | 2.4 | 12.8 |
| etaf = 17.5 | 3.1 | 6.6 | 4.9 | 3.2 | 3.8 | 4.0 | 2.3 | 4.6 | 1.9 | 3.1 | 13.8 |
| sigmadm = 4 | 2.8 | 6.5 | 4.7 | 2.8 | 3.1 | 3.7 | 1.9 | 4.5 | 1.3 | 2.9 | 14.5 |
| sigmadm = 2 | 2.2 | 5.7 | 4.2 | 2.8 | 2.4 | 3.1 | 1.4 | 2.6 | 2.6 | 2.3 | 11.9 |

Source: Authors’ calculations.

Notes:

a. The piecemeal sensitivity analysis employs central values for all parameters (see below) other than the tested parameter.

| Parameter | Central Value | Definitions of the parameter (see figures, especially figure 5) |
|-----------|---------------|-------------------------------------------------------------|
| esubc     | 1.25          | Elasticity of substitution in consumer demand               |
| esubs     | 1.25          | Elasticity of substitution between value-added and business services |
| sigmadm   | 3             | “Armington” elasticity of substitution between imports and domestic goods |
| etaf      | 15            | Elasticity of multinational service firm supply with respect to price of output |
| etad      | 7.5           | Elasticity of Russian service firm supply with respect to price of output |
| esub      | 3             | Elasticity of substitution between firm varieties in imperfectly competitive sectors |
| esubva    | 1             | Elasticity of substitution between primary factors of production in value added |
| etadx     | 5             | Elasticity of transformation (domestic output versus exports) |

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Table 23h. Piecemeal Sensitivity Analysis –Carbon Monoxide Emissions by Region from WTO Accession (percentage change from base year)

| Parameter being changed | Overall | Central | East | North | Siberia | South | Urals | Moscow | Peters. | Tumen | Northwest |
|-------------------------|---------|---------|------|-------|---------|-------|-------|--------|---------|-------|-----------|
|                         | average| Central | East | North | Siberia | South | Urals | Moscow | Peters. | Tumen | Northwest |
| Central Results for reference | 4.5 | 17.0 | 3.5 | 4.8 | 3.4 | 5.8 | 4.4 | 9.9 | 13.6 | 2.7 | 9.8 |
| esubc = 0.5 | 4.5 | 16.5 | 3.5 | 4.9 | 3.4 | 5.5 | 4.4 | 10.4 | 14.6 | 2.7 | 9.7 |
| esubc = 1.5 | 4.5 | 17.2 | 3.6 | 4.8 | 3.4 | 5.9 | 4.5 | 9.7 | 13.7 | 2.7 | 9.8 |
| esub = 2 | 3.6 | 13.4 | 3.5 | 4.3 | 3.1 | 4.5 | 3.3 | 6.0 | 10.8 | 2.3 | 9.4 |
| esub = 4 | 4.8 | 18.3 | 3.5 | 5.2 | 3.6 | 6.2 | 4.9 | 12.1 | 14.7 | 2.8 | 9.7 |
| esubs = 0.5 | 3.8 | 15.5 | 2.5 | 3.9 | 2.9 | 4.9 | 3.9 | 9.8 | 10.6 | 2.3 | 8.0 |
| esubs = 2.0 | 5.4 | 19.7 | 5.5 | 6.4 | 4.3 | 7.2 | 5.3 | 10.2 | 16.1 | 3.3 | 8.0 |
| esubva = 0.5 | 4.3 | 16.7 | 3.2 | 3.4 | 3.2 | 5.9 | 4.4 | 8.6 | 12.7 | 2.7 | 9.5 |
| esubva = 1.5 | 4.5 | 17.2 | 3.7 | 4.9 | 3.5 | 5.7 | 4.4 | 10.5 | 14.1 | 2.7 | 9.9 |
| etad = 10 | 4.6 | 18.0 | 3.3 | 4.9 | 3.6 | 5.9 | 4.6 | 10.9 | 15.4 | 2.7 | 9.1 |
| etad = 5 | 4.3 | 16.1 | 4.0 | 4.8 | 3.3 | 5.6 | 4.3 | 8.8 | 11.7 | 2.8 | 11.0 |
| etadx = 3 | 4.3 | 14.8 | 3.3 | 3.6 | 3.4 | 5.5 | 4.3 | 9.8 | 12.2 | 2.8 | 8.1 |
| etadx = 7 | 4.7 | 19.1 | 3.9 | 4.9 | 3.4 | 6.1 | 4.6 | 10.3 | 15.5 | 2.6 | 11.3 |
| etaf = 12.5 | 4.1 | 15.2 | 3.8 | 4.7 | 3.5 | 5.1 | 3.9 | 9.4 | 12.1 | 2.3 | 8.6 |
| etaf = 17.5 | 4.8 | 18.7 | 3.3 | 5.0 | 3.3 | 6.3 | 4.9 | 10.4 | 15.1 | 3.1 | 10.8 |
| sigmadm = 4 | 4.8 | 18.0 | 3.6 | 5.0 | 3.7 | 6.1 | 4.8 | 11.6 | 14.9 | 2.8 | 10.1 |
| sigmadm = 2 | 3.8 | 14.5 | 3.5 | 4.5 | 3.1 | 4.8 | 3.6 | 7.1 | 11.2 | 2.3 | 9.1 |

Source: Authors’ calculations.

Notes:

a. The piecemeal sensitivity analysis employs central values for all parameters (see below) other than the tested parameter.

| Parameter | Central value | Definitions of the parameter (see figures, especially figure 5) for more precise elasticity structure. |
|-----------|--------------|--------------------------------------------------------------------------------------------------|
| esubc     | 1.25         | Elasticity of substitution in consumer demand                                                      |
| subs      | 1.25         | Elasticity of substitution between value-added and business services                                |
| sigmadm   | 3            | “Armington” elasticity of substitution between imports and domestic goods                          |
| etaf      | 15           | Elasticity of multinational service firm supply with respect to price of output                   |
| etad      | 7.5          | Elasticity of Russian service firm supply with respect to price of output                           |
| esubva    | 1            | Elasticity of substitution between firm varieties in imperfectly competitive sectors               |
| etadx     | 5            | Elasticity of transformation (domestic output versus exports)                                     |
Figures

Figure 1. Demand for Representative CRTS good $g$ in Region $r$

$\sigma = \text{sigmadm} \neq$

Armington Aggregate Demand
for CRTS good $g$ in RM $r$

$\sigma = 1.5 \times \text{sigmadm}$

Russia goods

Rest of World Imports

$\sigma = 2 \times \text{sigmadm}$

Own Regional Market

Other Russian Imports

Imports from Regional Market 1

Imports from Regional Market $m$

Imports from Regional Market $q$

$\neq$ sigmadm = 3 in CRTS sectors, except in OTH (other goods producing sectors). For OTH we rely on estimates from Ivanova (2005).
Figure 2. Demand for Representative Dixit-Stiglitz (IRTS) good g in Regional Market r

We take $\sigma = 3$, except based on Ivanova (2005), we take $\sigma = 3.1$ in MWO; $\sigma = 2.6$ in TPP; $\sigma = 2.5$ in CNM; and $\sigma = 1.8$ in OTI.
Figure 3. Demand for Representative Business Service $s$ (Dixit-Stiglitz) Sectors in Regional Market (RM) $m$
Figure 4. Sales for Constant Returns to Scale Sectors: Determined by Constant Elasticity of Transformation Production Structure

*The elasticity of transformation is equal to 4 in crude oil, natural gas and coal; otherwise 5.*
Figure 5: Structure of Production (other than fossil fuels)
Figure 6: Structure of Production in fossil fuels

Notes:
\[ \alpha = \text{esub}(g, r) \] values:
for coal: \[ \sigma = \text{esub}("coal", r) = 4 \]
for gas: \[ \sigma = \text{esub}("gas", r) = 1 \]
for crude oil: \[ \sigma = \text{esub}("crude", r) = 1 \]
Figure 7: CO2 emissions across sectors and final demand (label “c”) for 2001 (in million tons of CO2)
Figure 8: Base-year CO2 emission intensities from fossil fuel combustion (direct) and indirect emissions from electricity inputs (ELE) (in kg per ruble)°

° Key: mean – average across all sectors; all – average across all sectors including final consumption; c – final consumption
Figure 9: Base-year pollution intensities – other than CO2 (in grams per ruble)
Figure 10: Energy cost shares across industries
Appendix: Environmental Database of the Model: 
Documentation of the Sources and Construction

A.1. Non-CO2 emission accounting

1.1. The environmental component of the data for the WTO model consists of emissions of seven air pollutants: PM, SO₂, CO, NOₓ, CₙHₘ, VOC, and CO₂, which constitute the most commonly observed source of air pollution in the Russian Federation (Table A1). Data on non-CO2 emissions comes from the SUST-RUS database, which in turn relies on several publications of the government of Russia as explained below. The CO₂ emission accounting is based on fuel-specific emission intensity and is discussed in part 0.

Table A1. Pollutants (p) in the model

| Pollutant                   | Abbreviation | Environmental impacts                                      | Health effects                                       |
|-----------------------------|--------------|------------------------------------------------------------|-----------------------------------------------------|
| Particulate matter          | PM           | Soiling and damage to materials, smog                      | Lung cancer, asthma, birth defects                   |
| Sulphur dioxide             | SO₂          | Acid rain, atmospheric particulates                         | Asthmatic, alterations in the lungs                  |
| Carbon monoxide             | CO           | Leads to increased concentrations of methane and tropospheric ozone | Headache, nausea, dizziness, seizures                |
| Nitrogen oxide              | NOₓ          | Acid rain, eutrophication in coastal waters                | Difficulty breathing, fluid build-up in the lungs    |
| Hydrocarbons                | CₙHₘ         | Smog, leads to increased concentrations of tropospheric ozone | Affects the central nervous system                    |
| Volatile organic components | VOC          | Damage to soil and groundwater                             | Damage to liver, cancer, headaches                   |
| Carbon dioxide              | CO₂          | Climate change, ocean acidification                        | High concentration: rapid heart rate, clumsiness     |

Source: SUST-RUS 2012(a); EPA: Health Effects of Air Pollution
1.2. The SUST-RUS database contains data on air pollution for 32 industries of 7 Federal Districts of the Russian Federation in year 2006. The industry list (s) is presented in Table A2, while set of regions (r) (Federal Districts) is presented in Table A3.

1.3. Total emissions of non-CO2 pollutants 
\( p \in NCO_2, \text{where } NCO_2 = \{ PM, SO_2, CO, NO_x, C_nH_m, VOC \} \) by industries at national level \( (NATEMIT_{s,p}) \) are presented in Table A4. These are data for year 2006, by industry and type of pollutant from industrial stationary and mobile sources in thousands of tons. The main source of these data is Ministry of Natural Resources and Environment of the Russian Federation (2007).

1.4. Aggregate regional emissions by the type of non-CO2 pollutants \( (REGEMIT_{r,p}) \) are presented in Table A5.

1.5. Non-CO2 pollution is assumed to be process-based and varies with output. Values of industrial output in the SUST-RUS database \( (Y_{s,r}) \) by Federal Districts of the RF, measured in millions of rubles of 2006, are presented in Table A6. Sources of values of industrial output in the SUST-RUS database are discussed in SUST-RUS (2012c, 3.1.5 Regional output statistics): “The origin of the regional output data is the Rosstat online database,” available at: (http://www.gks.ru/dbscripts/Cbsd/DBInet.cgi).

1.6. The authors calculate an emission intensity index of non-CO2 pollutants \( (p \in NCO_2) \) at the regional level \( (X_{p,s,r}) \) for the SUST-RUS pollution data. It is estimated according to an output-weighted least-squares procedure (Equation 1), subject to total regional emissions (Equation 2) and national sectoral emissions (Equation 3). The procedure ensures that emissions by pollutant, sector, and region are close to average national sectoral emissions intensity index \( (\bar{X}_{p,s}) \), deviating from the mean for more polluted regions proportionally with regional output \( (Y_{s,r}) \).

\begin{align*}
\text{Equation 1} & \\
\min_{X_{p,s,r}} & \sum_{p \in NCO_2, s, r} Y_{s,r} \cdot \left( X_{p,s,r} - \bar{X}_{p,s} \right)^2, \text{ subject to} \\
\text{Equation 2} & \\
\sum_{s} X_{p,s,r} \cdot Y_{s,r} = REGEMIT_{r,p} \\
\text{Equation 3} & \\
\sum_{r} X_{p,s,r} \cdot Y_{s,r} = NATEMIT_{s,p}
\end{align*}

1.7. The average national sectoral emissions intensity index \( (\bar{X}_{p,s}) \) for the SUST-RUS data is presented in Table A7, measured in thousand tons of pollutant per trillion rubles of output, in nominal prices of 2006.

1.8. The resulting regional emissions intensity indices of non-CO2 emissions \( (p \in NCO_2) \) at the regional level \( (X_{p,s,r}) \) for the SUST-RUS sectoral classification are presented in Table A9 - Table A14.

1.9. The model’s (“the WTO model’s”) sectoral and regional lists differ from those of SUST-RUS. The industry list \( (g) \) of the WTO model is presented in Table A15, while set of regions \( (reg) \) of the WTO model is presented in
1.10. Table A16.

1.11. The concordance \((g\text{map}(g, s))\) between the WTO model industry list \((g)\) and the SUST-RUS industries \((s)\) is presented in Table A17. We do not have a one to one mapping between the WTO model industry list and the SUST-RUS industry list. Differences in the underlying industry classifications are fundamental, as the model’s (“the WTO model”) industry list is based on the old Russian OKONH classification, which is production process-centric; but the SUST-RUS industry classification is based on the standard international industry classification (ISIC/NACE or, the Russian version, OKVED), which is activity-centric. In the presence of classification differences, the authors establish a many-to-one mapping from the WTO model industry list to the SUST-RUS list. For each industry from the WTO model industry list there is a corresponding industry from SUST-RUS’s list. There are several WTO industries that maps to the same SUST-RUS industry. For example, there is only one SUST-RUS industry that corresponds to transport services \(I_{trn}\), which is defined as an aggregate of all of the following types of transport services: land transport; transport via pipelines; water transport; air transport; supporting and auxiliary transport activities; activities of travel agencies. The WTO model’ industry list is very detailed in transport services: there are six different industries related to transport services: maritime transportation (MAR), railway transportation (RLW), truck transportation (TRK), pipeline transportation (PIP), air transportation (AIR), and other transportation (TRO). According to our mapping, all six types of transport services in the WTO model are mapped to one type of transport services in the SUST-RUS dataset. The concordance \((g\text{map}(g, s))\) doesn’t use every SUST-RUS industry, only those which are associated with any of the WTO model’s industries. Only 20 out of 32 SUST-RUS industries are used in the mapping. In the case, when SUST-RUS is more detailed in representing certain production sectors than the WTO model, only one industry from the SUST-RUS’s industry list is chosen to represent the WTO-model industry. For example, there are two sectors of light industry “Manufacture of textiles and textile products” (DB) and “Manufacture of leather and leather products” (DC) in the SUST-RUS industry list, but there is only one industry “Textiles and apparel” (CLI) in the WTO model. In this case, the concordance \((g\text{map}(g, s))\) associates “Textiles and apparel” (CLI) from the WTO model only with “Manufacture of textiles and textile products” (DB) of the SUST-RUS list, leaving “Manufacture of leather and leather products” (DC) industry unused in the concordance.

1.12. The mapping \((r\text{map}(\text{reg}, r))\) between the WTO models regions list \((\text{reg})\) and the SUST-RUS regions \((r)\) is presented in Table A18. A detailed list of all the WTO model’s regions and Federal Districts of the Russian Federation is presented in Table A19.

1.13. The geographical mapping \((r\text{map}(\text{reg}, r))\) between the WTO model’s regions list \((\text{reg})\) and the SUST-RUS regions \((r)\) is many to one, since the WTO model’s regions list is more detailed than the list of SUST-RUS. There is no exact mapping between Federal Districts regional division used in the SUST-RUS database and ten geographical regions of the WTO model. The authors examine the sensitivity of the results to the regional mapping.

1.14. The model’s dataset is based on the 2001 Russian Input-output data. The emission data are based on 2006 data of the SUST-RUS database and should be scaled to match the total emission level of 2001. Values of emissions by different types of non-CO2 pollutants for 2001 \((\text{emitstat}^{2001}_p)\) are presented in Table A20.

1.15. The adjusted regional emission intensity index of non-CO2 emissions in the WTO model region and sector list \((\text{emitint}^{0}_{p,g,\text{reg}})\) is calculated in three steps. In the first step (Equation 4) the regional emission intensity index of non-CO2 emissions in the WTO model \((\text{emitint}^{0}_{p,g,\text{reg}})\) is set to equal to values of the regional emission
intensity index of non-CO2 emissions in the SUST-RUS data \((X_{p,s,r})\) for those SUST-RUS industries \((s)\) and regions \((r)\) that correspond with the WTO model industries \((g)\) and regions \((reg)\). For example, the initial value of regional emission intensity index of SO\(_2\) (Sulphur dioxide) emissions for the WTO-model industry ELE ("Electricity") in region MSC ("Moscow") \((emit\text{int}_{SO2,ELE,MSC})\) is equal to the value of SUST-RUS emissions intensity index of SO\(_2\) (Sulphur dioxide) for SUST-RUS industry E_ely (Production and distribution of electricity) in the region \(reg\) \((X_{SO2,E_ely,reg})\).

**Equation 4**

\[
\forall p \in NCO2 and \forall g \in G and \forall reg \in REG, \quad emit\text{int}^0_{p,g,reg} = X_{p,s,r}, \text{if} \quad (g,s) \in gmap(g,s) \text{ and } (reg,r) \in rmap(reg,r).
\]

1.16. In the second stage (Equation 5), authors calculate the adjustment coefficient \((k_p)\) to rescale reference values of total emissions in 2001 \((emit\text{stat}_p^{2001})\). For each pollutant \((p)\), adjustment coefficient \((k_p)\) equals ratio of total volume of emissions of the pollutant \((p)\) in 2001 \((emit\text{stat}_p^{2001})\) and estimated volume of emissions with initial values of regional emission intensity index of non-CO2 emissions in the WTO model. Estimated volume of emissions equals to product of initial values of regional emission intensity index of non-CO2 emissions in the WTO model \((emit\text{int}^0_{p,g,reg})\) and 2001 production levels \((Y_{g,reg}^{2001})\).

**Equation 5**

\[
k_p = \frac{emit\text{stat}_p^{2001}}{\sum_{reg} \sum_g emit\text{int}^0_{p,g,reg} \ast Y_{g,reg}^{2001}}
\]

1.17. In the final, third stage of estimation of the adjusted regional emission intensity index of non-CO2 \((emit\text{int}_{p,g,reg})\), the adjustment coefficient is applied to initial values of the intensity index \((emit\text{int}^0_{p,g,reg})\) (Equation 6).

**Equation 6**

\[
emit\text{int}_{p,g,reg} = k_p \ast emit\text{int}^0_{p,g,reg}
\]

1.18. Values of regional emission intensity index of non-CO2 emissions in the WTO model region and sector list \((emit\text{int}_{p,g,reg})\) are presented in Table A21-Table A30.

1.19. Average regional emissions intensity index of non-CO2 emissions, WTO model's sectoral classification (thousands tons of emission per billion of 2001 rubles of output) is presented in Table A31.
A.2. CO2 emissions accounting

1.20. CO2 emissions are generated by fossil fuel combustion. There are three types of fossil fuels (ff) in the model: fluid (natural gas), solid (coal), and liquid (oil). Based on the input-output tables, the model contains data at the sector and region level of how intensively each sector in each region uses each fossil fuel; that is, we have the cost share of each fossil fuel for each sector and region. We lack, however, detailed data on differences in emission intensity across sectors and regions for a given value of fossil fuel use. Due to lack of detailed data on CO2 emissions intensity per ruble of expenditure on fossil fuel, by industry and regional level, aggregated data for CO2 emissions for each type of fuel in 2001 was used for emission intensity per ruble of expenditure. We assume that all sectors and regions that spend 1 billion rubles on a given fossil fuel, will emit the same amount of CO2. Differences in CO2 emissions per ruble of output in the WTO model are therefore only due to the differences in the intensity of fossil fuel use across sectors and regions, not due to the efficiency with which a sector in a given region controls its emission of CO2.

1.21. Aggregated CO2 emissions for 2001 for each type of fuel (SRCO2\textsubscript{ff} \textsubscript{2001}) is presented in Table A32. The source of CO2 emission data in year 2001 is Rosgidromet (2013, page 36, Table A3.3).

1.22. CO\textsubscript{2} emission intensity index (CO2\textsubscript{intff}) for a fuel (ff) is defined as total CO2 emissions of this type of fuel (measured in billions of tons, also called gigatons) divided by total demand for this type of fuel (in billions of rubles of 2001). More specifically, let $\text{ffd}_{ff,reg,g}$ equal demand for a particular fossil fuel by a given sector in one of the model's regions in billions of 2001 rubles. The CO\textsubscript{2} emission intensity index (CO2\textsubscript{intff}) is presented in Equation 7: it equals ratio of aggregated CO2 emissions by a specific type of fuel (SRCO2\textsubscript{ff} \textsubscript{2001}) and total value of fossil fuels demand in 2001 aggregated over regions and sectors, in billions of 2001 rubles.

\begin{equation}
\text{CO2int}_{ff} = \frac{\text{SRCO2}_{ff}^{2001}}{\sum_{reg} \sum_{g} \text{ffd}_{ff,reg,g}}
\end{equation}

1.23. Values of CO\textsubscript{2} emission intensity index (CO2\textsubscript{intff}) are presented in Table A33.

1.24. See figures 7 and 8 for emissions intensity at the sector level in our model. These figures combine the emission intensities of Table A33, with the different cost shares of fossil fuels across sectors based on the input-output tables. Since our regional input-output tables exhibit identical cost shares for a given sector across our ten regions, the national average for CO2 emission intensity of a sector applies to all ten regions.

Appendix References

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4. SUST-RUS. 2012 (b). SUST-RUS Deliverable 5: Description of the environmental, international and social part of the model, SUST-RUS project web site, accessed at May 28, 2014, http://sust-rus.org/wp-content/uploads/2012/03/d5-description-of-the-environmental-international-and-social-part-of-the-model.pdf

5. Rosgidromet. 2013. State inventory report of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol for 1990 - 2011 years, Part 1, Moscow 2013.

6. SUST-RUS. 2012 (c). SUST-RUS Deliverable 2.1: Description of the constructed database, data quality and data collection methods, SUST-RUS project web site, accessed at May 28, 2014, http://sust-rus.org/wp-content/uploads/2010/08/deliverable-2.pdf
Table A2. The industry list of the SUST-RUS database.

| #  | Code in SUST-RUS | NACE classification | Description                                                                 |
|----|------------------|---------------------|-----------------------------------------------------------------------------|
| 1  | A                | Section A           | Agriculture, hunting and forestry                                           |
| 2  | B                | Section B           | Fishing                                                                     |
| 3  | CA_col           | CA.10               | Mining of coal and lignite; extraction of peat                             |
| 4  | CA_gas           | CA.11.10.2-3        | Extraction of natural gas; service activities incidental to gas extraction, excluding surveying |
| 5  | CA_oil           | CA.11.10.1          | Extraction of crude petroleum; service activities incidental to oil extraction, excluding surveying |
| 6  | CB               | Subsection CB       | Mining and quarrying, except of energy producing materials                  |
| 7  | DA               | Subsection DA       | Manufacture of food products, beverages and tobacco                        |
| 8  | DB               | Subsection DB       | Manufacture of textiles and textile products                               |
| 9  | DC               | Subsection DC       | Manufacture of leather and leather products                                |
| 10 | DD               | Subsection DD       | Manufacture of wood and wood products                                      |
| 11 | DE               | Subsection DE       | Manufacture of pulp, paper and paper products; publishing and printing      |
| 12 | DF               | Subsection DF       | Manufacture of coke, refined petroleum products and nuclear fuel            |
| 13 | DG               | Subsection DG       | Manufacture of chemicals, chemical products and man-made fibres            |
| 14 | DH               | Subsection DH       | Manufacture of rubber and plastic products                                 |
| 15 | DI               | Subsection DI       | Manufacture of other non-metallic mineral products                          |
| # | Code in SUST-RUS | NACE classification | Description |
|---|-----------------|---------------------|-------------|
| 16 | DJ              | Subsection DJ       | Manufacture of basic metals and fabricated metal products |
| 17 | DK              | Subsection DK       | Manufacture of machinery and equipment n.e.c. |
| 18 | DL              | Subsection DL       | Manufacture of electrical and optical equipment |
| 19 | DM              | Subsection DM       | Manufacture of transport equipment |
| 20 | DN              | Subsection DN       | Manufacturing n.e.c. |
| 21 | E_distr         | 41 + 40.2 + 40.3    | Collection, purification and distribution of water; Manufacture of gas; distribution of gaseous fuels through mains; Steam and hot water supply |
| 22 | E_ely           | 40.1                | Production and distribution of electricity |
| 23 | F               | Section F           | Construction |
| 24 | G               | Section G           | Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods |
| 25 | H               | Section H           | Hotels and restaurants |
| 26 | I_cmn           | 64                  | Post and telecommunications |
| 27 | I_trn           | 60 + 61 + 62 + 63   | Land transport; transport via pipelines; Water transport; Air transport; Supporting and auxiliary transport activities; activities of travel agencies |
| 28 | J               | Section J           | Financial intermediation |
| 29 | LO              | Section L and O     | Public administration and defense; compulsory social security; Other community, social and personal service activities |
| 30 | K               | Section K           | Real estate, renting and business activities |
| #  | Code in SUST-RUS | NACE classification | Description                           |
|----|-----------------|---------------------|---------------------------------------|
| 31 | M               | Section M           | Education                             |
| 32 | N               | Section N           | Health and social work                |

*Source:* SUST-RUS. 2012(a).

Table A3. Regions of the SUST-RUS model

| Region number | Federal Districts of the Russian Federation                |
|---------------|------------------------------------------------------------|
| Reg1          | Central Federal District                                   |
| Reg2          | North-Western Federal District                             |
| Reg3          | Southern Federal District                                  |
| Reg4          | Volga Federal District                                     |
| Reg5          | Urals Federal District                                     |
| Reg6          | Siberian Federal District                                  |
| Reg7          | Far Eastern Federal District                               |

*Source:* SUST-RUS. 2012(a).
Table A4. Total emissions in 2006, by industry and by type of pollutant from industrial stationary and mobile sources (thousands of tons)

|       | Particulate matter | Sulphur dioxide | Carbon monoxide | Nitrogen oxide | Hydrocarbons | Volatile organic components |
|-------|--------------------|-----------------|-----------------|---------------|--------------|----------------------------|
| PM    | SO2                | CO              | NOx             | CnHm          | VOC          |
| A     | Agriculture, hunting and forestry | 38,60 | 7,30 | 44,50 | 8,90 | 7,50 | 3,40 |
| B     | Fishing            | -               | -               | -             | -            | -                          |
| CA_col| Mining of coal and lignite; extraction of peat | 60,60 | 13,50 | 39,20 | 12,50 | 776,20 | 1,00 |
| CA_gas| Extraction of natural gas; service activities incidental to gas extraction, excluding surveying | 27,30 | 8,58 | 257,05 | 8,29 | 104,88 | 67,30 |
| CA_oil| Extraction of crude petroleum; service activities incidental to oil extraction, excluding surveying | 244,10 | 84,14 | 2 236,38 | 74,02 | 508,25 | 984,70 |
| CB    | Mining and quarrying, except of energy producing materials | 138,10 | 101,60 | 235,00 | 34,00 | 1,90 | 5,20 |
| DA    | Manufacture of food products, beverages and tobacco | 25,90 | 20,90 | 63,20 | 16,90 | 1,40 | 10,70 |
| DB    | Manufacture of textiles and textile products | 3,20 | 2,20 | 5,80 | 2,00 | 0,10 | 0,50 |
| DC    | Manufacture of leather and leather products | 1,40 | 1,83 | 0,06 | 0,18 | - | 0,03 |
| DD    | Manufacture of wood and wood products | 17,00 | 3,90 | 54,10 | 5,40 | 0,10 | 3,10 |
| DE    | Manufacture of pulp, paper and paper products; publishing and printing | 46,60 | 47,00 | 39,20 | 22,90 | 0,30 | 4,80 |
|   | Particulate matter | Sulphur dioxide | Carbon monoxide | Nitrogen oxide | Hydrocarbons | Volatile organic components |
|---|--------------------|-----------------|-----------------|----------------|--------------|----------------------------|
|   | PM                 | SO2             | CO              | NOx            | CnHm         | VOC                        |
| DF | Manufacture of coke, refined petroleum products and nuclear fuel | 27,20 | 132,64 | 136,33 | 32,17 | 65,40 | 328,66 |
| DG | Manufacture of chemicals, chemical products and man-made fibres | 40,40 | 44,10 | 124,70 | 40,50 | 16,00 | 76,70 |
| DH | Manufacture of rubber and plastic products | 1,30 | 0,40 | 2,90 | 1,60 | 1,50 | 9,30 |
| DI | Manufacture of other non-metallic mineral products | 215,80 | 20,30 | 144,60 | 82,20 | 1,40 | 8,70 |
| DJ | Manufacture of basic metals and fabricated metal products | 369,60 | 2 642,10 | 1 585,80 | 133,80 | 2,60 | 14,20 |
| DK | Manufacture of machinery and equipment n.e.c. | 22,80 | 10,50 | 41,60 | 14,80 | 0,60 | 9,90 |
| DL | Manufacture of electrical and optical equipment | 7,00 | 5,10 | 28,10 | 5,50 | 1,20 | 5,60 |
| DM | Manufacture of transport equipment | 18,90 | 13,80 | 41,90 | 11,90 | 1,80 | 25,00 |
| DN | Manufacturing n.e.c. | 7,20 | 0,90 | 7,50 | 1,40 | 0,20 | 2,80 |
| E_distr | Collection, purification and distribution of water; Manufacture of gas; distribution of gaseous fuels through mains; Steam and hot water supply | 316,40 | 260,80 | 407,40 | 161,00 | 27,50 | 4,20 |
| E_ely | Production and distribution of electricity | 956,80 | 1 165,90 | 173,10 | 801,70 | 3,20 | 3,70 |
|   | Particulate matter | Sulphur dioxide | Carbon monoxide | Nitrogen oxide | Hydrocarbons | Volatile organic components |
|---|--------------------|----------------|----------------|---------------|-------------|-----------------------------|
|   | PM | SO2 | CO | NOx | CnHm | VOC |
| F | Construction | - | - | - | - | - |
| G | Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods | - | - | - | - | - |
| H | Hotels and restaurants | - | - | - | - | - |
| I_cmn | Post and telecommunications | - | - | - | - | - |
| I_trn | Land transport; transport via pipelines; Water transport; Air transport; Supporting and auxiliary transport activities; activities of travel agencies | 222,40 | 86,69 | 439,20 | 183,10 | 1 258,30 | 123,00 |
| J | Financial intermediation | - | - | - | - | - |
| LO | Public administration and defense; compulsory social security; Other community, social and personal service activities | 7,00 | 3,40 | 9,70 | 1,60 | 33,10 | 3,40 |
| K | Real estate, renting and business activities | 20,97 | 87,10 | 168,01 | 45,14 | 13,20 | 49,38 |
| M | Education | - | - | - | - | - |
| N | Health and social work | - | - | - | - | - |

Source: SUST-RUS. 2012(a), 2012 (b).
**Table A5. Regional Emissions by type of the Pollutant in 2006**

| Federal Districts of the Russian Federation | Particulate matter | Sulphur dioxide | Carbon monoxide | Nitrogen oxide | Hydrocarbons | Volatile organic components |
|--------------------------------------------|--------------------|-----------------|-----------------|---------------|--------------|-----------------------------|
| FD1-Central Central Federal District       | 232,7              | 214,5           | 583             | 267,9         | 125,6        | 108,9                       |
| FD2-Northwest North-West Federal District  | 290,4              | 590,2           | 685             | 170,5         | 409,3        | 134,4                       |
| FD3-South South Federal District           | 90,4               | 140,8           | 265,5           | 122,1         | 173,2        | 81,9                        |
| FD4-Volga Volga Federal District           | 229,5              | 508,4           | 885,3           | 289,2         | 589,4        | 518,5                       |
| FD5-Urals Urals Federal District           | 878,5              | 579,3           | 2653,9          | 413,8         | 868,7        | 873,6                       |
| FD6-Siberian Siberian Federal District     | 811,7              | 2536,3          | 1051,4          | 339,8         | 651,4        | 134,2                       |
| FD7-FarEast Far Eastern Federal District   | 309,8              | 195,3           | 214,2           | 99,8          | 9            | 11,7                        |

*Source: SUST-RUS. 2012(a), 2012 (b).*
Table A6. Regional and sectoral output (mln RUB, 2006)

| Federal Districts of the Russian Federation | FD1-Central | FD2-Northwest | FD3-South | FD4-Volga | FD5-Urals | FD6-Siberian | FD7-FarEast |
|--------------------------------------------|-------------|--------------|-----------|-----------|-----------|--------------|-------------|
| A                                          | 368 289,00  | 96 458,00    | 367 871,00| 436 079,00| 131 192,00| 249 916,00   | 61 477,00   |
| B                                          | 640,00      | 44 306,63    | 5 026,23  | 342,42    | 839,74    | 366,88       | 81 536,60   |
| CA_col                                     | 106 709,18  | 127 135,77   | 38 986,57 | 14 094,12 | 70 582,45 | 267 696,51   | 80 650,42   |
| CA_gas                                     | 5 053,99    | 13 390,99    | 145 773,25| 1 327 768,23| 836,14   | 1 306,07     |
| CA_oil                                     | 25 511,08   | 8 165,33     | 476 401,42| 580 550,49| 1 542,35  | 1 797,04     |
| CB                                         | 78 199,59   | 56 836,94    | 7 024,68  | 32 771,35 | 48 643,37 | 58 861,64    | 146 917,68  |
| DA                                         | 654 896,22  | 298 465,22   | 207 019,12| 266 014,91| 80 567,66| 169 907,16   | 51 000,78   |
| DB                                         | 72 004,30   | 11 781,52    | 11 829,66 | 23 244,02 | 4 648,13 | 5 480,88     | 1 152,56    |
| DC                                         | 13 715,10   | 1 309,06     | 2 218,06  | 2 582,67  | 1 549,38 | 1 370,22     | 288,14      |
| DD                                         | 44 574,09   | 49 744,20    | 4 436,12  | 23 244,02 | 13 944,40| 26 034,16    | 4 610,24    |
| DE                                         | 168 010,02  | 108 651,81   | 14 787,08 | 51 653,38 | 9 296,27 | 34 255,48    | 3 601,75    |
| DF                                         | 651 467,44  | 53 671,38    | 122 732,76| 550 108,50| 342 412,54| 206 903,07   | 12 101,88   |
| DG                                         | 216 012,89  | 81 161,60    | 48 797,36 | 309 920,28| 26 339,43 | 79 472,70    | 2 881,40    |
| DH                                         | 96 005,73   | 15 708,70    | 14 787,08 | 90 393,42 | 13 944,40| 23 293,72    | 2 305,12    |
| DI                                         | 229 727,99  | 64 143,84    | 56 190,90 | 92 976,08 | 71 271,39| 45 217,23    | 11 669,67   |
| DJ                                         | 404 595,57  | 301 083,34   | 121 993,41| 286 676,26| 718 911,39| 565 900,45   | 17 288,40   |
## Federal Districts of the Russian Federation

|       | FD1-Central | FD2-Northwest | FD3-South | FD4-Volga | FD5-Urals | FD6-Siberian | FD7-FarEast |
|-------|-------------|---------------|-----------|-----------|-----------|--------------|-------------|
| DK    | 229 727,99  | 66 761,96     | 46 579,30 | 136 881,46| 79 018,28 | 54 808,76    | 7 491,64    |
| DL    | 250 300,65  | 100 797,47    | 21 441,27 | 129 133,45| 48 030,72 | 47 957,67    | 4 610,24    |
| DM    | 205 726,56  | 111 269,93    | 49 536,72 | 529 447,15| 58 876,36 | 53 438,54    | 17 432,47   |
| DN    | 192 011,46  | 44 507,97     | 17 005,14 | 90 393,42 | 80 567,66 | 56 178,98    | 7 635,71    |
| E_distr | 432 695,86  | 143 469,33    | 80 757,51 | 205 916,99| 173 817,13| 127 188,46   | 58 543,97   |
| E_ely | 232 554,23  | 58 182,54     | 89 847,66 | 204 195,36| 94 444,54 | 144 957,49   | 55 949,09   |
| F     | 858 498,82  | 437 818,94    | 283 882,31| 426 834,45| 371 505,35| 261 617,21   | 210 678,51  |
| G     | 4 143 285,55| 517 927,98    | 424 564,12| 672 835,63| 996 788,33| 439 567,72   | 194 754,17  |
| H     | 160 374,23  | 38 580,21     | 46 359,91 | 52 744,21 | 61 517,44 | 36 329,59    | 16 935,51   |
| I_cmn | 164 244,23  | 65 355,58     | 50 751,75 | 80 429,06 | 95 905,87 | 68 781,08    | 32 450,74   |
| I_trn | 1 105 512,87| 439 902,43    | 341 605,38| 541 360,64| 645 533,61| 462 959,17   | 218 084,60  |
| J     | 1 026 038,75| 47 232,14     | 17 687,30 | 52 634,57 | 154 513,13| 24 930,87    | 11 386,42   |
| LO    | 1 140 675,07| 378 710,68    | 315 226,85| 436 068,27| 362 382,77| 389 550,13   | 229 126,93  |
| K     | 1 697 320,66| 308 834,91    | 188 960,73| 419 435,41| 588 173,66| 259 078,32   | 122 454,11  |
| M     | 240 250,04  | 103 744,17    | 89 169,03 | 148 128,27| 116 202,90| 129 762,60   | 58 811,29   |
| N     | 363 523,35  | 171 676,78    | 135 007,83| 203 868,61| 200 703,92| 187 389,36   | 78,25       |

*Source: SUST-RUS. 2012(a), 2012 (c).*
Table A7. Average pollution intensity by sector in SUST-RUS 2006 data (thousands tons of emission per trillion RUB of output)

| Sector | Particulate matter | Sulphur dioxide | Carbon monoxide | Nitrogen oxide | Hydrocarbons | Volatile organic components |
|--------|--------------------|-----------------|-----------------|---------------|--------------|---------------------------|
| A      | Agriculture, hunting and forestry | 22,56 | 4,27 | 26,00 | 5,20 | 4,38 | 1,99 |
| CA_col | Mining of coal and lignite; extraction of peat | 85,85 | 19,13 | 55,54 | 17,71 | 1,099,66 | 1,42 |
| CA_gas | Extraction of natural gas; service activities incidental to gas extraction, excluding surveying | 18,27 | 5,74 | 172,04 | 5,55 | 70,20 | 45,04 |
| CA_oil | Extraction of crude petroleum; service activities incidental to oil extraction, excluding surveying | 223,13 | 76,91 | 2,044,28 | 67,66 | 464,59 | 900,12 |
| CB | Mining and quarrying, except of energy producing materials | 321,72 | 236,69 | 547,46 | 79,21 | 4,43 | 12,11 |
| DA | Manufacture of food products, beverages and tobacco | 14,99 | 12,10 | 36,58 | 9,78 | 0,81 | 6,19 |
| DB | Manufacture of textiles and textile products | 24,59 | 16,91 | 44,57 | 9,78 | 15,37 | 3,84 |
| DC | Manufacture of leather and leather products | 60,78 | 79,45 | 2,61 | 7,82 | 0,77 | 1,30 |
| DD | Manufacture of wood and wood products | 102,05 | 23,41 | 324,76 | 32,42 | 0,60 | 18,61 |
| DE | Manufacture of pulp, paper and paper products; publishing and printing | 119,41 | 120,43 | 100,45 | 58,68 | 0,77 | 12,30 |
| DF | Manufacture of coke, refined petroleum products and nuclear | 14,03 | 68,39 | 70,30 | 16,59 | 33,72 | 169,47 |
|          | Particulate matter | Sulphur dioxide | Carbon monoxide | Nitrogen dioxide | Hydrocarbons | Volatile organic compounds |
|----------|--------------------|-----------------|----------------|-----------------|--------------|---------------------------|
|          | PM                 | SO2             | CO             | NOx             | CnHm         | VOC                       |
| fuel     |                    |                 |                |                 |              |                           |
| DG       | Manufacture of chemicals, chemical products and man-made fibres | 52,84 | 57,68 | 163,10 | 52,97 | 20,93 | 100,32 |
| DH       | Manufacture of rubber and plastic products | 5,07 | 1,56 | 11,31 | 6,24 | 5,85 | 36,27 |
| DI       | Manufacture of other non-metallic mineral products | 377,80 | 35,54 | 253,15 | 143,91 | 2,45 | 15,23 |
| DJ       | Manufacture of basic metals and fabricated metal products | 152,95 | 1,093,38 | 656,25 | 55,37 | 1,08 | 5,88 |
| DK       | Manufacture of machinery and equipment n.e.c. | 36,70 | 16,90 | 66,96 | 23,82 | 0,97 | 15,94 |
| DL       | Manufacture of electrical and optical equipment | 11,62 | 8,47 | 46,66 | 9,13 | 1,99 | 9,30 |
| DM       | Manufacture of transport equipment | 18,43 | 13,45 | 40,85 | 11,60 | 1,76 | 24,37 |
| DN       | Manufacturing n.e.c. | 14,75 | 1,84 | 15,36 | 2,87 | 0,41 | 5,73 |
| E_distr  | Collection, purification and distribution of water; Manufacture of gas; distribution of gaseous fuels through mains; Steam and hot water supply | 258,84 | 213,35 | 333,28 | 131,71 | 22,50 | 3,44 |
| E_ely    | Production and distribution of electricity | 1 087,11 | 1 324,69 | 196,68 | 910,89 | 3,64 | 4,20 |
| I_trn    | Land transport; transport via pipelines; Water transport; Air | 59,23 | 23,09 | 116,97 | 48,76 | 335,10 | 32,76 |
| LO | Public administration and defense; compulsory social security; Other community, social and personal service activities | PM | SO2 | CO | NOx | CnHm | VOC |
|----|-----------------------------------------------------------------------------------------------------------|----|-----|----|-----|------|------|
|    |                                                                                                           | 2,15 | 1,05 | 2,98 | 0,49 | 10,18 | 1,05 |
| K  | Real estate, renting and business activities                                                                 | 5,85 | 24,30 | 46,87 | 12,60 | 3,68 | 13,78 |

Source: Authors’ calculations based on SUST-RUS data
Table A8. Regional emissions intensity index of non-CO2 emissions, Central Federal District, SUST-RUS sectoral classification (thousands tons of emission per trillion nominal RUB of output of 2006)

| Central FD | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|------------|--------------|----------------|----------------|--------------------|-----------------|-----------------------------|
|            | CnHm         | CO             | NOx            | PM                 | SO2             | VOC                         |
| CA_col     | 829,19       |                |                |                    |                 |                             |
| CB         | 457,13       | 15,03          |                |                    |                 |                             |
| DB         | 6,72         |                |                |                    |                 |                             |
| DD         | 258,62       |                |                |                    |                 |                             |
| DE         | 33,35        | 20,66          |                |                    |                 |                             |
| DF         | 6,12         |                |                |                    | 131,39          |                             |
| DG         | 186,49       | 12,09          |                |                    | 71,17           |                             |
| DH         |              |                |                |                    | 10,80           |                             |
| DI         | 220,37       | 102,78         | 170,32         |                    |                 |                             |
| DJ         | 572,40       |                |                |                    | 194,46          |                             |
| E_distr    | 305,73       | 85,05          | 4,84           |                    |                 |                             |
| E_ely      | 146,34       | 859,92         | 821,11         | 584,03             |                 |                             |
| I_trn      | 33,58        | 28,91          |                |                    |                 |                             |

Source: Authors’ calculations based on SUST-RUS data
Table A9. Regional emissions intensity index of non-CO2 emissions, North-Western Federal District, SUST-RUS sectoral classification (thousands tons of emission per trillion nominal RUB of output of 2006)

| North-Western FD | Hydrocarbons CnHm | Carbon monoxide CO | Nitrogen oxide NOx | Particulate matter PM | Sulphur dioxide SO2 | Volatile organic components VOC |
|------------------|-------------------|-------------------|-------------------|----------------------|-------------------|-----------------------------|
|                  |                   |                   |                   |                      |                   |                             |
| A                |                   | 44,55             |                   |                      |                   | 5,96                        |
| CA_col           | 1 302,67          | 34,77             | 1,45              |                      |                   | 1,93                        |
| CA_gas           | 46,17             | 170,18            |                   |                      | 616,60            | 43,11                       |
| CA_oil           | 446,27            | 2 269,31          | 60,46             | 287,39               | 709,08            | 945,20                      |
| CB               | 610,48            | 83,16             | 297,77            | 59,68                | 29,28             |                             |
| DA               | 77,93             | 13,62             |                   |                      |                   | 16,61                       |
| DB               | 160,06            | 44,14             | 62,25             |                      |                   | 17,76                       |
| DC               |                   | 18,91             | 202,21            | 101,47               |                   |                             |
| DD               | 411,96            | 39,09             | 103,34            |                      |                   | 32,78                       |
| DE               | 186,70            | 88,79             | 247,82            | 63,61                | 29,58             |                             |
| DF               | 37,61             | 159,46            | 21,21             |                      |                   | 236,19                      |
| DG               | 17,79             | 339,84            | 80,22             | 117,92               | 175,96            |                             |
| DH               | 16,34             | 6,01              |                   |                      |                   | 115,60                      |
| North-Western FD | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|------------------|--------------|-----------------|----------------|-------------------|-----------------|-----------------------------|
|                  | CnHm         | CO              | NOx            | PM                | SO2             | VOC                         |
| DI               |              | 373,71          | 170,91         | 637,47            | 37,38           |                             |
| DJ               |              | 725,74          | 49,83          | 111,93            | 1,353,18        | 6,28                        |
| DK               |              | 152,86          | 38,27          | 10,22             | 40,02           |                             |
| DL               |              | 111,94          | 10,87          |                   |                 |                             |
| DM               |              | 138,03          | 28,76          |                   |                 |                             |
| DN               |              | 8,76            |                |                   |                 |                             |
| E_distr          | 25,86        | 459,08          | 153,18         | 471,99            | 346,59          | 7,11                        |
| E_ely            | 299,68       | 928,05          | 1,288,26       | 1,742,76          | 10,91           |                             |
| I_trn            | 507,05       | 182,26          | 62,77          | 11,16             | 62,06           |                             |
| K                | 102,30       | 11,47           |                |                   |                 | 35,39                       |
| LO               | 4,86         |                 |                |                   |                 | 1,14                        |

Source: Authors’ calculations based on SUST-RUS data
Table A10. Regional emissions intensity index of non-CO2 emissions, Southern Federal District, SUST-RUS sectoral classification (thousands tons of emission per trillion nominal RUB of output of 2006)

| Southern FD | Hydrocarbons CnHm | Carbon monoxide CO | Nitrogen oxide NOx | Particulate matter PM | Sulphur dioxide SO2 | Volatile organic components VOC |
|-------------|-------------------|--------------------|-------------------|-----------------------|---------------------|-----------------------------|
| CA_col      | 1 162,63          |                    |                   |                       |                     |                             |
| CA_gas      | 106,02            |                    |                   |                       |                     | 32,62                       |
| CA_oil      | 306,23            | 2 205,15           | 36,52             |                       |                     | 934,71                      |
| CB          | 546,32            | 59,23              |                   |                       |                     | 18,79                       |
| DA          | 13,77             |                    |                   |                       |                     | 6,12                        |
| DB          | 95,91             | 20,20              |                   |                       |                     | 7,28                        |
| DD          | 347,81            | 15,15              |                   |                       |                     | 22,29                       |
| DE          | 122,54            | 64,86              |                   |                       |                     | 19,10                       |
| DF          | 95,31             |                    |                   |                       |                     | 225,70                      |
| DG          | 275,68            | 56,28              |                   |                       |                     | 165,48                      |
| DH          |                   |                    |                   |                       |                     | 105,11                      |
| DI          | 309,56            | 146,97             | 198,80            |                       |                     | 26,90                       |
| DJ          | 661,59            | 25,89              |                   | 499,40                |                     |                             |
| DK          | 88,71             | 14,33              |                   |                       | 29,53               |                             |
| DL          | 47,79             |                    |                   |                       |                     | 14,98                       |
| Southern FD | Hydrocarbons CnHm | Carbon monoxide CO | Nitrogen oxide NOx | Particulate matter PM | Sulphur dioxide SO2 | Volatile organic components VOC |
|------------|-------------------|-------------------|-------------------|----------------------|-------------------|-----------------------------|
| DM         |                   | 73,87             | 4,83              |                      |                   | 78,42                       |
| DN         |                   |                   |                   |                      |                   | 2,09                        |
| E_distr    | 394,92            | 129,25            |                   | 33,32                |                   |                             |
| E_ely      | 235,53            | 904,12            | 849,59            | 888,98               |                   |                             |
| I_trn      | 367,02            | 118,10            | 38,83             |                      | 51,57             |                             |
| K          | 38,15             |                   |                   |                      |                   | 24,90                       |

Source: Authors’ calculations based on SUST-RUS data
Table A11. Regional emissions intensity index of non-CO2 emissions, Volga Federal District, SUST-RUS sectoral classification (thousands tons of emission per trillion nominal RUB of output of 2006)

| Volga FD | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|----------|--------------|-----------------|----------------|-------------------|-----------------|-----------------------------|
| Row Labels | CnHm       | CO              | NOx            | PM                | SO2             | VOC                         |
| A        | 4,09        |                 |                |                   |                 |                             |
| CA_col   | 1 317,14    |                 |                |                   |                 |                             |
| CA_gas   | 60,63       |                 |                |                   | 20,85           |                             |
| CA_oil   | 460,73      | 1 727,42        | 33,13          |                   | 113,33          | 833,40                      |
| CB       | 5,11        | 68,59           | 55,84          |                   |                 |                             |
| DB       |             |                 |                | 16,81             |                 |                             |
| DD       |             |                 |                | 11,76             |                 |                             |
| DE       |             |                 |                | 61,47             |                 |                             |
| DF       | 52,08       |                 |                |                   | 124,38          |                             |
| DG       | 32,26       | 52,89           |                |                   | 64,16           |                             |
| DH       | 8,56        |                 |                |                   | 3,80            |                             |
| DI       | 0,49        | 143,58          | 258,74         |                   |                 |                             |
| DJ       | 183,86      | 22,50           |                |                   | 757,44          |                             |
| DK       |             |                 |                | 10,94             |                 |                             |
| DL       | 0,62        |                 |                |                   |                 |                             |
| Volga FD | Hydrocarbons | Carbon monoxide | Nitrogen monoxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|---------|--------------|-----------------|------------------|--------------------|-----------------|---------------------------|
| Row Labels | CnHm | CO | NOx | PM | SO2 | VOC |
| DM | 0,87 | | 1,43 | | | |
| E_distr | 40,33 | | 125,86 | 93,25 | | |
| E_ely | 1,30 | | 900,73 | 909,53 | 1 147,02 | |
| I_trn | 521,52 | | 35,44 | | | |
| K | 2,92 | | | | | |
| LO | 19,33 | | | | | |

*Source: Authors’ calculations based on SUST-RUS data*
Table A12. Regional emissions intensity index of non-CO2 emissions, Urals Federal District, SUST-RUS sectoral classification (thousands tons of emission per trillion nominal RUB of output of 2006)

| Urals FD | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|----------|--------------|-----------------|----------------|--------------------|-----------------|-----------------------------|
|          | CnHm         | CO              | NOx            | PM                 | SO2             | VOC                         |
| A        | 15,57        | 65,95           | 26,10          | 40,63              |                 | 13,02                       |
| CA_col   | 1 328,62     | 56,16           | 37,68          | 89,11              |                 | 8,99                        |
| CA_gas   | 72,11        | 191,57          | 6,24           | 20,41              |                 | 50,17                       |
| CA_oil   | 472,21       | 2 290,71        | 96,69          | 405,09             | 13,35           | 952,26                      |
| CB       | 16,59        | 631,87          | 119,39         | 415,46             |                 | 36,34                       |
| DA       | 6,18         | 99,32           | 49,86          | 36,97              |                 | 23,67                       |
| DB       | 10,34        | 181,46          | 80,37          | 179,95             |                 | 24,82                       |
| DC       |              |                 | 55,14          | 319,91             |                 | 14,28                       |
| DD       | 3,07         | 433,36          | 75,32          | 221,04             |                 | 39,84                       |
| DE       | 7,57         | 208,09          | 125,02         | 365,52             |                 | 36,64                       |
| DF       | 63,56        | 180,86          | 57,44          | 23,59              |                 | 243,25                      |
| DG       | 43,74        | 361,23          | 116,45         | 235,62             |                 | 183,02                      |
| DH       | 20,04        | 37,74           | 42,24          |                    |                 | 122,66                      |
| DI       | 11,97        | 395,11          | 207,14         | 755,17             |                 | 44,44                       |
| DJ       | 2,41         | 747,14          | 86,06          | 229,62             | 657,45          | 13,34                       |
| Urals FD | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|----------|--------------|-----------------|----------------|-------------------|-----------------|-----------------------------|
|          | CnHm         | CO              | NOx            | PM                | SO2             | VOC                         |
| DK       | 4,84         | 174,26          | 74,50          | 127,92            | 47,08           |                             |
| DL       | 12,10        | 133,34          | 47,11          | 35,99             | 32,52           |                             |
| DM       | 12,35        | 159,43          | 64,99          | 109,04            | 95,97           |                             |
| DN       | 1,82         | 30,16           | 11,96          | 21,20             | 19,63           |                             |
| E_distr  | 51,81        | 480,48          | 189,42         | 589,69            | 14,17           |                             |
| E_ely    | 12,78        | 321,08          | 964,29         | 1 405,96          | 1 047,03        | 17,97                       |
| I_trn    | 533,00       | 203,65          | 99,00          | 128,86            | 69,12           |                             |
| K        | 14,40        | 123,70          | 47,70          | 42,45             |                 |                             |
| LO       | 30,81        | 4,30            |                |                   | 8,20            |                             |

Source: Authors' calculations based on SUST-RUS data
Table A13. Regional emissions intensity index of non-CO2 emissions, Siberian Federal District, SUST-RUS sectoral classification (thousands tons of emission per trillion nominal RUB of output of 2006)

| Row Labels | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|------------|--------------|-----------------|----------------|-------------------|----------------|-----------------------------|
| Siberian FD | CnHm         | CO              | NOx            | PM                | SO2            | VOC                         |
| A          | 14,70        | 119,10          | 21,91          | 103,40            | 29,21          | 4,47                        |
| CA_col     | 1 327,75     | 109,31          | 33,49          | 151,88            | 50,43          | 0,45                        |
| CA_gas     | 71,24        | 244,72          | 83,18          | 1 700,75          | 41,63          |                             |
| CA_oil     | 471,34       | 2 343,85        | 92,50          | 467,86            | 1 793,23       | 943,72                      |
| CB         | 15,72        | 685,02          | 115,21         | 478,23            | 1 143,84       | 27,80                       |
| DA         | 5,31         | 152,47          | 45,67          | 99,74             | 123,01         | 15,13                       |
| DB         | 9,47         | 234,60          | 76,18          | 242,72            | 401,40         | 16,28                       |
| DC         |              | 43,79           | 50,95          | 382,68            | 1 185,63       | 5,74                        |
| DD         | 2,20         | 486,51          | 71,13          | 283,81            | 149,80         | 31,30                       |
| DE         | 6,70         | 261,24          | 120,84         | 428,29            | 1 147,77       | 28,10                       |
| DF         | 62,69        | 234,01          | 53,26          | 86,36             | 641,07         | 234,71                      |
| DG         | 42,87        | 414,38          | 112,26         | 298,39            | 554,91         | 174,48                      |
| DH         | 19,17        | 90,88           | 38,05          | 49,22             | 17,17          | 114,12                      |
| DI         | 11,10        | 448,26          | 202,95         | 817,94            | 448,94         | 35,90                       |
| Siberian FD | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|------------|--------------|----------------|---------------|------------------|----------------|---------------------------|
| Row Labels | CnHm         | CO             | NOx           | PM               | SO2            | VOC                       |
| DJ         | 1.54         | 800.28         | 81.87         | 292.39           | 21437.34       | 4.80                      |
| DK         | 3.97         | 227.40         | 70.31         | 190.69           | 1191.58        | 38.54                     |
| DL         | 11.23        | 186.48         | 42.92         | 98.76            | 10196.34       | 23.98                     |
| DM         | 11.48        | 212.57         | 60.81         | 171.81           | 258.24         | 87.42                     |
| DN         | 0.95         | 83.30          | 7.77          | 83.97            | 16.02          | 11.09                     |
| E_distr    | 50.94        | 533.62         | 185.23        | 652.46           | 14103.74       | 5.63                      |
| E_ely      | 11.91        | 374.22         | 960.10        | 1468.73          | 2826.92        | 9.43                      |
| I_trn      | 532.13       | 256.80         | 94.81         | 191.63           | 187.25         | 60.58                     |
| K          | 13.53        | 176.84         | 43.51         | 49.37            | 336.19         | 33.91                     |
| LO         | 29.94        | 24.90          | 0.11          | 4.87             | 8.73           |                           |

Source: Authors’ calculations based on SUST-RUS data
Table A14. Regional emissions intensity index of non-CO2 emissions, Far Eastern Federal District, SUST-RUS sectoral classification (thousands tons of emission per trillion nominal RUB of output of 2006)

| Far Eastern FD | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|----------------|--------------|-----------------|----------------|--------------------|-----------------|--------------------------|
| Row Labels | CnHm | CO | NOx | PM | SO2 | VOC |
| A | | 29,05 | | 120,80 | | |
| CA_col | 111,59 | 19,27 | 8,56 | 169,28 | | |
| CA_gas | | 154,67 | | 100,58 | | 767,10 |
| CA_oil | | 2,253,81 | 67,57 | 485,26 | 859,58 | 907,98 |
| CB | | 594,97 | 90,28 | 495,63 | | 210,19 |
| DA | | 62,43 | 20,74 | | 117,14 | |
| DB | | 144,56 | 51,25 | | 260,12 | |
| DC | | | | | 400,08 | | 251,98 |
| DD | | 396,46 | 46,20 | | 301,20 | |
| DE | | 171,20 | 95,91 | | 445,68 | | 214,12 |
| DF | | 143,96 | 28,33 | | 103,75 | | 198,97 |
| DG | | 324,34 | 87,33 | | 315,78 | | 138,74 |
| DH | | | 13,12 | | 66,61 | | 78,38 |
| DI | | 358,21 | 178,02 | | 835,34 | | |
| Row Labels | CnHm | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|------------|------|-----------------|----------------|-------------------|----------------|-----------------------------|
| DJ         |      | 710,24          | 56,94          | 309,79            | 1 503,69        |                             |
| DK         |      | 137,36          | 45,38          | 208,08            | 2,80            |                             |
| DL         |      | 96,44           | 17,99          | 116,15            |                |                             |
| DM         |      | 122,53          | 35,87          | 189,21            | 51,69           |                             |
| DN         |      |                 |                |                   | 101,37          |                             |
| E_distr    |      | 443,58          | 160,30         | 669,85            | 497,09          |                             |
| E_ely      |      | 284,18          | 935,17         | 1 486,13          | 1 893,27        |                             |
| I_trn      |      | 166,76          | 69,88          | 209,03            | 24,84           |                             |
| K          |      | 86,80           | 18,58          | 66,77             |                |                             |
| LO         |      |                 |                |                   | 22,27           |                             |

Source: Authors’ calculations based on SUST-RUS data
Table A15. List of sectors in the WTO model

| Code | Description                                      |
|------|--------------------------------------------------|
| ELE  | "Electricity"                                   |
| CRU  | "Oil"                                            |
| OIL  | "Oil processing"                                |
| GAS  | "Gas"                                            |
| COL  | "Coal"                                           |
| FME  | "Ferrous metals"                                |
| NFM  | "Non-ferrous metals"                            |
| CHM  | "Chemical and petrochemical products"            |
| MWO  | "Machinery"                                      |
| TPP  | "Forestry - wood - pulp - paper"                 |
| CNM  | "Construction materials"                         |
| OTI  | "Other industrial products"                      |
| CLI  | "Textiles and apparel"                           |
| FOO  | "Food industry"                                  |
| AGR  | "Agricultural products"                          |
| MAR  | "Maritime transportation (*)"                    |
| RLW  | "Railway transportation (*)"                     |
| TRK  | "Truck transportation (*)"                       |
| Code | Description |
|------|-------------|
| PIP  | "Pipelines transportation (*)" |
| AIR  | "Air transportation (*)" |
| TRO  | "Other transportation (*)" |
| TRD  | "Wholesale and retail trade" |
| CON  | "Construction" |
| TMS  | "Telecommunications (*)" |
| PST  | "Post (*)" |
| OTH  | "Other goods and services" |
| HOU  | "Housing and other communal services" |
| HEA  | "Public health, sports, social security, education, culture and arts" |
| SCI  | "Science, geology, mineral exploration, geodesy and hydrometeorology" |
| FIN  | "Financial intermediaries, insurance, management and public organizations" |

Source: Authors’ mapping based on the Russian input-output table of 2001. See the main text for details.
Table A16. Regions of the WTO model

| Regions | Name of the macro-region                  |
|---------|-----------------------------------------|
| msc     | "Moscow"                                |
| stp     | "Saint-Petersburg"                      |
| tmn     | "Tumenskaya region"                     |
| vgd     | "Northwest"                             |
| nor     | "North"                                 |
| cen     | "Central"                               |
| sou     | "South"                                 |
| url     | "Urals and near east"                   |
| sib     | "Siberia"                               |
| far     | "Far East"                              |

Source: Authors’ mapping, see table 2 of the Tables section.
Table A17. Concordance between WTO model industry list (g) and the SUST-RUS industries (s)

| WTO sector | SUST-RUS sector | Description                                |
|------------|-----------------|--------------------------------------------|
| ELE        | E_ely           | "Electricity"                              |
| CRU        | CA_oil          | "Oil"                                      |
| OIL        | DF              | "Oil processing"                           |
| GAS        | CA_gas          | "Gas"                                      |
| COL        | CA_col          | "Coal"                                     |
| FME        | DJ              | "Ferrous metals"                           |
| NFM        | DJ              | "Non-ferrous metals"                       |
| CHM        | DG              | "Chemical and petrochemical products"      |
| MWO        | DK              | "Machinery"                                |
| TPP        | A               | "Forestry - wood - pulp - paper"           |
| CNM        | DI              | "Construction materials"                   |
| OTI        | DN              | "Other industrial products"                |
| CLI        | DB              | "Textiles and apparel"                     |
| FOO        | DA              | "Food industry"                            |
| AGR        | A               | "Agricultural products"                    |
| MAR        | I_trn           | "Maritime transportation (*)"              |
| RLW        | I_trn           | "Railway transportation (*)"               |
| TRK        | I_trn           | "Truck transportation (*)"                 |
| WTO sector | SUST-RUS sector | Description |
|------------|----------------|-------------|
| PIP        | I_trn          | "Pipelines transportation (*)" |
| AIR        | I_trn          | "Air transportation (*)" |
| TRO        | I_trn          | "Other transportation (*)" |
| TRD        | G              | "Wholesale and retail trade" |
| CON        | F              | "Construction" |
| TMS        | I_cmn          | "Telecommunications (*)" |
| PST        | I_cmn          | "Post (*)" |
| OTH        | DN             | "Other goods and services" |
| HOU        | K              | "Housing and other communal services" |
| HEA        | N              | "Public health, sports, social security, education, culture and arts" |
| SCI        | M              | "Science, geology, mineral exploration, geodesy and hydrometeorology" |
| FIN        | J              | "Financial intermediaries, insurance, management and public organizations" |

*Source: Authors’ estimations*
Table A18. Mapping between WTO model regions list (reg) and the SUST-RUS regions (r)

| Regional code | Regions of the SUST-RUS model | Name of the macro-region  |
|---------------|--------------------------------|---------------------------|
| msc           | FD1-Central                    | "Moscow"                  |
| stp           | FD2-Northwest                  | "Saint-Petersburg"        |
| tmn           | FD5-Urals                      | "Tumenskaya region"       |
| vgd           | FD4-Volga                      | "Northwest"               |
| nor           | FD2-Northwest                  | "North"                   |
| cen           | FD1-Central                    | "Central"                 |
| sou           | FD3-South                      | "South"                   |
| url           | FD5-Urals                      | "Urals and near east"     |
| sib           | FD6-Siberian                   | "Siberia"                 |
| far           | FD7-FarEast                    | "Far East"                |

Source: Authors’ estimations

Table A19. Detailed list of subjects of the Russian Federation corresponding to WTO 10-regions macro-regions and Federal Districts of the Russian Federation (coincides with regional division in the SUST-RUS model)

| Federal District | Subject of the Russian Federation | WTO 10-reg code | WTO subj of RF code | Russian Name | SR FD code |
|------------------|----------------------------------|------------------|---------------------|--------------|------------|


| Federal District      | Subject of the Russian Federation | WTO 10-reg code | WTO subj of RF code | Russian Name                      | SR FD code |
|----------------------|-----------------------------------|----------------|---------------------|-----------------------------------|------------|
| Central Federal District | Moscow Oblast                     | msc            | msk                 | г. Москва                        | reg1       |
| Central Federal District | Moscow                            | msc            | mos                 | Московская область               | reg1       |
| Central Federal District | Belgorod Region                   | cen            | bel                 | Белгородская область             | reg1       |
| Central Federal District | Bryansk Region                    | cen            | bry                 | Брянская область                 | reg1       |
| Central Federal District | Vladimir Region                   | cen            | vla                 | Владимирская область             | reg1       |
| Central Federal District | Voronezh Region                   | cen            | vor                 | Воронежская область              | reg1       |
| Central Federal District | Ivanovo Region                    | cen            | iva                 | Ивановская область               | reg1       |
| Central Federal District | Kaluga Region                     | cen            | kal                 | Калужская область                 | reg1       |
| Central Federal District | Kostroma Region                   | cen            | kos                 | Костромская область              | reg1       |
| Central Federal District | Kursk Region                      | cen            | krs                 | Курская область                   | reg1       |
| Central Federal District | Lipetsk Region                    | cen            | lip                 | Липецкая область                  | reg1       |
| Central Federal District | Oryol Region                      | cen            | orl                 | Орловская область                | reg1       |
| Central Federal District | Ryazan Region                     | cen            | rya                 | Рязанская область                 | reg1       |
| Central Federal District | Smolensk Region                   | cen            | smo                 | Смоленская область                | reg1       |
| Central Federal District | Tambov Region                     | cen            | tam                 | Тамбовская область                | reg1       |
| Central Federal District | Tver Region                       | cen            | tve                 | Тверская область                  | reg1       |
| Central Federal District | Tula Region                       | cen            | tul                 | Тульская область                   | reg1       |
| Central Federal District | Yaroslavl Region                  | cen            | yar                 | Ярославская область              | reg1       |
| Federal District | Subject of the Russian Federation | WTO 10-reg code | WTO subj of RF code | Russian Name | SR FD code |
|-----------------|----------------------------------|-----------------|---------------------|--------------|------------|
| North-West Federal District | Vologda Region | vgd | vol | Вологодская область | reg2 |
| North-West Federal District | Kaliningrad Region | vgd | klg | Калининградская область | reg2 |
| North-West Federal District | Novgorod Region | vgd | nov | Новгородская область | reg2 |
| North-West Federal District | Pskov Region | vgd | psk | Псковская область | reg2 |
| North-West Federal District | Republic of Karelia | nor | krl | Республика Карелия | reg2 |
| North-West Federal District | Komi Republic | nor | kom | Республика Коми | reg2 |
| North-West Federal District | Arkhangelsk Region | nor | arh | Архангельская область | reg2 |
| North-West Federal District | Murmansk Region | nor | mur | Мурманская область | reg2 |
| North-West Federal District | Leningrad Region | stp | len | Ленинградская область | reg2 |
| Federal District | Subject of the Russian Federation | WTO 10-reg code | WTO subj of RF code | Russian Name | SR FD code |
|-----------------|---------------------------------|-----------------|---------------------|--------------|------------|
| North-West Federal District | St. Petersburg | stp | spb | г. Санкт-Петербург | reg2 |
| South Federal District | Republic of Adygea | sou | ady | Республика Адыгея | reg3 |
| South Federal District | Republic of Karachay-Cherkessia | sou | ast | Астраханская область | reg3 |
| South Federal District | Krasnodar Krai | sou | kdk | Краснодарский край | reg3 |
| South Federal District | Astrakhan Region | sou | vlg | Волгоградская область | reg3 |
| South Federal District | Rostov Region | sou | ros | Ростовская область | reg3 |
| South Federal District | Ingushetia | sou | dag | Республика Дагестан | reg3 |
| South Federal District | Republic of Ingushetia | sou | ing | Республика Ингушетия | reg3 |
| South Federal District | Kabardino-Balkar Republic | sou | kab | Кабардино-Балкарская Республика | reg3 |
| South Federal District | Karachay-Cherkessia | sou | kar | Карачаево-Черкесская Республика | reg3 |
| South Federal District | Republic of North Ossetia- | sou | sev | Республика Северная Осетия- | reg3 |
| South Federal District | Republic of North Ossetia- | | | | |
| South Federal District | Chechen Republic | | | | reg3 |
| South Federal District | Stavropol Krai | sou | sta | Ставропольский край | reg3 |
| Volga Federal District | Republic of Bashkortostan | url | bas | Республика Башкортостан | reg4 |
| Federal District         | Subject of the Russian Federation | WTO 10-reg code | WTO subj of RF code | Russian Name                          | SR FD code |
|-------------------------|-----------------------------------|-----------------|---------------------|---------------------------------------|------------|
| Volga Federal District  | Republic of Mari El               | url             | mar                 | Республика Марий Эл                   | reg4       |
| Volga Federal District  | Republic of Mordovia              | url             | mor                 | Республика Мордовия                   | reg4       |
| Volga Federal District  | Republic of Tatarstan             | url             | tat                 | Татарстан                             | reg4       |
| Volga Federal District  | Udmurt Republic                   | url             | udm                 | Удмуртская Республика                  | reg4       |
| Volga Federal District  | Chuvash Republic                  | url             | chv                 | Чувашская Республика                   | reg4       |
| Volga Federal District  | Perm Krai                         | url             | per                 | Пермская область                      | reg4       |
| Volga Federal District  | Kirov Region                      | url             | kir                 | Кировская область                     | reg4       |
| Volga Federal District  | Nizhny Novgorod Region            | url             | niz                 | Нижегородская область                  | reg4       |
| Volga Federal District  | Orenburg Region                   | url             | ore                 | Оренбургская область                   | reg4       |
| Volga Federal District  | Penza Region                      | url             | pen                 | Пензенская область                     | reg4       |
| Volga Federal District  | Samara Region                     | url             | sam                 | Самарская область                      | reg4       |
| Volga Federal District  | Ulyanovsk Region                  | url             | ulo                 | Ульяновская область                    | reg4       |
| Ural Federal District   | Kurgan Region                     | url             | krg                 | Курганская область                     | reg5       |
| Ural Federal District   | Sverdlovsk Region                 | url             | sve                 | Свердловская область                   | reg5       |
| Ural Federal District   | Chelyabinsk Region                | url             | chl                 | Челябинская область                    | reg5       |
| Ural Federal District   | Tyumen Region                     | tmn             | tum                 | Тюменская область                      | reg5       |
| Siberian Federal District| Altai Republic                    | sib             | alr                 | Республика Алтай                       | reg6       |
| Siberian Federal District| Republic of Buryatia              | sib             | bur                 | Республика Бурятия                     | reg6       |
| Federal District                  | Subject of the Russian Federation | WTO 10-reg code | WTO subj of RF code | Russian Name                  | SR FD code |
|----------------------------------|-----------------------------------|-----------------|---------------------|------------------------------|------------|
| Siberian Federal District        | Republic of Tuva                  | sib             | tyv                 | Республика Тыва              | reg6       |
| Siberian Federal District        | Republic of Khakassia             | sib             | hak                 | Республика Хакасия            | reg6       |
| Siberian Federal District        | Altai Krai                        | sib             | alt                 | Алтайский край               | reg6       |
| Siberian Federal District        | Krasnoyarsk Krai                  | sib             | kra                 | Красноярский край            | reg6       |
| Siberian Federal District        | Kemerovo Region                   | sib             | kem                 | Кемеровская область          | reg6       |
| Siberian Federal District        | Novosibirsk Region                | sib             | nvs                 | Новосибирская область        | reg6       |
| Siberian Federal District        | Omsk Region                       | sib             | oms                 | Омская область               | reg6       |
| Siberian Federal District        | Tomsk Region                      | sib             | tom                 | Томская область              | reg6       |
| Siberian Federal District        | Irkutsk Region                    | sib             | irk                 | Иркутская область            | reg6       |
| Siberian Federal District        | Trans-Baikal Krai (Zabaikalskii)  | far             | chi                 | Читинская область            | reg6       |
| Far East Federal District        | Republic of Sakha (Yakutia)       | sib             | sah                 | Республика Саха (Якутия)      | reg7       |
| Far East Federal District        | Kamchatka                         | sib             | kam                 | Камчатская область           | reg7       |
| Far East Federal District        | Magadan Region                    | sib             | mag                 | Магаданская область          | reg7       |
| Far East Federal District        | Chukotka Autonomous District      | sib             | chu                 | Чукотский автономный округ   | reg7       |
| Far East Federal District        | Primorsky Krai                    | far             | pri                 | Приморский край              | reg7       |
| Far East Federal District        | Khabarovsky Krai                  | far             | hab                 | Хабаровский край             | reg7       |
| Far East Federal District        | Amur Region                       | far             | amu                 | Амурская область             | reg7       |
| Federal District                     | Subject of the Russian Federation | WTO 10-reg code | WTO subj of RF code | Russian Name                      | SR FD code |
|-------------------------------------|-----------------------------------|-----------------|---------------------|-----------------------------------|------------|
| Far East Federal District           | Sakhalin Region                   | far             | sao                 | Сахалинская область               | reg7       |
| Far East Federal District           | Jewish Autonomous Region          | far             | eao                 | Еврейская автономная область      | reg7       |

*Source: Authors’ estimations*

Table A20. Total emissions in 2001 and 2006, by type of pollutant from industrial stationary (thousands tons)

| Pollutant                      | Abbreviation | 2001     | 2006     |
|--------------------------------|--------------|----------|----------|
| Particulate matter             | PM           | 2 973,20 | 2 836,60 |
| Sulphur dioxide                | SO₂          | 5 254,00 | 4 764,70 |
| Carbon monoxide                | CO           | 5 148,00 | 6 285,30 |
| Nitrogen oxide                 | NOx          | 1 678,90 | 1 701,50 |
| Hydrocarbons                   | CnHm         | 2 723,60 | 2 826,60 |
| Volatile organic components    | VOC          | 1 130,80 | 1 745,30 |

*Source: Ministry of Natural Resources and Environment of the Russian Federation (2007).*
Table A21. Regional emissions intensity index of non-CO2 emissions, North-west region, WTO model's sectoral classification (thousands tons of emission per billion 2001 RUB of output)

| "Northwest" | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|-------------|--------------|-----------------|----------------|-------------------|-----------------|----------------------------|
| Row Labels  | CnHm         | CO              | NOx            | PM                | SO2             | VOC                        |
| MAR         | 1 639,63     |                 | 68,44          |                   |                 |                            |
| AGR         | 12,86        |                 |                |                   |                 |                            |
| AIR         | 1 639,63     |                 | 68,44          |                   |                 |                            |
| CHM         | 101,41       | 102,15          |                |                   |                 | 77,72                      |
| CLI         |              |                 |                |                   |                 |                            |
| CNM         | 1,53         | 277,30          | 509,68         |                   |                 |                            |
| col         | 4 141,01     |                 |                |                   |                 |                            |
| CRU         | 1 448,52     | 2 882,35        | 63,98          |                   | 257,36          | 1 009,50                   |
| ELE         | 4,09         | 1 739,56        | 1 791,64       |                   | 2 604,70        |                            |
| FME         |              | 306,78          | 43,46          |                   | 1 720,03        |                            |
| gas         | 190,62       |                 |                |                   | 47,35           |                            |
| HOU         | 9,18         |                 |                |                   |                 |                            |
| MWO         |              | 21,13           |                |                   |                 |                            |
| NFM         |              | 306,78          | 43,46          |                   | 1 720,03        |                            |
| oil         | 163,73       |                 |                |                   |                 | 150,67                     |
Table A22. Regional emissions intensity index of non-CO2 emissions, Urals and Near East region, WTO model's sectoral classification (thousands tons of emission per billion 2001 RUB of output)

| Region | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|--------|--------------|-----------------|----------------|-------------------|-----------------|----------------------------|
| MAR    | 1,675.72     | 339.81          | 191.19         | 253.84            | 83.73           |                            |
| AGR    | 48.95        | 110.05          | 50.40          | 80.04             | 15.77           |                            |
| AIR    | 1,675.72     | 339.81          | 191.19         | 253.84            | 83.73           |                            |
| CHM    | 137.51       | 602.75          | 224.89         | 464.13            | 221.70          |                            |
| CLI    | 32.52        | 302.78          | 155.22         | 354.48            | 30.07           |                            |
| CNM    | 37.62        | 659.28          | 400.05         | 1,487.57          | 53.83           |                            |

Source: Authors’ estimations
| "Urals and near east" | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|----------------------|--------------|----------------|---------------|-------------------|----------------|---------------------------|
| Row Labels           | CnHm         | CO             | NOx           | PM                | SO2            | VOC                       |
| col                  | 4 177,10     | 93,72          | 72,77         | 175,54            | 30,31          | 1 153,48                  |
| CRU                  | 1 484,61     | 3 822,24       | 186,73        | 797,97            | 2 377,65       | 21,77                     |
| ELE                  | 40,19        | 535,75         | 1 862,30      | 2 769,54          | 1 492,98       | 16,16                     |
| FME                  | 7,57         | 1 246,67       | 166,21        | 452,33            | 21,77          |                           |
| F00                  | 19,43        | 165,73         | 96,28         | 72,83             | 28,67          |                           |
| gas                  | 226,72       | 319,66         | 12,06         | 40,20             | 60,77          |                           |
| HOU                  | 45,27        | 206,40         | 92,12         |                  | 51,42          |                           |
| MWO                  | 15,22        | 290,77         | 143,88        | 251,98            | 57,02          |                           |
| NFMO                 | 7,57         | 1 246,67       | 166,21        | 452,33            | 1 492,98       | 16,16                     |
| oil                  | 199,82       | 301,78         | 110,94        | 46,46             | 294,65         |                           |
| OTH                  | 5,72         | 50,33          | 23,09         | 41,77             | 23,78          |                           |
| OTI                  | 5,72         | 50,33          | 23,09         | 41,77             | 23,78          |                           |
| PIP                  | 1 675,72     | 339,81         | 191,19        | 253,84            | 83,73          |                           |
| RLW                  | 1 675,72     | 339,81         | 191,19        | 253,84            | 83,73          |                           |
| TPP                  | 48,95        | 110,05         | 50,40         | 80,04             | 15,77          |                           |
| TRK                  | 1 675,72     | 339,81         | 191,19        | 253,84            | 83,73          |                           |
| Row Labels | "Urals and near east" | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|------------|----------------------|--------------|-----------------|----------------|-------------------|-----------------|-------------------------------|
| TRO        |                      | CnHm         | CO              | NOx            | PM                | SO2             | 83,73                         |
|            |                      | 1675,72      | 339,81          | 191,19         | 253,84            |                 |                               |

*Source: Authors’ estimations*
Table A23. Regional emissions intensity index of non-CO2 emissions, Tumenskaya region, WTO model's sectoral classification (thousands tons of emission per billion 2001 RUB of output)

| "Tumenskaya region" | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|---------------------|--------------|-----------------|----------------|--------------------|-----------------|---------------------------|
| Row Labels          | CnHm         | CO              | NOx            | PM                 | SO2             | VOC                       |
| MAR                 | 1 675,72     | 339,81          | 191,19         | 253,84             | 83,73           |
| AGR                 | 48,95        | 110,05          | 50,40          | 80,04              | 15,77           |
| AIR                 | 1 675,72     | 339,81          | 191,19         | 253,84             | 83,73           |
| CHM                 | 137,51       | 602,75          | 224,89         | 464,13             | 221,70          |
| CLI                 | 32,52        | 302,78          | 155,22         | 354,48             | 30,07           |
| CNM                 | 37,62        | 659,28          | 400,05         | 1 487,57           | 53,83           |
| col                 | 4 177,10     | 93,72           | 72,77          | 175,54             | 10,89           |
| CRU                 | 1 484,61     | 3 822,24        | 186,73         | 797,97             | 30,31           | 1 153,48                  |
| ELE                 | 40,19        | 535,75          | 1 862,30       | 2 769,54           | 2 377,65        | 21,77                     |
| FME                 | 7,57         | 1 246,67        | 166,21         | 452,33             | 1 492,98        | 16,16                     |
| FOO                 | 19,43        | 165,73          | 96,28          | 72,83              | 28,67           |
| gas                 | 226,72       | 319,66          | 12,06          | 40,20              | 60,77           |
| HOU                 | 45,27        | 206,40          | 92,12          |                   | 51,42           |
| MWO                 | 15,22        | 290,77          | 143,88         | 251,98             | 57,02           |
| "Tumenskaya region" | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|--------------------|--------------|----------------|----------------|-------------------|----------------|-----------------------------|
| Row Labels         | CnHm         | CO             | NOx            | PM                | SO2            | VOC                         |
| NFM                | 7,57         | 1 246,67       | 166,21         | 452,33            | 1 492,98       | 16,16                       |
| oil                | 199,82       | 301,78         | 110,94         | 46,46             | 294,65         | 23,78                       |
| OTH                | 5,72         | 50,33          | 23,09          | 41,77             | 23,78          | 23,78                       |
| OTI                | 5,72         | 50,33          | 23,09          | 41,77             | 23,78          | 23,78                       |
| PIP                | 1 675,72     | 339,81         | 191,19         | 253,84            | 83,73          |                             |
| RLW                | 1 675,72     | 339,81         | 191,19         | 253,84            | 83,73          |                             |
| TPP                | 48,95        | 110,05         | 50,40          | 80,04             | 15,77          |                             |
| TRK                | 1 675,72     | 339,81         | 191,19         | 253,84            | 83,73          |                             |
| TRO                | 1 675,72     | 339,81         | 191,19         | 253,84            | 83,73          |                             |

*Source: Authors’ estimations*
Table A24. Regional emissions intensity index of non-CO2 emissions, Saint-Petersburg region, WTO model's sectoral classification (thousands tons of emission per billion 2001 RUB of output)

| "Saint-Petersburg" | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|--------------------|--------------|-----------------|----------------|-------------------|-----------------|----------------------------|
| Row Labels         | CnHm         | CO              | NOx            | PM                | SO2             | VOC                        |
| MAR                | 1 594,15     | 304,11          | 121,22         | 21,99             |                 | 75,17                      |
| AGR                |              | 74,34           |                |                   |                 | 7,21                       |
| AIR                | 1 594,15     | 304,11          | 121,22         | 21,99             |                 | 75,17                      |
| CHM                | 55,94        | 567,05          | 154,92         | 232,28            |                 | 213,14                     |
| CLI                |              | 267,08          | 85,24          | 122,63            |                 | 21,52                      |
| CNM                |              | 623,58          | 330,07         | 1 255,73          |                 | 45,28                      |
| col                | 4 095,53     | 58,01           | 2,80           |                   |                 | 2,34                       |
| CRU                | 1 403,05     | 3 786,54        | 116,76         | 566,12            | 1 610,21        | 1 144,93                   |
| ELE                |              | 500,05          | 1 792,33       | 2 537,69          | 3 957,55        | 13,22                      |
| FME                | 1 210,96     | 96,23           | 220,48         | 3 072,88          |                 | 7,61                       |
| FOO                | 130,03       | 26,31           |                |                   |                 | 20,12                      |
| gas                | 145,15       | 283,95          |                |                   |                 | 52,22                      |
| HOU                | 170,70       | 22,14           |                |                   |                 | 42,86                      |
| MWO                | 255,07       | 73,90           | 20,13          |                   |                 | 48,47                      |
| "Saint-Petersburg" Row Labels | Hydrocarbons CnHm | Carbon monoxide CO | Nitrogen oxide NOx | Particulate matter PM | Sulphur dioxide SO2 | Volatile organic components VOC |
|-----------------------------|-------------------|--------------------|-------------------|-----------------------|---------------------|-------------------------------|
| NFM                         |                   | 1 210,96           | 96,23             | 220,48                | 3 072,88            | 7,61                          |
| oil                         | 118,25            | 266,08             | 40,97             |                       |                     | 286,10                        |
| OTH                         | 14,62             |                    |                   |                       |                     | 15,23                         |
| OTI                         | 14,62             |                    |                   |                       |                     | 15,23                         |
| PIP                         | 1 594,15          | 304,11             | 121,22            | 21,99                 |                     | 75,17                         |
| RLW                         | 1 594,15          | 304,11             | 121,22            | 21,99                 |                     | 75,17                         |
| TPP                         |                   | 74,34              |                   |                       |                     | 7,21                          |
| TRK                         | 1 594,15          | 304,11             | 121,22            | 21,99                 |                     | 75,17                         |
| TRO                         | 1 594,15          | 304,11             | 121,22            | 21,99                 |                     | 75,17                         |

Source: Authors’ estimations
Table A25. Regional emissions intensity index of non-CO2 emissions, South region, WTO model's sectoral classification (thousands tons of emission per billion 2001 RUB of output)

| "South" | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|---------|--------------|----------------|----------------|-------------------|-----------------|---------------------------|
| Row Labels | CnHm | CO | NOx | PM | SO2 | VOC |
| MAR | 1 153,88 | 197,06 | 74,99 | | | 62,47 |
| AIR | 1 153,88 | 197,06 | 74,99 | | | 62,47 |
| CHM | 460,00 | 108,70 | | | | 200,44 |
| CLI | 160,03 | 39,02 | | | | 8,81 |
| CNM | 516,53 | 283,85 | 391,61 | | | 32,58 |
| col | 3 655,26 | | | | | |
| CRU | 962,77 | 3 679,49 | 70,53 | | 1 132,22 |
| ELE | 393,00 | 1 746,10 | 1 673,57 | 2 018,74 |
| FME | 1 103,92 | 50,01 | | 1 134,07 |
| FOO | 22,98 | | | 7,41 |
| gas | 176,90 | | | 39,51 |
| HOU | 63,65 | | | 30,16 |
| MWO | 148,02 | 27,68 | | 35,77 |
| NFM | 1 103,92 | 50,01 | | 1 134,07 |
| "South" Hydrocarbons | Carbon monoxide CO | Nitrogen oxide NOx | Particulate matter PM | Sulphur dioxide SO2 | Volatile organic components VOC |
|----------------------|-------------------|--------------------|-----------------------|---------------------|-------------------------------|
| oil                  | 159,03            |                    |                       |                     | 273,39                        |
| OTH                  |                   |                    |                       |                     | 2,53                          |
| OTI                  |                   |                    |                       |                     | 2,53                          |
| PIP 1 153,88         | 197,06            | 74,99              |                       |                     | 62,47                         |
| RLW 1 153,88         | 197,06            | 74,99              |                       |                     | 62,47                         |
| TRK 1 153,88         | 197,06            | 74,99              |                       |                     | 62,47                         |
| TRO 1 153,88         | 197,06            | 74,99              |                       |                     | 62,47                         |

*Source: Authors' estimations*
Table A26. Regional emissions intensity index of non-CO2 emissions, Siberia region, WTO model's sectoral classification (thousands tons of emission per billion 2001 RUB of output)

| "Siberia" | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|-----------|--------------|----------------|----------------|--------------------|-----------------|--------------------------|
| Row Labels | CnHm         | CO             | NOx            | PM                 | SO2             | VOC                      |
| MAR       | 1 672,99     | 428,49         | 183,11         | 377,49             | 425,22          | 73,38                    |
| AGR       | 46,22        | 198,72         | 42,32          | 203,69             | 66,33           | 5,42                     |
| AIR       | 1 672,99     | 428,49         | 183,11         | 377,49             | 425,22          | 73,38                    |
| CHM       | 134,77       | 691,43         | 216,81         | 587,78             | 1 260,11        | 211,35                   |
| CLI       | 29,78        | 391,46         | 147,13         | 478,13             | 911,51          | 19,72                    |
| CNM       | 34,89        | 747,95         | 391,96         | 1 611,22           | 1 019,49        | 43,49                    |
| col       | 4 174,37     | 182,39         | 64,68          | 299,18             | 114,52          | 0,54                     |
| CRU       | 1 481,88     | 3 910,92       | 178,65         | 921,61             | 4 072,17        | 1 143,13                 |
| ELE       | 37,45        | 624,43         | 1 854,22       | 2 893,18           | 6 419,51        | 11,43                    |
| FME       | 4,83         | 1 335,34       | 158,12         | 575,97             | 5 534,84        | 5,82                     |
| FOO       | 16,69        | 254,40         | 88,20          | 196,48             | 279,33          | 18,32                    |
| gas       | 223,98       | 408,33         | 163,85         | 3 862,16           | 50,42           |                          |
| HOU       | 42,54        | 295,08         | 84,03          | 97,25              | 763,44          | 41,07                    |
| MWO       | 12,48        | 379,44         | 135,79         | 375,62             | 435,04          | 46,68                    |
| "Siberia" | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|-----------|--------------|----------------|---------------|-------------------|-----------------|---------------------------|
| Row Labels | CnHm          | CO             | NOx           | PM                | SO2             | VOC                       |
| NFM       | 4.83          | 1335.34        | 158.12        | 575.97            | 5534.84         | 5.82                      |
| oil       | 197.09        | 390.46         | 102.86        | 170.11            | 1455.78         | 284.30                    |
| OTH       | 2.99          | 139.00         | 15.01         | 165.42            | 36.38           | 13.44                     |
| OTI       | 2.99          | 139.00         | 15.01         | 165.42            | 36.38           | 13.44                     |
| PIP       | 1672.99       | 428.49         | 183.11        | 377.49            | 425.22          | 73.38                     |
| RLW       | 1672.99       | 428.49         | 183.11        | 377.49            | 425.22          | 73.38                     |
| TPP       | 46.22         | 198.72         | 42.32         | 203.69            | 66.33           | 5.42                      |
| TRK       | 1672.99       | 428.49         | 183.11        | 377.49            | 425.22          | 73.38                     |
| TRO       | 1672.99       | 428.49         | 183.11        | 377.49            | 425.22          | 73.38                     |

*Source: Authors’ estimations*
Table A27. Regional emissions intensity index of non-CO2 emissions, North region, WTO model's sectoral classification (thousands tons of emission per billion 2001 RUB of output)

| "North" | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|----------|--------------|-----------------|----------------|-------------------|-----------------|---------------------------|
| Row Labels | CnHm          | CO              | NOx            | PM                | SO2             | VOC                       |
| MAR      | 1 594,15     | 304,11          | 121,22         | 21,99             |                 | 75,17                     |
| AGR      |               | 74,34           |                |                   |                 | 7,21                      |
| AIR      | 1 594,15     | 304,11          | 121,22         | 21,99             |                 | 75,17                     |
| CHM      | 55,94        | 567,05          | 154,92         | 232,28            |                 | 213,14                    |
| CLI      |               | 267,08          | 85,24          | 122,63            |                 | 21,52                     |
| CNM      | 623,58       | 330,07          | 1 255,73       |                   |                 | 45,28                     |
| col      | 4 095,53     | 58,01           | 2,80           |                   |                 | 2,34                      |
| CRU      | 1 403,05     | 3 786,54        | 116,76         | 566,12            | 1 610,21        | 1 144,93                  |
| ELE      |               | 500,05          | 1 792,33       | 2 537,69          | 3 957,55        | 13,22                     |
| FME      | 1 210,96     | 96,23           | 220,48         | 3 072,88          |                 | 7,61                      |
| FOO      | 130,03       | 26,31           |                |                   |                 | 20,12                     |
| gas      | 145,15       | 283,95          |                |                   | 1 400,20        | 52,22                     |
| HOU      | 170,70       | 22,14           |                |                   |                 | 42,86                     |
| MWO      | 255,07       | 73,90           | 20,13          |                   |                 | 48,47                     |
| "North" Hydrocarbons | CnHm | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|----------------------|------|----------------|----------------|-------------------|-----------------|--------------------------|
| NFM                  |      | 1 210,96       | 96,23          | 220,48            | 3 072,88        | 7,61                     |
| oil                  | 118,25 | 266,08       | 40,97          |                   |                 | 286,10                   |
| OTH                  |      | 14,62          |                |                   |                 | 15,23                    |
| OTI                  |      | 14,62          |                |                   |                 | 15,23                    |
| PIP                  | 1 594,15 | 304,11      | 121,22         | 21,99             |                 | 75,17                    |
| RLW                  | 1 594,15 | 304,11      | 121,22         | 21,99             |                 | 75,17                    |
| TPP                  |      | 74,34          |                |                   |                 | 7,21                     |
| TRK                  | 1 594,15 | 304,11      | 121,22         | 21,99             |                 | 75,17                    |
| TRO                  | 1 594,15 | 304,11      | 121,22         | 21,99             |                 | 75,17                    |

Source: Authors’ estimations
Table A28. Regional emissions intensity index of non-CO2 emissions, Moscow region, WTO model's sectoral classification (thousands tons of emission per billion 2001 RUB of output)

| Row Labels | Hydrocarbons CnHm | Carbon monoxide CO | Nitrogen oxide NOx | Particulate matter PM | Sulphur dioxide SO2 | Volatile organic components VOC |
|------------|-------------------|--------------------|-------------------|-----------------------|---------------------|---------------------------------|
| MAR        | 105,56            | 48,24              |                   |                       |                     |                                 |
| AIR        | 105,56            | 48,24              |                   |                       |                     |                                 |
| CHM        | 311,18            | 23,34              |                   |                       |                     | 86,20                           |
| CLI        |                   | 11,21              |                   |                       |                     |                                 |
| CNM        | 367,70            | 198,49             | 335,51            |                       |                     |                                 |
| Col        | 2 606,94          |                    |                   |                       |                     |                                 |
| ELE        | 244,18            | 1 660,75           | 1 617,47          | 1 326,25              |                     |                                 |
| FME        | 955,09            |                    |                   |                       | 441,58              |                                 |
| NFM        | 955,09            |                    |                   |                       | 441,58              |                                 |
| Oil        | 10,21             |                    |                   |                       |                     | 159,16                          |
| PIP        | 105,56            | 48,24              |                   |                       |                     |                                 |
| RLW        | 105,56            | 48,24              |                   |                       |                     |                                 |
| TRK        | 105,56            | 48,24              |                   |                       |                     |                                 |
| TRO        | 105,56            | 48,24              |                   |                       |                     |                                 |
Table A29. Regional emissions intensity index of non-CO2 emissions, Far East region, WTO model's sectoral classification (thousands tons of emission per billion 2001 RUB of output)

| "Far East" | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|------------|--------------|-----------------|----------------|-------------------|----------------|---------------------------|
| Row Labels | CnHm         | CO              | NOx            | PM                | SO2            | VOC                       |
| MAR        |              | 278,25          | 134,96         | 411,75            | 30,09          |                           |
| AGR        |              | 48,48           |                |                   |                |                           |
| AIR        |              | 278,25          | 134,96         | 411,75            | 30,09          |                           |
| CHM        |              | 541,18          | 168,66         | 622,05            | 168,06         |                           |
| CLI        |              | 241,22          | 98,98          |                   | 512,39         |                           |
| CNM        |              | 597,71          | 343,81         | 1 645,49          |                |                           |
| col        |              | 350,85          | 32,15          | 16,54             | 333,45         |                           |
| CRU        |              | 3 760,67        | 130,50         | 955,88            | 1 951,99       | 1 099,84                  |
| ELE        |              | 474,18          | 1 806,07       | 2 927,45          | 4 299,33       |                           |
| FME        |              | 1 185,10        | 109,97         | 610,24            | 3 414,66       |                           |
| FOO        |              | 104,16          | 40,05          | 230,75            |                |                           |
| gas        |              | 258,09          | 198,12         | 1 741,98          |                |                           |
| "Far East" Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|-------------------------|-----------------|----------------|-------------------|----------------|---------------------------|
| Row Labels              | CO              | NOx            | PM                | SO2            | VOC                       |
| HOU                     | 144.84          | 35.88          | 131.52            |                |                           |
| MWO                     | 229.20          | 87.64          | 409.89            |                | 3.39                      |
| NFM                     | 1,185.10        | 109.97         | 610.24            | 3,414.66       |                           |
| Oil                     | 240.22          | 54.71          | 204.38            |                | 241.01                    |
| OTH                     |                 |                | 199.68            |                |                           |
| OTI                     |                 |                | 199.68            |                |                           |
| PIP                     | 278.25          | 134.96         | 411.75            | 30.09          |                           |
| RLW                     | 278.25          | 134.96         | 411.75            | 30.09          |                           |
| TPP                     | 48.48           |                | 237.96            |                |                           |
| TRK                     | 278.25          | 134.96         | 411.75            | 30.09          |                           |
| TRO                     | 278.25          | 134.96         | 411.75            | 30.09          |                           |

Source: Authors’ estimations
Table A30. Regional emissions intensity index of non-CO2 emissions, Central region, WTO model's sectoral classification (thousands tons of emission per billion 2001 RUB of output)

| "Central" | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|------------|--------------|-----------------|----------------|--------------------|-----------------|-----------------------------|
| Row Labels | CnHm         | CO              | NOx            | PM                 | SO2             | VOC                         |
| MAR        | 105,56       | 48,24           |                |                    |                 |                             |
| AIR        | 105,56       | 48,24           |                |                    |                 |                             |
| CHM        | 311,18       | 23,34           |                |                    |                 | 86,20                       |
| CLI        | 11,21        |                 |                |                    |                 |                             |
| CNM        | 367,70       | 198,49          | 335,51         |                    |                 |                             |
| col        | 2 606,94     |                 |                |                    |                 |                             |
| ELE        | 244,18       | 1 660,75        | 1 617,47       | 1 326,25           |                 |                             |
| FME        | 955,09       |                 |                |                    | 441,58          |                             |
| NFM        | 955,09       |                 |                |                    | 441,58          |                             |
| oil        | 10,21        |                 |                |                    |                 | 159,16                      |
| PIP        | 105,56       | 48,24           |                |                    |                 |                             |
| RLW        | 105,56       | 48,24           |                |                    |                 |                             |
| TRK        | 105,56       | 48,24           |                |                    |                 |                             |
| TRO        | 105,56       | 48,24           |                |                    |                 |                             |
Table A31. Average regional emissions intensity index of non-CO2 emissions, WTO model's sectoral classification (thousands tons of emission per billion 2001 RUB of output)

| Average Russian region | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|------------------------|--------------|-----------------|----------------|-------------------|-----------------|----------------------------|
| Row Labels             | CnHm          | CO              | NOx            | PM                | SO2             | VOC                        |
| MAR                    | 1 259,33      | 270,18          | 131,83         | 180,23            | 62,74           | 59,51                      |
| AGR                    | 22,01         | 67,42           | 21,48          | 62,69             | 10,22           | 5,77                       |
| AIR                    | 958,96        | 213,96          | 96,35          | 130,02            | 50,04           | 44,49                      |
| CHM                    | 78,64         | 490,39          | 147,82         | 270,51            | 143,46          | 174,89                     |
| CLI                    | 11,62         | 172,03          | 70,91          | 173,05            | 106,77          | 12,39                      |
| CNM                    | 13,39         | 519,00          | 295,47         | 863,74            | 96,84           | 25,95                      |
| col                    | 3 693,30      | 145,83          | 52,08          | 265,96            | 84,97           | 0,86                       |
| CRU                    | 1 423,09      | 3 808,23        | 173,39         | 725,07            | 195,00          | 1 150,30                   |
| ELE                    | 19,21         | 432,92          | 1 781,79       | 2 313,84          | 2 806,44        | 10,04                      |
| FME                    | 3,67          | 1 044,61        | 98,21          | 261,25            | 1 745,68        | 7,57                       |
| FOO                    | 5,24          | 82,52           | 32,17          | 46,23             | 29,45           | 10,77                      |
| gas                    | 219,65        | 316,29          | 11,53          | 40,39             | 45,97           | 59,89                      |

Source: Authors’ estimations
| Average Russian region | Hydrocarbons | Carbon monoxide | Nitrogen oxide | Particulate matter | Sulphur dioxide | Volatile organic components |
|------------------------|--------------|-----------------|----------------|--------------------|-----------------|----------------------------|
| Row Labels             | CnHm         | CO              | NOx            | PM                 | SO2             | VOC                        |
| HOU                    | 17,54        | 116,01          | 37,98          | 16,61              | 92,62           | 25,14                      |
| MWO                    | 7,13         | 185,72          | 80,41          | 148,30             | 28,42           | 33,16                      |
| NFM                    | 4,58         | 1276,13         | 143,69         | 483,98             | 4010,49         | 7,64                       |
| oil                    | 129,97       | 248,84          | 71,43          | 58,89              | 251,99          | 265,18                     |
| OTH                    | 2,76         | 41,29           | 11,56          | 46,63              | 5,08            | 13,15                      |
| OTI                    | 1,38         | 19,66           | 5,73           | 20,79              | 2,09            | 7,14                       |
| PIP                    | 1349,39      | 286,83          | 145,06         | 194,62             | 44,78           | 65,77                      |
| RLW                    | 1121,30      | 242,15          | 114,19         | 155,81             | 61,85           | 51,76                      |
| TPP                    | 17,71        | 77,95           | 16,65          | 59,85              | 10,73           | 6,09                       |
| TRK                    | 1083,34      | 236,05          | 110,72         | 149,12             | 52,92           | 50,75                      |
| TRO                    | 1075,02      | 233,86          | 109,74         | 146,82             | 49,96           | 50,42                      |

Source: Authors’ estimations
Table A32. Total CO2 emissions from combustion of fossil fuels in 2001, Gigatons ($\text{Gi}$).

| Abbreviation | Type of fossil fuel       | WTO model | Rosgidromet data |
|--------------|---------------------------|-----------|------------------|
| Oil          | Liquid fuel               | 0,35      | 0,33             |
| Gaz          | Fluid fossil fuel         | 0,75      | 0,74             |
| Col          | Solid fossil fuels        | 0,31      | 0,31             |

Source: Authors’ estimations and Rosgidromet (2013Table A).

Table A33. CO2 emission intensities from combustion of fossil fuels in 2001, Gt/bln RUB 2001

| Abbreviation | Type of fossil fuel       | WTO model |
|--------------|---------------------------|-----------|
| Oil          | Liquid fossil fuel        | 8,20E-04  |
| Gaz          | Fluid fossil fuel         | 9,98E-03  |
| Col          | Solid fossil fuels        | 4,46E-03  |

Source: Authors’ estimations