REGIONAL ECONOMIES

WHAT IF RUSSIA SHUT OFF UKRAINE'S GAS AGAIN? A COMPUTABLE GENERAL EQUILIBRIUM MODEL

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ABSTRACT

This paper asks the question: what would happen to the economies of the world should Russia completely shut off natural gas shipments to the Ukraine. Significant findings of this model include the following:

The impact of the gas shutoff is overwhelmingly concentrated in Ukraine and Russia, whose economies would suffer GDP declines of 2.47 percent and 2.16 percent, respectively. Perhaps surprisingly, the model suggests Eastern Europe would experience only a small decline in GDP (0.13 percent) and Western Europe's GDP would be unaffected. The GDP of gas-pruducing republics of the Other Former Soviet Union (FSU), major gas suppliers through the Russian pipelines, would decline by 0.75 percent.

While the impacts to overall GDP are possibly smaller than expected, effects to individual industry sectors in many countries are quite large. One response of Ukraine and Europe to the cessation of Russian gas is an attempt to replace supplies with domestically-produced gas. While output of natural gas decreases by 4.86 percent in Russia and 11.6 percent in the Rest of the Former Soviet Union, gas production increases in Ukraine, Eastern Europe, and Western Europe by 140.1 percent, 88.1 percent, and 12.0 percent, respectively (though note that each region starts with a small base). Production of

natural gas increases in Africa (6.9 percent), the Middle East (5.2 percent), the United States (2.0 percent), and the Rest of the World (2.2 percent).

Industry sectors within the Ukraine are forced to adjust to the decrease in gas imports. While ouput of Ukrainian domestic gas increases by 140.1 percent, Ukraininan ouput of many sectors significantly decrease, including Heavy Manufacturing (–12.5 percent), Light Manufacturing (–5.3 percent), Utilities and Construction (–5.0 percent), capital goods (–4.7 percent), and processed food (–2.4 percent).

While Russia suffers a major decline in its massive gas inductry (–4.9 percent), the domestic surplus of gas provides for cheaper production in other Russian industries. Russian output in several sectors significantly increases, including that in Heavy Manufacturing (3.9 percent), Light Manufacturing (3.1 percent), Oil (1.0 percent), and extraction (1.5 percent). Perhaps surprisingly, other than in natural gas production, the industry sectors of Eastern and Western Europe do not experience significant changes.

The gas shutoff decreases gas supply in several regions, resulting in significantly higher gas prices, including those in Ukraine (27.6 percent price increases), Eastern Europe (14.5 percent), and Western Europe (4.7 percent). Greater supplies lower prices in Russia (–5.0 percent) and the other gas-producing republics of the FSU (–3.6 percent).

A shutoff of Russian gas would directly result in a decrease of aggregate gas imports by volume to Ukraine (–48.3 percent or –$3.4 billion), Eastern Europe (–33.8 percent or –2.1 billion), and Western Europe (–2.9 percent or –1.1 billion).

Russia's shutting off gas to Ukraine would hurt Russia the most, with a net welfare loss to Russia of $11.8 billion. Other large welfare losses would accrue to Ukraine (–$722 million), Eastern Europe (–$469 million), and Western Europe (–$1.37 billion).

KEYWORDS: ***Russia, Ukraine, natural gas , energy economics, computable general equilibrium (CGE), development, Global Trade Analysis Project, GTAP.***

Introduction

A significant factor in the current poitcal tensions between Russia, Ukraine, and Western Europe is the massive flow of natural gas from Russia and Central Asia through Ukraine's gas pipelines. Citing unpaid bills and other issues, Russia has periodically threatened to shut off the flow of gas to Ukraine, affecting gas supplies to much of Eastern and Western Europe. Critics accuse Russia of using such threats as a bargaining tool to lure Ukraine away from political and economic alliances with the EU and the West. Irrespective of Russia's motives, the cutoff of gas supplies would affect the economic wellbeing of much of Europe. This paper employs a computable general equilibrium model to analyze those effects. While the effects are significant, the model would suggest a smaller impact than the popular press might suggest.

1. Background

Russia provides approximately a quarter of the natural gas consumed in the European Union; approximately 80% of those exports travel through pipelines across Ukrainian soil prior to arriving

in the EU.[1] Disputes between Ukrainian oil and gas company Naftogaz Ukrainy and Russian gas supplier Gazprom over natural gas supplies, prices, and debts have escalated into serious international political and economic disagreements between governments. Repeated disputes erupted in the 1990s, and in each of the winters from 2005 to the present. The dispute during the winter of 2008-2009 was especially serious, and resulted in widescale shutdowns of Russian gas shipments. The countries of Eastern Europe warned of millions of apartments without heat, while businesses across Europe complained of disruptions to production and national output.

In the Fall and Winter of 2013, Ukraine's leaders have been navigating relations with East and West. While a trade agreement with the EU appeared in the offering, Russia's disapproval and financial incentives appear to have convinced Ukraine to forgoe such alliances with the West. The threat of a gas shutdown might also have played a role in convincing Ukraine to maintain its closer relations with its former Soviet partner. Popular press has suggested gas shutdowns would cause economic calamity for Ukraine and parts of Europe. This paper is aimed at quantifying that effect.

2. CGE Model for Natural Gas Trade

What would be the macroeconomic effect of Russia's totally stopping natural gas shipments to the Ukraine? The section is broken into several parts, including,

(a) a background of CGE models;

(b) the Global Trade Analysis Project (GTAP);

(c) the structure of this paper's model,

(d) model results;

(e) model limitations and future research.

2.1. Background of General Equilibrium Models

General equilibrium, a concept which dates back to Leon Walras (1834-1910), is a pillar of modern economic thought. General equilibrium recognizes that there are many markets in an economy, and that these markets all interact in complex ways with each other. In rough terms, everything depends on everything else. Demand for any one good depends on the prices of all other goods and on income. Income, in turn, depends on wages, profits, and rents, which depend on technology, factor supplies and production, the last of which, in its turn, depends on sales (i.e., demand).[2]

Computable General Equilibrium (CGE) modeling specifies all economic relationships in mathematical terms and puts them together in a form that allows the model to predict the change in variables such as prices, output and economic welfare resulting from a change in economic policies. To

[1] See: "EU Reaches Gas Deal with Ukraine," BBC News, 1 August, 2009.

[2] See: T. Hertel, R. Keeney, M. Ivanic, A. Winters, "Distributional Effects of WTO Agricultural Reforms in Rich and Poor Countries," *Economic Policy*, April 2007, pp. 289-337.

do this, the model requires information about technology (the inputs required to produce a unit of output), policies and consumer preferences. The key of the model is "market clearing," the condition that says supply should equal demand in every market. The solution, or "equilibrium," is that set of prices where supply equals demand in every market— goods, factors, foreign exchange, and everything else.[3]

A CGE model is a closed system. This means that no production or financial flow escapes the system and none are created outside of the system. In basic closure terms, we assume output will equal income. Households, businesses, the government, and the financial sector, and the foreign sector are all connected by real flows and financial flows. Intuitively, the idea of a "general" equilibrium is captured; any given market is connected to all of the other markets for the system.

Over the last 25 years, CGE models have become an important tool for analyzing economic issues, including trade policy, taxation policy, technological growth, energy policy, environmental issues, and even warfare. This development is explained by the ability of CGE models to provide an elaborate and realistic representation of the economy, including the linkages between all agents, sectors and other economies. While this complete coverage permits a unique insight into the effects of changes in the economic environment throughout the whole economy, single country, and especially global CGE models very often include an enormous number of variables, parameters and equations.[4]

CGE modeling is a very powerful tool, allowing economists to explore numerically a huge range of issues on which econometric estimation would be impossible; in particular to forecast the effects of future policy changes. The models have their limitations, however. First, CGE simulations are not unconditional predictions but rather "thought experiments" about what the world would be like if the policy change had been operative in the assumed circumstances and year. The real world will doubtless have changed by the time we get there. Second, while CGE models are quantitative, they are not empirical in the sense of econometric modeling: they are basically theoretical, with limited possibilities for rigorous testing against experience. Third, conclusions about trade and other policies are very sensitive to data assumption. One can readily do sensitivity analysis on the parameter values assumed for economic behavior, although less so on the data, because altering one element of the base data requires compensating changes elsewhere in order to keep the national accounts and social accounting matrix in balance. Of course, many of these criticisms apply to other types of economic modeling, and therefore, while imperfect, CGE models remain the preferred tool for analysis of many global issues.

2.2. The Global Trade Analysis Project

One of the most widely-used CGE models is the GTAP Model. The Global Trade Analysis Project (GTAP), with headquarters at Purdue University, has organized a consortium of national and international agencies which provide guidance and base-level support for the Project.[5]

GTAP is a multi-regional CGE model which captures world economic activity in 57 different industries of 66 regions. The underlying equation system of GTAP includes two different kinds of equations. One part covers the accounting relationships which ensure that receipts and expenditures

[3] Ibidem.

[4] See: M. Brockmeier, "A Graphical Exposition of the GTAP Model," *GTAP Technical Paper*, No. 8, October 1996, Minor Edits, January 2000, Revised, March 2001.

[5] See: *Global Trade Analysis Project (GTAP)*, Department of Agricultural Economics, Purdue University, 2008, available at [https://www.gtap.agecon.purdue.edu/about/consortium.asp].

of every agent in the economy are balanced. The other part of the equation system consists of behavioral equations based upon microeconomic theory. These equations specify the behavior of optimizing agents in the economy, such as demand functions.[6] Input-out tables summarize the linkages between all industries and agents.

The mathematical relationships assumed in the GTAP model are simplified, though they adhere to the principle of "many markets." The simplification is that thousands of markets are "aggregated" into groups. For example, transport and communications services, financial services, banking, defense, health, education, and other services appear as a single industry, listed as simply "services" in this model. In principle, all the relationships in a model could be estimated from detailed data on the economy over many years. In practice, however, their number and parameterization generally outweigh the data available. In the GTAP model, only the most important relationships have been econometrically estimated. These include the international trade elasticities and the agricultural factor supply and demand elasticities. The remaining economic relationships are based on literature reviews.

2.3. Structure of this Paper's Model

The model employed in this paper is that of the GTAP project. While the core database has 57 sectors and 66 regions, we have aggregated the matrices to simplify the world into just nine sectors (plus capital investment goods), nine regions, and five factors of production. This aggregation is described in Table 1. The data is first, "calibrated," meaning the model is solved for its original equilibrium prices and volumes in all markets. This baseline is meant to represent the economy as is, before

Table 1

Data Aggregation

Regions	Sectors	Factors
Russia	NaturalGas	Land
Ukraine	Oil	UnSkLab
EastEurope	Agriculture	SkLab
WestEurope	Extraction	Capital
FSU	ProcFood	NatRes
MiddleEast	LightMnfc	
Africa	HeavyMnfc	
U.S.	Util_Cons	
RestofWorld	Services	
	CGDS	

Source: Generated by the author.

[6] See: M. Brockmeier, op. cit.

any shock takes place. Thousands of equations are created, each representing supply and demand conditions in markets inside each region, including markets for goods, services, factors of production, savings, government expenditure, and more. Equations are also generated for trade of all goods between each of the regions, separately created for each industry. The calibrated result is a large set of simultaneous equations, of which the solution matches the existing prices and quantity levels of the economy.

A "shock" is then introduced to system. Mathematically, a "shock" is the alteration of a single parameter or variable in the giant system. That change acts like a stone thrown in a pond, with waves created throughout every one of the thousands of equations in the system. The model is re-solved with the one autonomous change, and the effects on the system are then measured.

The "shock" in this model is a complete stoppage of Russian gas shipments to Ukraine. This includes shipments originating in the Russian Federation as well as transhipments of gas from former Soviet republics in Central Asia, from which gas is piped by Russia's Gazprom to and through Ukraine. While the framework of the standard GTAP model does not provide for specifying an exogeneous export quota (zero in this case), this model accomplishes the same gas trade stoppage with prohibitively high tariffs on trade of gas from Russia and Central Asia. The tariffs are modeled at the level high enough to result in zero exports of Russian gas. The change in gas supplies will affect production and consumption in Ukraine and all of Europe. Possible economic effects will be seen in GDP, prices, employment, consumption, imports, exports, and overall economic welfare. The role of a CGE model is to quantify the direction and magnitude of these changes.[7]

3. Model Results

A computable general equilibrium model can generate an enormous array of matrix results. In this model, results are grouped into the following sections:

(1) output and income;

(2) prices;

(3) international trade; and

(4) welfare effects.

3.1. Output and Income Effects

The impact of the gas shutoff is overwhelmingly concentrated in Ukraine and Russia, whose economies would suffer GDP declines of 2.47 percent and 2.16 percent respectively (see Table 2). Perhaps surprisingly, the model suggests Eastern Europe would experience only a small decline in GDP (0.13 percent) and Western Europe's GDP would be unaffected. The GDP of gas-pruducing republics of the Other Former Soviet Union (FSU), major gas suppliers through the Russian pipelines, would decline by 0.75 percent.

[7] For more on economic efficiency and taxation, see, Campbell R. McConnell and Stanley L. Brue, *Economics: Principles, Problems, and Policies*, 16th Ed., McGraw Hill Publishing, 2006.

Table 2

Real GDP

qgdp	Percent change
Russia	–2.16
Ukraine	–2.47
EastEurope	–0.13
WestEurope	–0.01
FSU	–0.75
MiddleEast	0.01
Africa	0.02
U.S.	0.00
RestofWorld	0.00

Source: Generated by the author.

While the impacts to overall GDP are possibly smaller than expected, effects to individual industry sectors in many countries are quite large (see Table 3). One response of Ukraine and Europe to the cessation of Russian gas is an attempt to replace supplies with domestically-produced gas. While output of natural gas decreases by 4.86 percent in Russia and 11.6 percent in the Rest of the Former Soviet Union, gas production increases in Ukraine, Eastern Europe, and Western Europe by 140.1 percent, 88.1 percent, and 12.0 percent, respectively (though note that each region starts with a small base). Production of natural gas increases in Africa (6.9 percent), the Middle East (5.2 percent), the United States (2.0 percent), and the Rest of the World (2.2 percent).

Table 3

Industry Output by Region (percent change)

qo	Russia	Ukraine	EastEurope	WestEurope	FSU	MiddleEast	Africa	U.S.	RestofWorld
NaturalGas	–4.86	140.14	88.06	12.01	–11.6	5.15	6.92	1.98	2.24
Oil	0.97	–1.64	0.01	–0.01	0.71	–0.09	–0.17	–0.02	0
Agriculture	–0.12	–1.31	–0.1	–0.04	–0.01	–0.16	–0.12	–0.03	–0.01
Extraction	1.49	–4	–0.06	–0.02	1.17	–0.18	–0.18	–0.02	–0.01
ProcFood	0.28	–2.38	–0.13	–0.03	–0.15	–0.12	–0.1	–0.01	–0.01

Table 3 (continued)

qo	Russia	Ukraine	EastEurope	WestEurope	FSU	MiddleEast	Africa	U.S.	RestofWorld
LightMnfc	3.12	–5.25	–0.17	–0.06	2.72	–0.54	–0.51	–0.05	–0.01
HeavyMnfc	3.87	–12.45	–0.32	–0.08	2.94	–0.81	–0.82	–0.05	0
Util_Cons	0.05	–4.98	–0.12	–0.06	–0.16	–0.03	0.09	0.01	–0.04
Services	–0.86	–0.31	–0.09	–0.02	–0.19	–0.05	–0.12	0	–0.01
CGDS	–0.6	–4.68	–0.43	–0.07	–0.63	0.06	0.34	–0.01	–0.05

Source: Generated by the author.

Industry sectors within the Ukraine are forced to adjust to the decrease in gas imports. While ouput of Ukrainian domestic gas increases by 140.1 percent, Ukraininan ouput of many sectors significantly decrease, including Heavy Manufacturing (–12.5 percent), Light Manufacturing (–5.3 percent), Utilities and Construction (5.0 percent), capital goods (–4.7 percent), and processed food (–2.4 percent) (see Table 4).

Table 4

Ukrainian Output

qo	Percent change
NaturalGas	140.14
Oil	–1.64
Agriculture	–1.31
Extraction	–4
ProcFood	–2.38
LightMnfc	–5.25
HeavyMnfc	–12.45
Util_Cons	–4.98
Services	–0.31
CGDS	–4.68

Source: Generated by the author.

While Russia suffers a major decline in its massive gas inductry (–4.9 percent), the domestic surplus of gas provides for cheaper production in other Russian industries. Russian output in several

sectors significantly increases, including that in Heavy Manufacturing (3.9 percent), Light Manufacturing (3.1 percent), Oil (1.0 percent), and extraction (1.5 percent). Perhaps surprisingly, other than in natural gas production, the industry sectors of Eastern and Western Europe do not experience significant changes.

3.2. Prices

New levels of domestic gas supply and demand determine prices in each region (see Table 5). The gas shutoff decreases gas supply in several regions, resulting in significantly higher gas prices, including those in Ukraine (27.6 percent price increases), Eastern Europe (14.5 percent), and Western Europe (4.7 percent). Greater supplies lower prices in Russia (–5.0 percent) and the gas-producing republics of the Other Former Soviet Union (–3.6 percent). The model suggests gas price increases in Africa (2.0 percent) and the United States (0.7 percent), while price declines in the Middle East (–2.9 percent).

Table 5

Market Price of Natural Gas
(percent change)

pm	
Russia	–5.04
Ukraine	27.55
EastEurope	14.45
WestEurope	4.68
FSU	–3.63
MiddleEast	–2.87
Africa	2.03
U.S.	0.72
RestofWorld	0.53

Source: Generated by the author.

3.3. International Trade

A shutoff of Russian gas would directly result in a decrease of aggregate gas imports by volume to Ukraine (–48.3 percent or –$3.4 billion), Eastern Europe (–33.8 percent or –2.1 billion), and Western Europe (–2.9 percent or –1.1 billion) (see Tables 6 and 7).

Table 6

Imports by Sector (percent change)

qim	Russia	Ukraine	EastEurope	WestEurope	FSU	MiddleEast	Africa	U.S.	RestofWorld
NaturalGas	23.84	–48.31	–33.83	–2.94	–10.72	55.62	21.31	–3.47	2.08
Oil	4.1	–13.63	–0.25	–0.09	2.82	–0.49	–0.78	–0.07	0.01
Agriculture	–4.55	–1.64	–0.13	–0.01	–1.79	0.24	0.36	0.05	0
Extraction	1.68	–11.18	1.1	–0.04	1.15	0.7	–0.19	–0.01	0.01
ProcFood	–3.37	0.18	–0.09	–0.01	–1.59	0.17	0.29	0.06	0.03
LightMnfc	–3.02	–3.06	–0.16	–0.02	–0.76	0.17	0.29	0.04	–0.01
HeavyMnfc	–2.47	–0.71	–0.07	–0.03	–0.19	0.1	0.24	0.05	–0.01
Util_Cons	–3.82	1.68	0.87	0.05	–2.44	0.75	0.69	0.04	0.05
Services	–4.51	1.29	–0.09	–0.01	–2.44	0.35	0.38	0.06	0

Source: Generated by the author.

Table 7

Natural Gas Imports (*$m*)

qim	
Russia	132.23
Ukraine	–3,428.46
EastEurope	–2,100.75
WestEurope	–1,108.3
FSU	–498.12
MiddleEast	–468.83
Africa	49.99
U.S.	527.87
RestofWorld	518.43

Source: Generated by the author.

3.4. Welfare Decomposition

Table 8 presents the overall welfare decomposition from the CGE simulation. The welfare decomposition is essentially a consumer surplus concept, broken down by gains or losses to consumers from efficiency gains, factor endowments, technological improvements, terms of trade effects, and the savings-investment mechanism. According the CGE model results, Russia's shutting off gas to Ukraine would hurt Russia the most, with a net welfare loss to Russia of $11.8 billion. Other large welfare losses would accrue to Ukraine (–$722 million), Eastern Europe (–$469 million), and Western Europe (–$1.37 billion).

Table 8

Welfare Decomposition by Region ($m)

WELFARE	Allocative Efficiency	Factor Endowment	Technological Change	Terms of Trade	Savings and Investment	Total
Russia	–10,872.0	0.0	0.0	–1,783.5	804.3	–11,851.1
Ukraine	–1,347.5	0.0	0.0	596.4	29.1	–722.0
EastEurope	–493.6	0.0	0.0	22.5	1.9	–469.2
WestEurope	–1,158.1	0.0	0.0	–14.6	–198.5	–1,371.2
FSU	–25.6	0.0	0.0	152.4	–20.3	106.5
MiddleEast	–11.4	0.0	0.0	256.2	–112.2	132.6
Africa	100.7	0.0	0.0	646.1	–43.4	703.5
U.S.	41.0	0.0	0.0	123.0	–87.5	76.5
RestofWorld	–4.2	0.0	0.0	–12.9	–368.6	–385.7
Total	–13,770.6	0.0	0.0	–14.3	4.7	–13,780.2

Source: Generated by the author.

4. Model Limitations and Future Research

This experiment raises several methodological questions. The largest issue would be the static nature of this CGE model. It is a counterfactual simultaneous equations model which introduces a one-time shock to an economic equilibrium, and then measures a new equilibrium. A more dynamic model would better capture effects over time, such as the accumulation of capital stock, investment

flows, and economic growth over a longer period of time. The long-term effects of trade liberalization on capital mobility, investment spending, infrastructure, productive capacity, and other long-term economic phenomena are not competely captured in a static CGE model.

Other issues involve the ability of Ukraine to trade gas.

- First are the import substitution elasticities specified in the model. The model results suggest that Ukraine and Europe would over time be able to substitute Russian gas imports with gas from other suppliers.
- Second, a related issue is country of origin and transhipments. The model does not well specify the quantity of gas which goes through a third country on its way to Ukraine or Europe.

This would be partially covered by an examination of import substitution elasticities, but further research and estimation of elasticities would likely provide useful results for examining Russia's gas shutoff effects.