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Distributional Impacts of Energy Cross-Subsidization in Transition Economies

Evidence from Belarus

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Abstract

Subsidies and cross-subsidies in the energy sector are common throughout Eastern Europe and Central Asia. In Belarus, revenues from an industrial tariff on electricity are used to cross-subsidize heating for households. Input-output (IO) data and a household consumption survey are used to analyze the distributional impacts of this cross-subsidization. This paper illustrates cost shares and electricity-intensity of different sectors and consumption categories and uses the IO data to obtain first-order estimates of the distributional incidence of policy reform. The paper then analyzes distributional impacts of subsidy reform with a Computable General Equilibrium model. Although poorer households benefit from reduced heating costs, the increase in prices of other consumer goods due to higher electricity prices more than offsets the benefits they receive from the subsidies. The analysis finds that the current cross-subsidies are regressive, and policy reform would be highly progressive.

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Distributional Impacts of Energy Cross-Subsidization in Transition Economies: Evidence from Belarus

Corbett Grainger[†] Fan Zhang[‡] and Andrew Schreiber[§]

1 Introduction

Energy subsidies are often used by governments to achieve economic and social objectives. The International Energy Agency estimates the global bill of fossil fuel subsidies reached $523 billion in 2011, up from just $60 billion in 2003. Many studies have analyzed the economic consequences of energy subsidies (IEA 2013; Vagliasindi 2012; IEA et al. 2010), and conclude that while poor people receive some of the benefits of energy subsidies, overall they are skewed to wealthier groups, crowd out priority public spending and encourage inefficient, carbon-intensive use of energy.

Energy subsidies take many forms. They can be direct budget support to energy suppliers or consumers, undercollected/forgone revenues, or non-internalized externalities (Davis 2014). One type of subsidies and its impact that have received little attention in the literature is the cross-subsidies between consumer groups, i.e. industrial customers pay an energy price higher than its supply costs to support affordable rates to households. In addition to cross-subsidies between different customer groups, government sometimes also imposes

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cross-subsidies between different services. For example, in Belarus, industrial customers pay a 30 percent premium for electricity to keep heating prices low for residential customers (currently about 17 percent of the cost of the service).

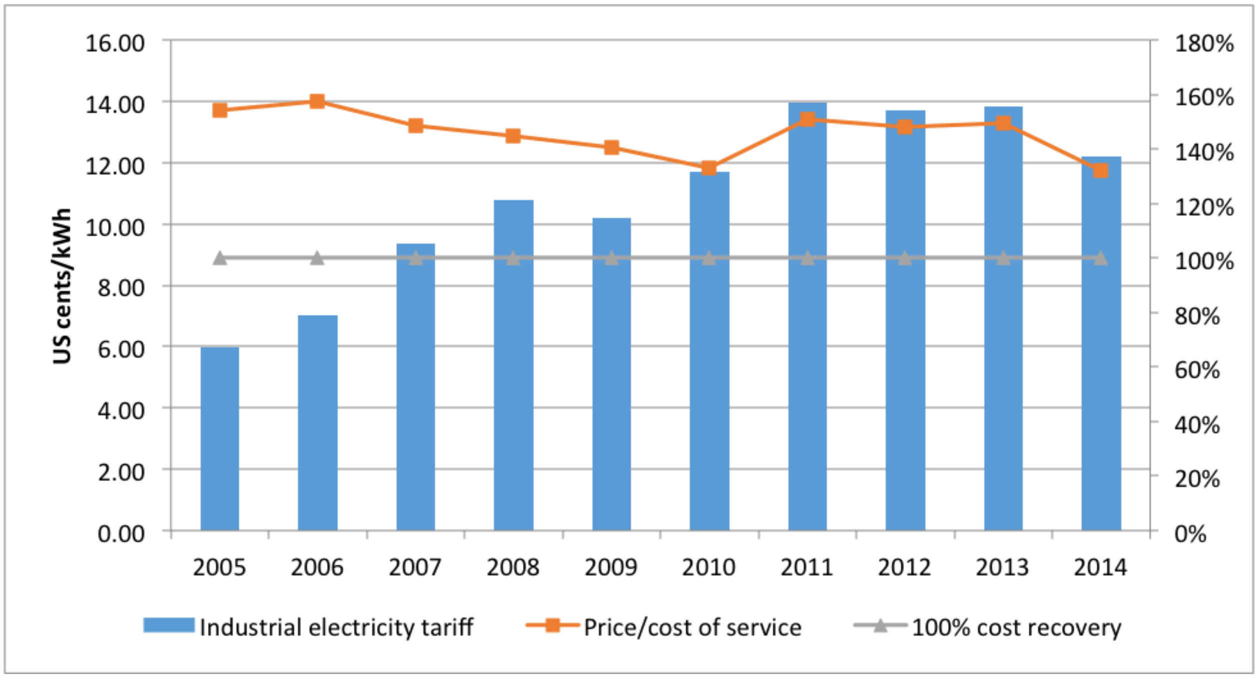
Since electricity is required to produce and distribute goods from all sectors in an economy, by charging higher tariffs to nonresidential customers, cross-subsidies impose an implicit tax on industries. The purpose of this analysis to understand the economic incidence of the implicit energy tax in the context of Belarus district heating sector. Though our study focuses on Belarus, our findings potentially inform policy debate about other countries in Eastern Europe and Central Asia, where such cross-subsidies are widespread.

We proceed as follows. We first offer a brief background to the policy environment and data in Belarus. We then describe our input-output approach and illustrate the key parameters for our distributional analysis. We then show distributional estimates at the household level by income decile before using a CGE model to obtain general equilibrium predictions of subsidy reform. We then conclude with a discussion of our results.

2 Background

Residential tariffs for district heating are well below the cost of service in Belarus. Since 2003, production costs have risen sharply while the cost-recovery levels of residential heat service have dropped by 50 percent due to inflation and depreciation of the Belarusian ruble to the US dollar. Belenergo, the state-owned district heating utility, on average achieves 17.2 percent cost recovery from residential heat consumers. Belenergo does not receive state subsidies and so must make up the entire shortfall by cross-subsidization. As a result, Belenergo's non-residential energy consumers pay tariffs that are substantially above cost (Figure 1).

Figure 1: Nonresidential Electricity Tariffs in Belarus



Source: Belarusian Ministry of Economy.

Because electricity is widely used as an input to other production processes, it is critical to understand how other prices would be affected by a change in non-residential electricity prices. Electricity is consumed directly by households as a final product, but it also plays a critical role in production processes for intermediate and final goods. Electricity is required to produce and distribute goods from all sectors in an economy. As a result, a tax on electricity (as with the current cross-subsidization policy) will likely impact the price of nearly all goods and services.

The economic incidence of a tax differs from its statutory incidence because a tax burden is passed on through product and factor markets (Fullerton and Metcalf 2002). The extent to which a tax burden is passed "forward" (to consumers) or "backward" (to factor owners) depends on behavioral and technological responses to the tax.[1] If consumers can easily substitute for a different product, or if prices for a good are effectively determined in

[1]Previous studies have looked at the distributional impacts of taxes on carbon or energy. For example, see Metcalf (1999) and Grainger and Kolstad (2010).

international markets, firms will not be able to simply pass on the cost increase to its consumers (Coxhead and Grainger 2014). Similarly, the substitutability of production factors (such as labor for capital, which is generally a complementary input to electricity) will affect how a firm responds to a higher cost of electricity. In general, the tax burden is distributed according to relative magnitudes of relevant elasticities of demand or supply.

The high tax rates on industrial uses of electricity raises the cost of a critical input to other production processes, services, and the distribution of final goods and services. When the costs of producing a good increase (such as due to an electricity tax), someone must bear the burden. Since consumer prices would be impacted by taxes on industrial electricity use, we can calculate how the burden is distributed across different household types.

Finally, the role of government plays a critical role in determining the overall distributional impacts of the cross-subsidization. Taxes on industrial uses of electricity create government revenue. How the revenues are used will affect the net impact on different consumer groups. Under the current system, high electricity taxes cross-subsidize heating for consumers. While consumer prices for most goods are likely higher due to the electricity tariff, consumers are compensated by paying low communal heating prices. Under current prices, consumers spend a relatively small share of their overall income on district heating and fuels for heating. If the electricity tariff were reduced and the heating subsidy were reduced proportionately, lower prices for other consumer goods would come at an increased cost for heating. This analysis quantifies the net impact of ratcheting down the tax and subsidy for households of different regions and incomes.

3 Input-Output Analysis

We begin by taking an input-output approach to the aggregate data to study the distributional impacts of cross-subsidization and policy reform. The input output table describes inter-sectoral relationships within an economy. We can use this information to determine how taxes in one sector (such as taxes on industrial use of electricity) would move through an economy to the goods purchased by consumers. This formulation is well-known in the economics literature (Leontief 1936; Leontief 1986). Because it has been widely applied, the restrictions and assumptions of this approach are also well-known. That said, it provides a useful first-order approximation of how different sectors, and hence different consumption goods, would be impacted by changes elsewhere in the economy.

Because the model is described in detail in the literature, the description that follows will be succinct. The economy is modeled at the sector level. There are n sectors, each of which produces x_i units of a homogeneous good. Sector i uses a_{ij} units from sector j in order to produce one unit. Each sector sells output to other sectors in the form of intermediate outputs and some of its output goes to consumers in the form of final demand. Denote f_i as the final demand for good i, where $i = 1, ..., n$. For each sector i we can write

$$x_i = a_{1i}x_1 + a_{2i}x_2 + ... + a_{ni}x_n + f_i. \tag{1}$$

Let A be the matrix of coefficients a_{ij}, x be the vector of total output, and f be the vector of final demands, then we can simplify our expression for the economy as

$$x = Ax + f \tag{2}$$

which can be rewritten $(I - A)x = f$, where I is the n-dimensional identity matrix. Rearranging (and assuming that the normal conditions for invertibility hold), we can rewrite as follows:

$$x = (I - A)^{-1}f. \tag{3}$$

The term $(I - A)^{-1}$ is the Leontief Inverse matrix. This matrix shows how an additional dollar of final demand in a given sector leads to direct and indirect effects across sectors.

In the following section we describe how the Leontief Inverse for Belarus was derived for our analysis. It is also worth emphasizing that this approach describes an equilibrium. Deviations from the observed data assume that changes will be linear and proportional, which may not be true, especially for ”large” changes.

3.1 Restructuring the Basic Price Input-Output Table

Upon initial inspection of the input-output tables acquired from the National Statistical Committee of the Republic of Belarus, we've decided to restructure the basic price use table for later computation of input output indirect distributions and multipliers. Before continuing, note the relationship between basic and purchaser prices:

Basic Prices + Taxes (less subsidies) + Trade/Transport Margins = Purchaser Prices

Aside from this basic relationship, one must also be careful about how imports and exports are incorporated into the input output table. In what follows, we calculate multipliers and distributional impacts from direct and indirect use of intermediate goods with concern for *domestic use* rather than total use of a good. The initial basic price use table supplied included imports in the interindustry use matrix, which would thus obscure information concerning domestic production and retention of goods and services. Therefore, we have restructured the total input output table to account only for domestic interindustry transactions with an additional row for total imports by each industry.

The table was slightly off-balanced initially (meaning that row sums do not equal column sums for a given sector). In order to enforce micro-consistency, we choose to use two matrix balancing routines for enforcing equivalence between row and column totals. The first routine is a nonlinear program formulated using least squares. The program can be summarized as follows. Let $\overline{a}_{ij}$ denote the benchmark inconsistent input output table (i.e. row sums not equal to column sums) and A_{ij} denote the variable to be solved for. The least squares routine seeks to minimize the percent difference between the benchmark data and variable subject to micro-consistency constraints. Also, let γ denote a zero penalty term used to induce sparsity,[2] Θ_{ij} be the set of (i,j) pairs such that $\overline{a}_{ij} \neq 0$ and Θ_{ij}^c be its compliment. The program is formulated as:

$$\begin{aligned}
\min_{A_{ij}} \quad & \sum_{\Theta_{ij}} \left(1 - \frac{A_{ij}}{\overline{a}_{ij}}\right)^2 + \gamma \sum_{\Theta_{ij}^c} A_{ij}^2 \\
\text{s.t.} \quad & \sum_i A_{ij} = \sum_i \overline{a}_{ij} \quad \forall j \\
& \sum_i A_{ij} = \sum_i A_{ji} \quad \forall j
\end{aligned}$$

Care needs to be taken when dealing with negative values within the input output table by

[2] In practice, this is simply a large constant such that entries that were initially zero remain zero; it imposes a large penalty in the optimization framework for large deviations from the initial values.

enforcing upper and lower bounds on variable types. All primary findings in what follows correspond to this matrix balancing routine.[3]

Once the table satisfies the micro-consistency checks, we aggregate the sector indices to match the Belarusian consumer expenditure data. Table 1 details the disaggregated list of input output indices (including the GAMs index we attach). In order to examine the distributional implications of subsidy reform, the sector-level data will need to be combined with household consumption data. Because there is no direct bridge available between the IO sectors and consumption categories (such as the Personal Consumption Expenditure, or PCE, Bridge in the United States), we aggregate sectors such that we can develop a correspondence with the household consumption data. Similarly, we aggregate the consumption categories so that the household consumer data can be matched to the newly-defined aggregate IO sectors. That correspondence is described in detail below.

In order to provide relevance for the energy intensity measures calculated in subsequent sections to the detailed consumer expenditure data, a mapping scheme is in order. We've used the mapping as outlined in Table 2.

3.2 Multiplier Calculations

Before detailing the derivations of a measure for indirect energy intensity, we first describe and compute type I multipliers for this aggregated input output table. The input output table provides a convenient structure for writing down basic economic identities that must hold given the current accounting system. In order to derive the multipliers, let t_{ij} denote an element in the interindustry transactions table, f_i denote an aggregate final demand measure, and x_i denote total output. Note, then that:

$$\sum_j t_{ij} + f_i = x_i, \quad \forall i$$

[3] Additional results using another matrix balancing method is given in the appendix for a robustness check. Such is perhaps the more common balancing technique and is denoted as RAS (Stone 1966). The procedure used closely resembles Tom Rutherford's RAS program he included on a GAMs wiki; see `http://support.gams.com/doku.php?id=gams:rasing_a_matrix`. This provides an optimization formulation of the traditional iterative approach. Look to A for the exact algebraic formulation.

Table 1: Table of IO Indices

Category	GAMs Index	Description
Interindustry Transactions	s1	Agriculture, hunting husbandry and related services
	s2	Forestry and related services
	s3	Fishery, fish husbandry and related services
	s4	Extraction of fuels
	s5	Extraction of natural resources, other than fuels
	s6	Production of foods, including beverages and tobaccos
	s7	Production of textiles and clothing
	s8	Production of leather, articles of leather and production of footwear
	s9	Wood processing and production of articles of wood
	s10	Pulp and paper production. Publishing
	s11	Production of coke, oil products and nuclear materials
	s12	Production of chemicals
	s13	Production of articles of rubber and plastics
	s14	Production of other non-metal mineral products
	s15	Metallurgic production and production of finished metal articles
	s16	Production of machines and equipment
	s17	Production of electrical equipment, electronic and optical equipment
	s18	Production of transportation means and equipment
	s19	Other industries
	s20	Production and distribution of electricity, gas and water
	s21	Construction
	s22	Trade, repair of cars, household and personal articles
	s23	Hotels and restaurants
	s24	Transportation and communication
	s25	Financial operations
	s26	Real estate transactions, lease and consumer services
	s27	Public administration
	s28	Education
	s29	Healthcare and social services
	s30	Municipal, social and personal services
Value added		
	s32	Labor remuneration
	s33	Gross profit
	s34	Gross mixed income
	s35	Other production duties
	s36	Transportation margin on disposed products
	s37	Trade margin on disposed products
	s38	Net taxes on disposed products
Final Demand		
	s31	Indirectly measured financial intermediation services
	s39	Households
	s40	Public institutions for individual goods and services
	s41	Public institutions for collective services
	s42	Noncommercial service providers for households
	s43	Gross fixed capital formation
	s44	Changes in inventory
	s45	Exports of goods and services
	s46	Imports of goods and services

Table 2: Mapping

Category	GAMs Index	Mapping
Food and beverage,	m11	s1,s3,s6
Energy,	m221	s4,s2,s11,s20
Housing and Utility,	m22	s5,s21
Clothing,	m33	s7,s8
HH articles and appliances,	m44	s9,s10,s13,s14,s15,s16,s17
Goods and services,	m55	s12,s19,s22,s23,s27,s30
Transportation/communication,	m66	s18,s24
Education,	m77	s28
Health Care,	m88	s29
Banking/finance,	m99	s25,s26
Labor remuneration,	m01	s32
Gross profit,	m02	s33
Gross mixed income,	m03	s34
Other production duties,	m04	s35
Households,	m05	s39
Public institutions for individual goods and services,	m06	s40
Public institutions for collective services,	m07	s41
Noncommercial service providers for households,	m08	s42
Gross fixed capital formation,	m09	s43
Changes in inventory,	m010	s44
Exports of goods and services	m011	s45
Imports of goods and services,	m012	s46
Transportation margin on disposed products,	m013	s36
Trade margin on disposed products,	m014	s37
Net taxes on disposed products	m015	s38
Indirectly measured financial intermediation services	m016	s31

Letting $a_{ij} = t_{ij}/x_i$, we can write the above as:

$$x_i \sum_j a_{ij} + f_i = x_i, \quad \forall i$$

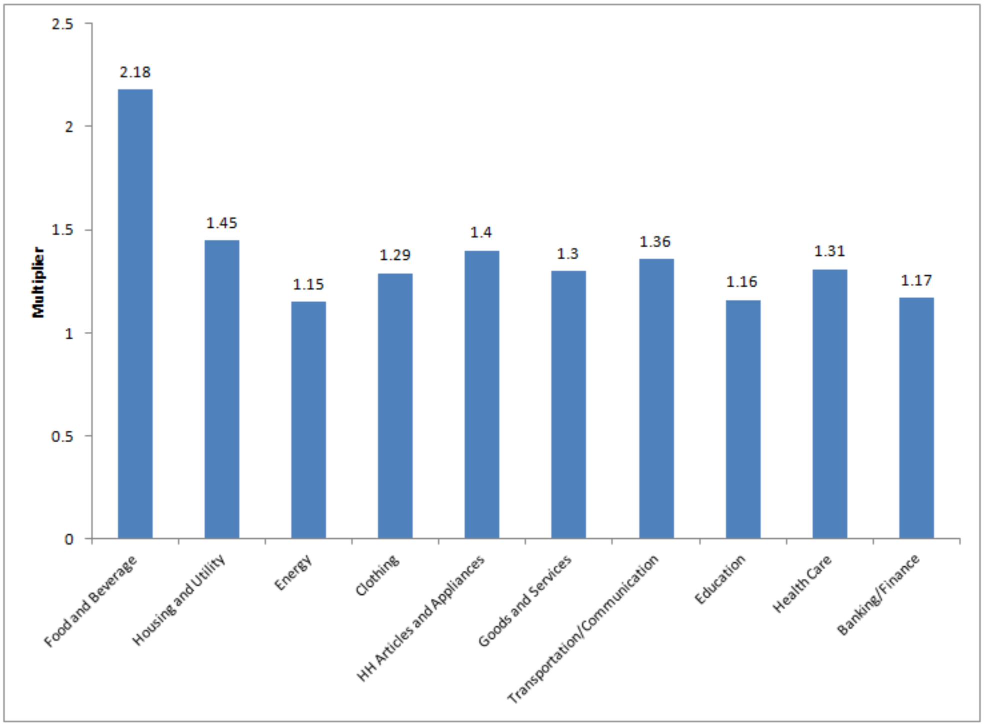
Rearranging terms, and returning to the popular matrix form:

$$x = (I - A)^{-1} f$$

where x is a vector of total outputs, I is the identity matrix, A is the matrix of coefficients, and f is the vector of final goods.

This computation has a long standing history dating back to the times of Wassily Leontief (Leontief 1936). Indeed, the term $(I - A)^{-1}$ is denoted as the *Leontief Inverse* and describes a distribution of domestic indirect effects of an additional dollar of final demand for a given sector. Multipliers are calculated thereafter by summing over all rows in the Leontief inverse. Output multipliers from the aggregated input output table for Belarus are computed as:

Figure 2: Multipliers



Such multipliers denote the value of production needed to satisfy an additional dollar's worth of final demand (Miller and Blair 2009). More intuitively, it provides a measure of how much economic activity is generated by final consumption. For instance, the output multiplier on our aggregated energy sector, $m22$, is roughly 1.45. Thus, after a *direct* effect of one dollar being injected into the economy, an additional \$0.45 can be expected to be generated, all else equal. This number represents the *indirect* effect as a consequence of the interindustry transactions necessary to produce the good.

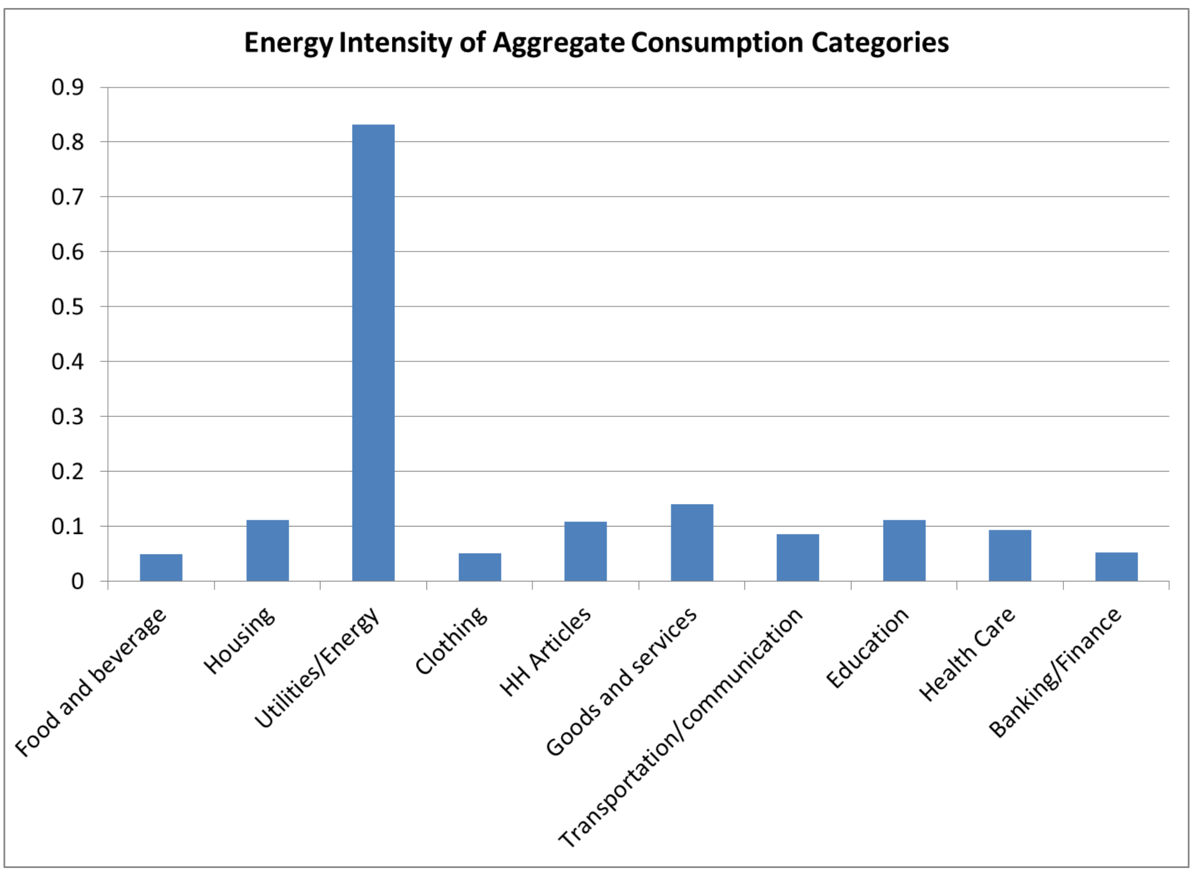
It should be noted that such estimates should be interpreted with caution because the input output model tends to be quite restrictive in its assumptions. The typical model described above denotes a fixed price model with Leontief production functions (fixed proportions).[4]

[4]For a more flexible analysis, a computable general equilibrium models will be explored in a subsequent

3.3 Calculating Energy Intensity

The input output model allows us to understand the revenue generation implications of current policies. That is, we are able to calculate the direct use tax revenue and indirect tax revenue generated by final demand consumption in sectors other than energy. In order to explore this, we analyze the full Leontief inverse matrix described above. Consider such a matrix for the aggregated sectors net of any direct final demand impacts. This matrix allows us to disentangle the per dollar indirect implications that a change in final demand for any of the given aggregated sectors has for energy use. In terms of the cost share of energy as an input, we can calculate the energy-intensity for each of the aggregate consumption categories. These are given in the following figure.

Figure 3: Energy Intensity of Aggregate Consumption Categories



section.

3.4 A Price Model of a Tax Reduction

The price model can be thought of as the “dual” of the traditional input output model described up to this point. Whereas input output analysis often considers the impacts of final demand shocks, we can also consider the impact of “cost-push" forces, such as changes in tax rates.

When creating the multipliers in traditional input output analysis, we formulate it by considering the row identity:

$$\sum_j z_{ij} + f_i = x_i, \quad \forall i$$

where z_{ij} denotes interindustry transactions between sectors i and j, f_i denotes final demand for sector i, and x_i represents total output for sector i. Then by restructuring the data, we are able to construct the Leontief inverse. The price model, conversely, uses the column identity:

$$\sum_i z_{ij} + v_j = x_j, \quad \forall j$$

where v_j denotes value added for sector j. The identity states the sum of interindustry payments from j to i, plus value added paid by j equals total inputs. Note that total inputs equal total outputs to enforce microconsistency; this is guaranteed because we are dealing with a balanced matrix.

The input output matrices for Belarus are constructed in *value* terms. Therefore we can decompose value terms into (price*quantity) terms by writing the above column identity as (switching to matrix notation):

$$x = Z'i + v$$

where $v = [v_1, \ldots, v_n]$ is a vector of value added, i denoting the summation vector, x the vector of total outputs and Z a matrix of interindustry transactions. By our typical construction, we can substitute $Z = Ax$ where $[A]_{ij} = z_{ij}/x_j$. Post multiplying the above by x^{-1}, we have:

$$i = A'i + vx'^{-1}$$

Let $v_c = vx'^{-1}$ be the fraction of total input use attributed to value added purchases. In order to find relative price changes, simply assume a price index of $p = i$ such that all prices, in this benchmark equilibrium as represented by the input output table are set to unity. Moreover, the following introduces Q as a diagonal matrix of wages/rents for value added represented in v_c. In the benchmark equilibrium, $Q = I$, the identity matrix. Now we have

$$p = A'p + Qv_c \tag{4}$$

which can be rewritten as the following:

$$p = (1 - A')^{-1}Qv_c \tag{5}$$

Note the relationship between this expression and our originally defined input output model in matrix notation. The Leontief inverse here is the *transpose* of the Leontief inverse as computed by the standard model.

3.5 Introducing a Price Shock

Before we are able to introduce a price shock for the energy sector, we must calibrate the price model. In our initial benchmark equilibrium as represented by the data, computing the model above will result in a vector of prices solely consisting of one. This serves as a check to make sure the data are correctly calibrated (and thus microconsistency is enforced).

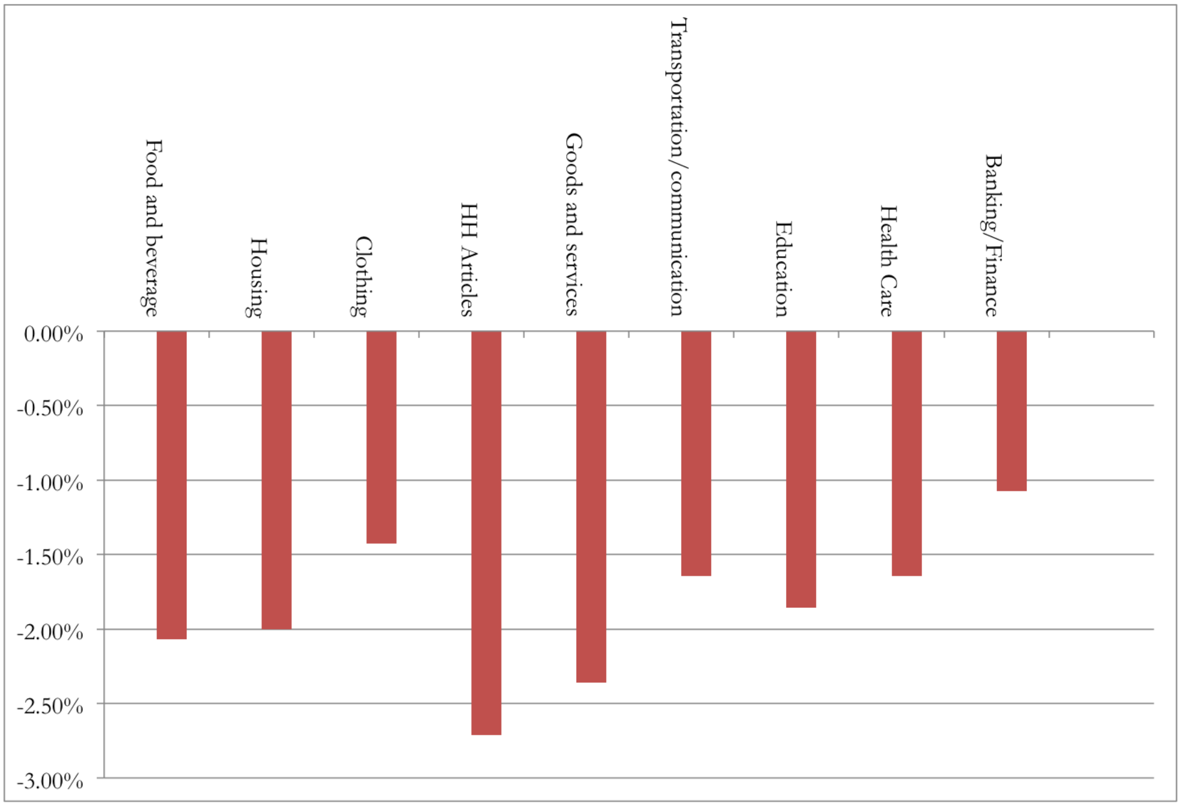
In order introduce a price shock, we simply change the element of concern in the diagonal matrix, Q.

In this case, we are interested in reducing the tariff on industrial electricity use, which is roughly 40% under the status quo. This corresponds to the *new* electricity price being roughly 29% lower, or multiplying that element by 1/1.4. Because this calculation is linear, this is easily altered for smaller reductions or to model a phasing out:

$$Q = \begin{bmatrix} 1 & 0 & \dots & \dots & \dots \\ 0 & 1 & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ \dots & 0 & 1/1.4 & 0 & \dots \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & 0 & 1 & 0 \\ \dots & \dots & \dots & 0 & 1 \end{bmatrix}$$

This leads to nearly identical reduction in the output price for our aggregate "energy and utilities" sector (m221), and the following figure shows the reduction in output prices from this simulation. For our aggregated sectors, the impacts range from a one percent reduction in the output price in the "banking and finance sector" to nearly a three percent decrease in the output price for household articles. For food and beverages, the sector with the largest share of total expenditures for most households, output prices decrease by roughly two percent.

Figure 4: Output Price Reductions from Removing Tax on Industrial Energy Use



With these modeled reductions in output prices, we now turn to the household data to determine how reforming the current cross-subsidization would affect different income groups.

4 Household Analysis Using IO Data

Now that the input-output data estimates have been generated, we can take the estimates to the consumer data to determine how different household types would be impacted by reducing electricity taxes and the corresponding subsidy to residential heating.

Because the impacts vary by income and region, we first begin by describing household income distributions for the country as a whole, and then by region. Table 3 shows household incomes and sizes, by income decile.

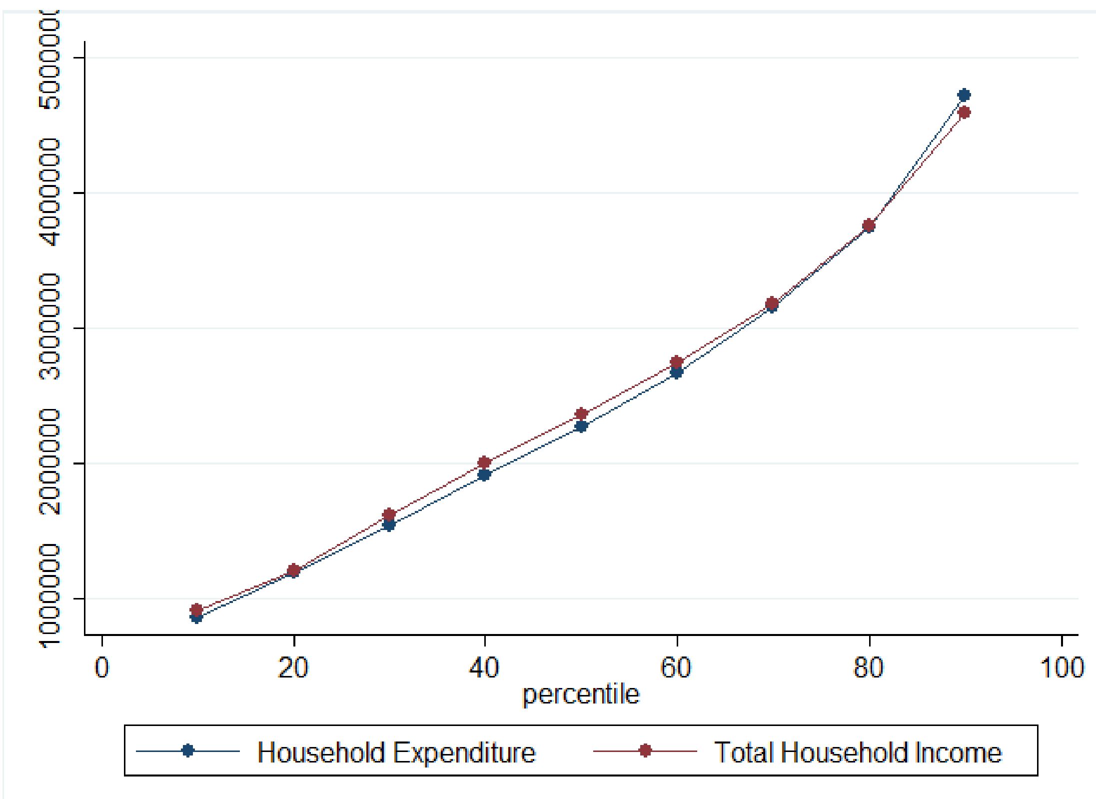
Household incomes vary widely between the bottom and top deciles. A household at the

Table 3: Household Income and Size, by Income Decile

Top Percentile Bound	Total Income	Average Household Size
10	809,575	1.10
20	1,163,036	1.40
30	1,582,812	2.02
40	1,919,941	2.35
50	2,237,421	2.58
60	2,562,030	2.85
70	2,924,984	2.90
80	3,360,679	3.12
90	3,959,351	3.30
100	5,541,067	3.52

90^{th} percentile earns nearly five times that of a household at the bottom decile. Moreover, the average household varies systematically with income.

Figure 5: 2011 Distribution of Household Incomes and Expenditures



Incomes vary significantly by region, as shown in the following figures, which suggests that a region-by-region analysis may be appropriate in what follows. Notably, household incomes in Minsk are substantially higher than in other regions.

The household survey provides detailed information regarding each household's expenditures on the goods categorized above. Though there are differences in consumption patterns between regions, we initially focus on the differences in expenditure shares at the country level. The following figure summarizes expenditure shares by income group.

The first category, food, constitutes the largest expenditure share on average for each income decile. The top income group spends less than a quarter of its income, on average, on food, while the average household in the bottom decile spends nearly half of its income on food. Heat and fuels shows a similar pattern, but the expenditure shares are much smaller due to the subsidization (which we will address in the next section). Other good categories, such as clothing, household articles, and banking/finance take up a larger share of income as household income grows.

4.1 Calculating Distributional Impacts

Under the current tax and subsidy policy, high taxes on industrial use of electricity are driving up consumer good prices for all goods, including food. In this section we calculate how much consumers of each income group could save if the tax on industrial electricity use were eliminated. Stated another way, we calculate how much consumers are currently paying indirectly due to the electricity tax.

Recall that the elimination of the electricity tariff would lead to an overall reduction in the price levels for consumers. We can calculate those savings by income group for each type of consumption good. For the time being, we will ignore the impact on housing-related costs (rent, heat, electricity), as the subsidization also has an impact on those costs. For the other good types, the savings from eliminating the electricity tax is summarized in the following figure.

Figure 6: 2011 Distribution of Household Incomes by Region

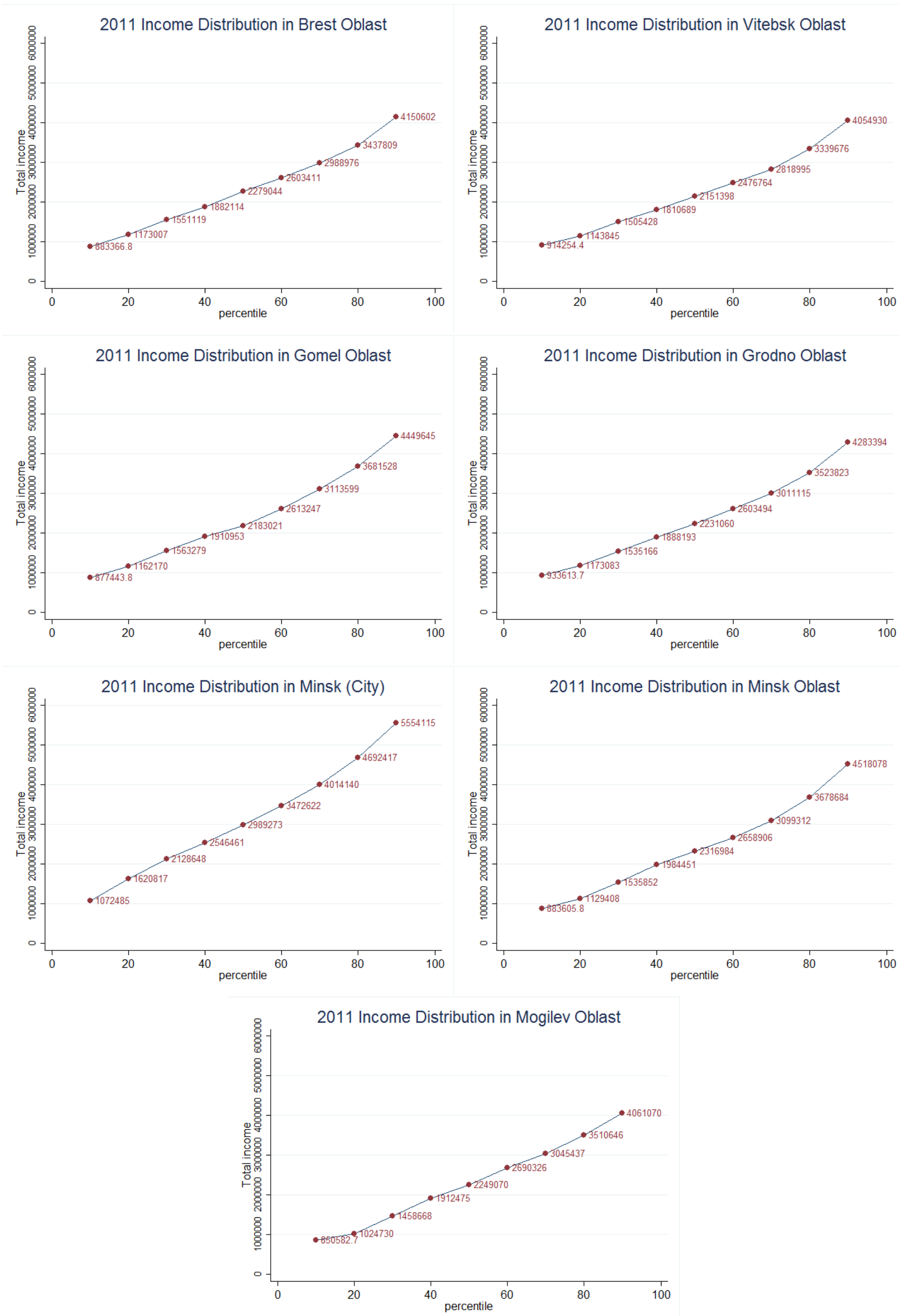


Figure 7: Expenditure Shares by Consumption Category and Income Decile

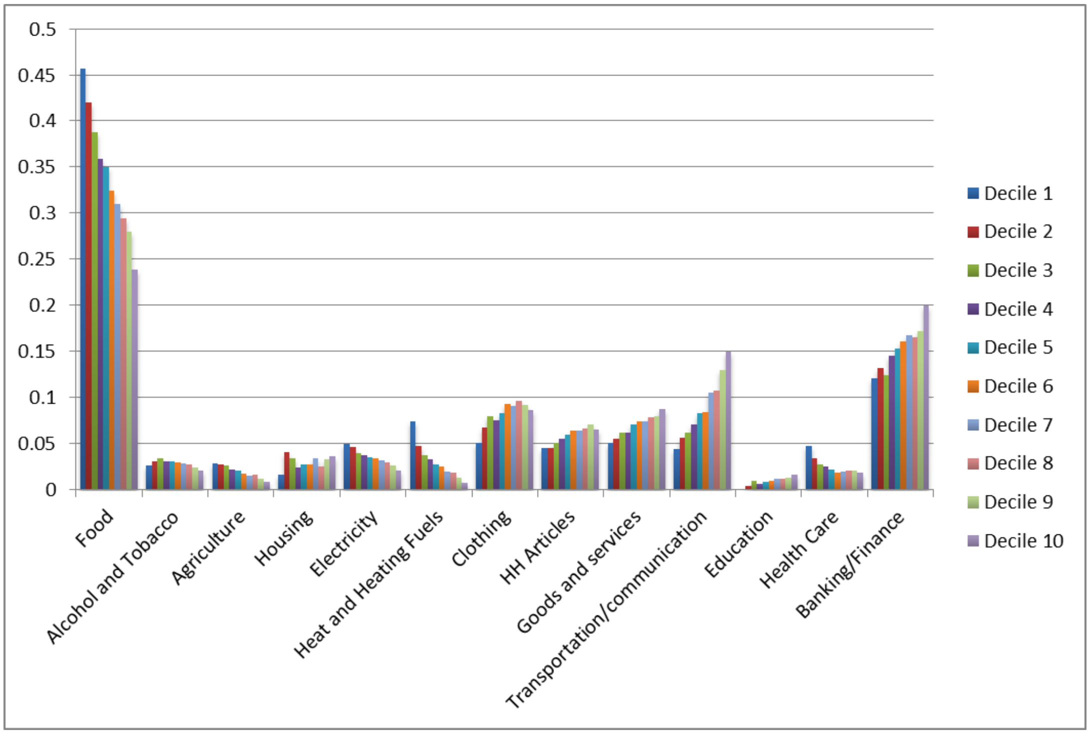
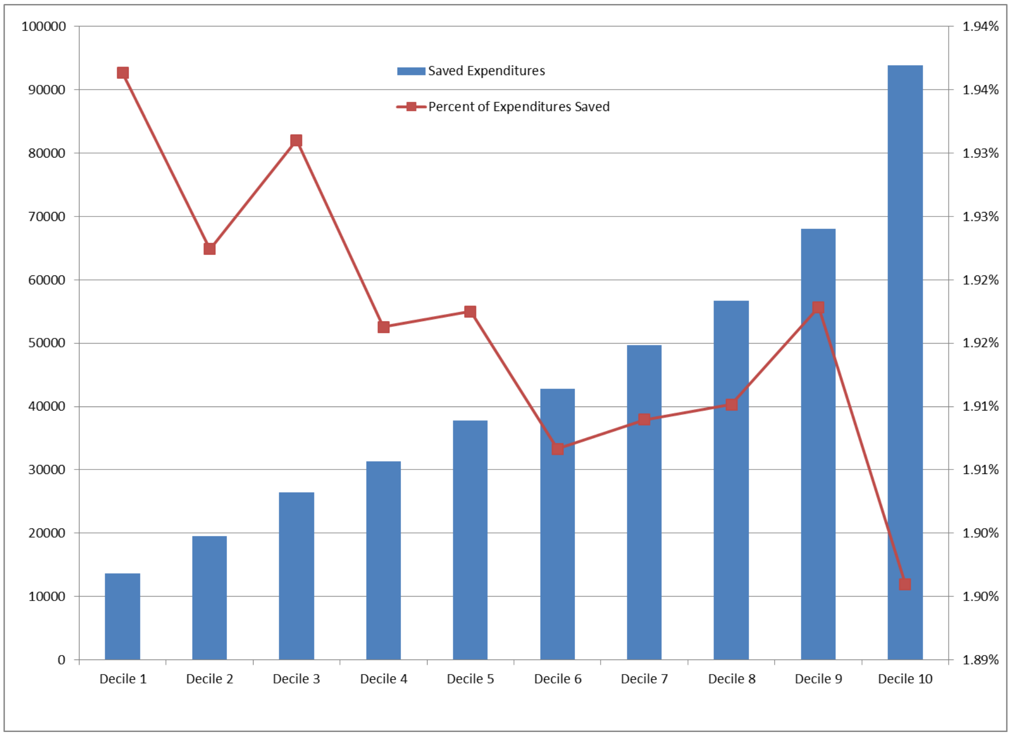


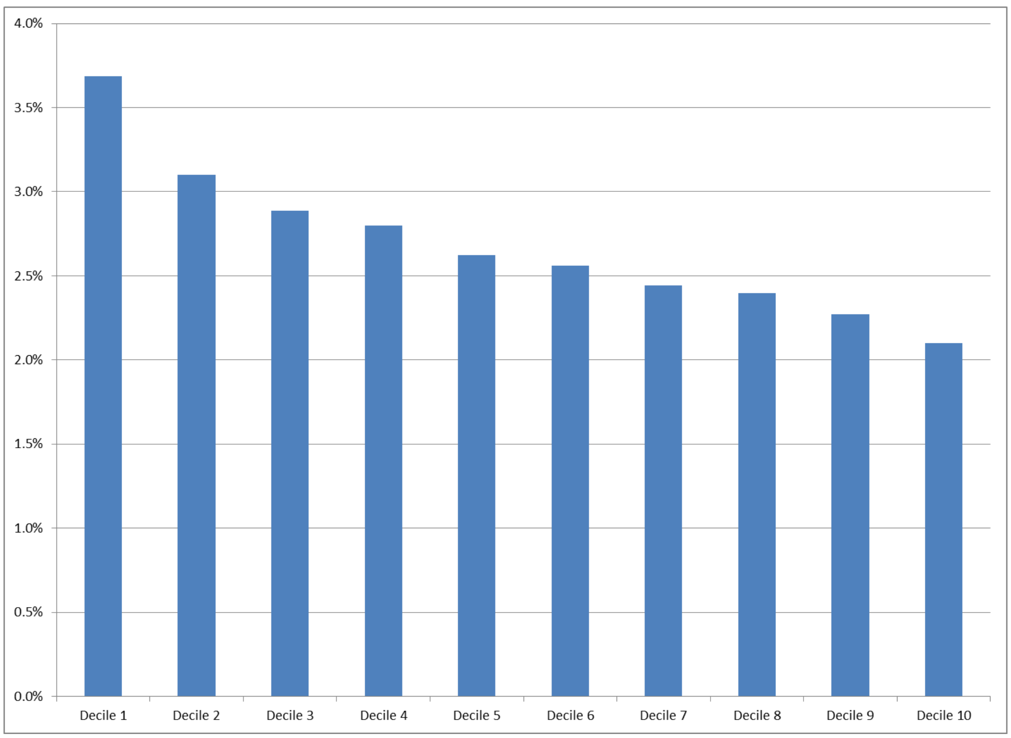
Figure 8: Savings from Eliminating Electricicty Tax



Every income group would see a cost decrease on key consumption goods such as food, clothing, and household articles. The amount saved in absolute terms is highest for households in the top income decile, but the policy appears to distributionally neutral or even modestly *progressive*, as the percent of expenditures saved is roughly equal across deciles.

The tax reduction would lower prices for electricity and housing, due to the indirect impacts of the tax on these sectors. The total savings to consumers, including all sectors, would be progressive, meaning that it benefits the poorest households the most.

Figure 9: Savings from Eliminating Electricicty Tax



In the next subsection, we consider the revenue-recycling (cross-subsidization) effects of the current policy.

4.2 Heat Cross-Subsidization

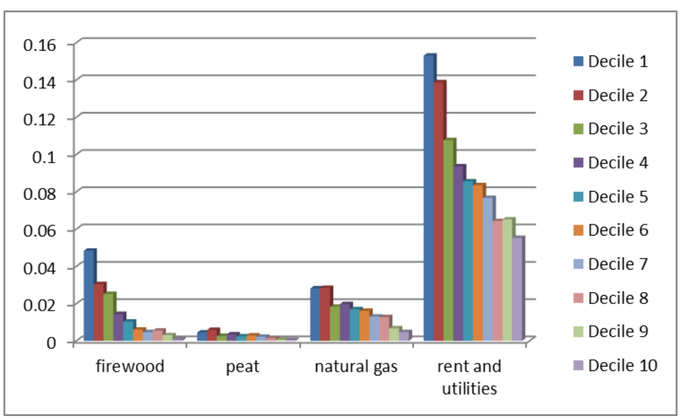
Along with the decrease in electricity tax (and the decreases in the price levels of other sectors that would occur), revenues currently cross-subsidize heating for consumers. Given the large savings associated with scaling back the tax on industrial use of electricity, targeted reductions in the subsidy would be possible. Moreover, since overall price levels would be so dramatically reduced, scaling back the cross-subsidization of heat could be implemented without harming consumers. However, the degree of reduction in the subsidy as well as differences over regions and between urban and rural consumers would need to be carefully considered.

Currently residents of large and small cities are served by district heating. They pay a relatively small share of the total cost of heating, though cost calculations vary (due to cogeneration, etc.). An increase in the price charged to consumers for district heating could be paired with a reduction in the tax on industrial use of electricity.

As a share of income, average urban households in the bottom and top deciles spend between 15% and 5.5%, respectively, of total income on rent and utilities.

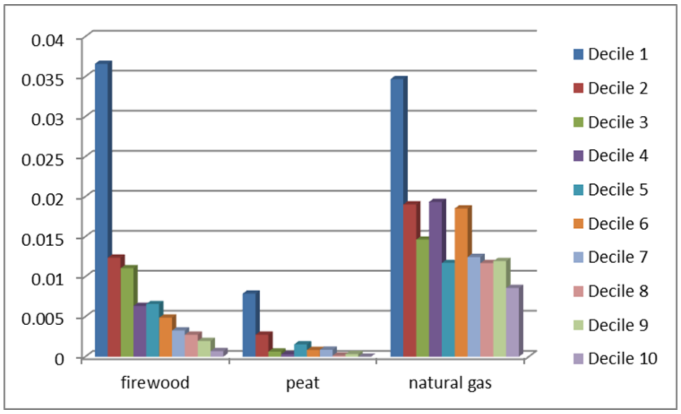
Firewood, peat and gas are also subsidized. Urban households in the bottom ten percent spend an average of 8% of their income, while the average urban household in the top decile spends about one-half of one percent on these fuels.

Figure 10: Urban Household Spending on Heating Fuels and Rent



The shares of income spent on firewood, peat and gas are similar for rural consumers, though not all rural households receive district heating.

Figure 11: Rural Household Spending Patterns on Heating Fuels



5 Computable General Equilibrium

A common critique of input output models concerns the strong assumptions of fixed prices and proportions in the production structure.[5] As is the case for input output modeling, CGE models use input output data in order to *calibrate* its many equations and conditions. We assume initially that the input output table represents a benchmark equilibrium in a snapshot in time. That is, in the current state, everyone (both agents and firms) is maximizing subject to feasibility restrictions and all markets clear at equilibrium price levels. Note that input output tables are compiled in value terms, so all initial prices can simply be set to unity. Using this benchmark equilibrium, we can calibrate the many equations of the model to characterize optimal conditions in which the observed allocations would correspond.

The model in its current implementation assumes a perfectly competitve environment; firms are price-taking profit maximizers, and consumers (both the representative agent and government) maximize utility subject to a budget constraint. We assume revenue recycling of taxes in lump sum transfers to the representative agent. Consider Figure 12 for market flows.

Figure 12 describes the circular nature of the economy (as prescribed by the input output table). Table 4 lists sets and variable names used in the model. The market flows for

[5]In addition, there is no behavioral response in such IO calculations, which may overstate the regressivity or progressivity of a tax (e.g. West and Williams III (2004)).

Figure 12: CGE Market Flows

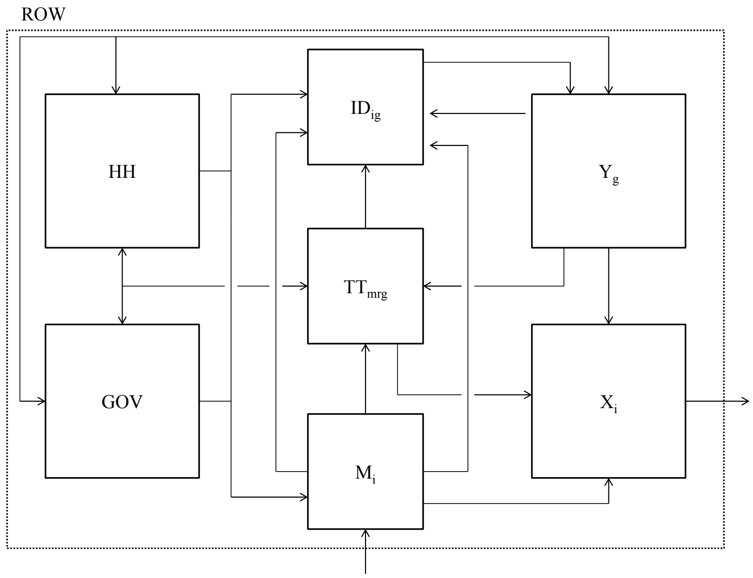


Table 4: Variables and Sets

Type	Item	Description
Sets		
	g	Aggregate index for all sectors in IO table
	i	Commodity subset index
	mrg	Margins subset index
Variables		
	Y_g	Aggregate production market in sector g
	ID_{ig}	Intermediate demand market of i in g
	X_i	Export market for index i
	TT_{mrg}	Transport/Trade Margin market for index mrg
	M_i	Import market for set i
	HH	Representative agent
	GOV	Government final demand

producing good g is characterized by combining intermediate demand inputs from ID_{ig} and factors of production owned by the representative agent, HH. Such production is then allocated back for use as intermediate inputs to the intermediate demand block, ID_{ig}, trade and transport margins, to the export market (which would then be exported to the rest of the world) or back to final demand blocks, HH or GOV. Imports come from the rest of the world which supply intermediate demand, margins and some go directly to the export market. Note that flows from such markets like imports and transport margins to final demand consumers denote tax revenue transfers.

While Figure 12 conceptualizes the flows in the modeled economy, it does not characterize the optimal choice by producing sectors and consumers. In order to conceptually understand the structure of our choice rules, a tree diagram (Figure 13) can be used to detail the assumed production structure in the model.

Figure 13: Production Structure

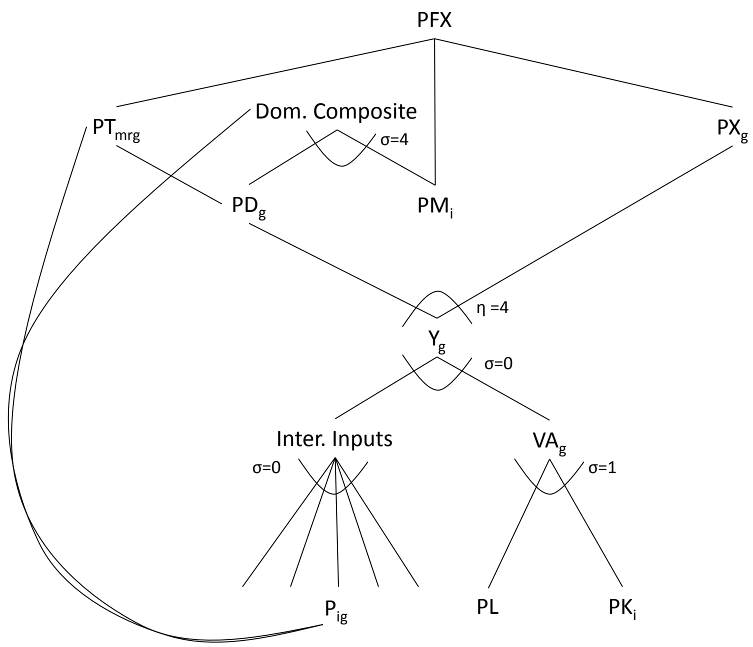


Figure 13 illustrates the assumed structure of production and the elasticity values in the model. We employ nested constant elasticity of substitution (CES) functional forms to capture various levels of trade-offs between inputs to the production process. To produce Y_g, the producer must use a fixed proportion of value added inputs (capital and labor) and intermediate inputs (commodities). We specify a value added sub-nest in the production function where labor and capital are substitutes with elasticity of substitution equal to unity (Cobb-Douglas). Output Y_g is then allocated between the domestic market at price PD_g and the export market PX_g. We employ the Armington assumption in that locally produced goods are not perfect substitutes for imports (location of production matters in terms of substitutability) by specifying an elasticity of substitution $\sigma = 4$ to create a domestic composite commodity. Such domestic composite commodity as well as residual margins, priced at PT_{mrg} are combined to form intermediate inputs at price P_{ig} to be used again in the production process. Finally, trade margins, imports and exports are combined to formulate the price of foreign exchange (PFX). We set PFX as the numeraire for the model in order to describe relative price changes in terms of foreign prices.

5.1 Model Equations

Equilibrium conditions are characterized by the mixed complementarity problem (MCP) formulation of the generic nonlinear programming competitive general equilibrium framework. In order to do so, three separate conditions must be satisfied.

1. *Zero-Profit* – Unit revenues must not exceed unit costs for all activity levels. The complementarity condition requires that if costs exceed revenues, the associated activity level must be zero. Letting $\Pi_i(p)$ be the unit profit function, $C_i(p)$ denote the unit cost function in industry i, and $R_i(p)$ the unit revenue function, both in terms of prices, the zero profit conditions can be concisely written as:

$$\Pi_i(p) = -C_i(p) + R_i(p) \leq 0 \quad \perp \quad Y_i \geq 0, \quad \forall\ i$$

   where $\perp$ denotes the associated complementarity condition (production in i).

2. *Market-Clearance* – Supply must be greater than or equal to demand for all prices. The complementarity condition requires that if supply exceeds demand, the associated price must be zero. The algebraic structure of these conditions relies heavily on Shepard's lemma. That is,

$$\sum_j Y_j \frac{\partial \Pi_j(p)}{\partial p_i} + \sum_h \omega_{ih} \geq \sum_h \delta_{ih} \quad \perp \quad p_i \geq 0 \quad \forall\ i$$

   The generic market clearance equation above dictates that the sum over all net outputs (note we specify a unit profit function which contrives supply *coefficients* rather than total supply) and household endowments, ω_{ih}, must be greater than or equal to the sum of household demands, δ_{ih}, where h denotes household type.

3. *Income-Balance* – Consumers cannot spend more than their endowment income. The algebraic structure is that of a simple budget constraint:

$$I_h = \sum_i p_i \omega_{ih} \geq \sum_i p_i \delta_{ih} \quad \perp \quad I_h \geq 0 \quad \forall\, h$$

That is, total endowment income, I_h, for household type h must be greater than or equal to the amount spent. The complementarity condition here generally is not a problem because we deal with well behaved utility functions in which Walras' Law holds and consumers spend their total budget.

Model formulation is done in GAMS and MPSGE. The specific algebraic structure is characterized by the above three conditions (and involves extensive use of the CES functional form). In order to calibrate the above equations to represent the equilibrium associated with the benchmark input output table, we use calibrated share form equations (Böhringer et al. 2004). In doing so, we parametrize value shares with the input output data to impose an equilibrium in the model. As a simple exercise, consider a simple calibrated share form cost function composed of two goods:

$$C(p_d, p_m) = \bar{c}(\theta_d p_d^{1-\sigma} + (1-\theta_d) p_m^{1-\sigma})^{1/1-\sigma}$$

where $\bar{c}$ are benchmark costs, θ are value shares, σ denotes the imposed elasticity of substitution and benchmark prices are set to unity (as is the case with input output data). Suppose that the above denotes an Armington cost function where p_m represents imported goods, $\overline{m}$ and p_d denotes local goods, $\overline{d}$. We then can calibrate the above cost function by assigning data to the value shares, θ_d.

$$\bar{c} = \overline{d} + \overline{m}$$

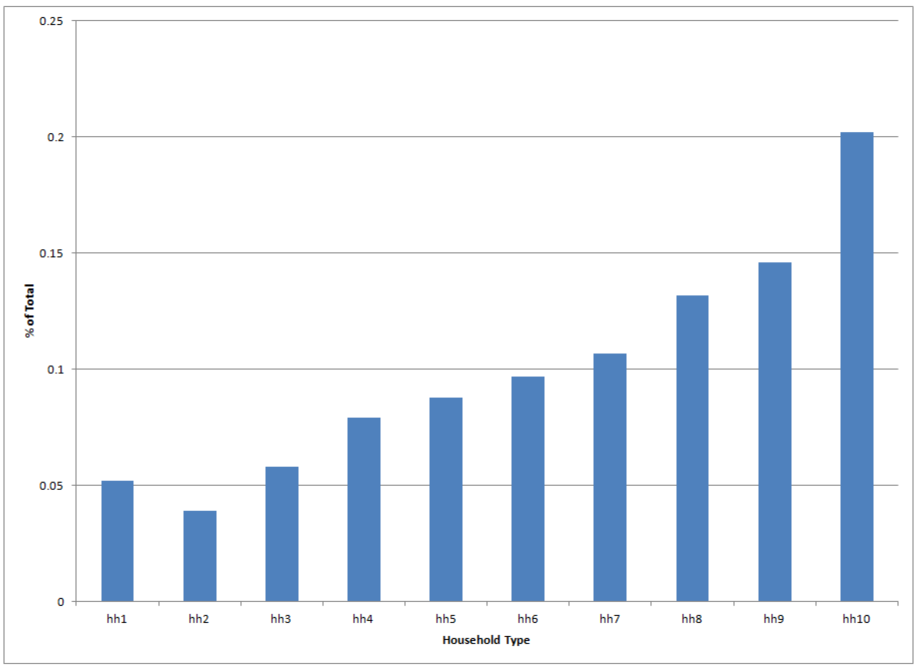
$$\theta_d = \overline{d}/\bar{c}$$

In order to be able to pin down equilibrium prices, we must specify exogenous elasticities of substitution (seen in Figure 13).

5.2 Heterogeneous Households

The model can be solved assuming a representative agent, but we are primarily concerned with impacts across households (in addition to the sector-level effects). In order to understand the distributional impacts associated with a subsidy reduction on consumer types, we disaggregate household endowments based on expenditure shares corresponding to Figure 7 and income shares corresponding to Table 5. To do so, aggregate value shares were computed and subjected to either the distribution of expenditure shares or income shares (depending on the particular input). This then creates an implied expenditure share on the demand side for the household type of the aggregate household expenditures. Such distribution is given in Figure 14. To see how precisely this was done, consider Appendix A for model code.

Figure 14: Household Share of Total Expenditures

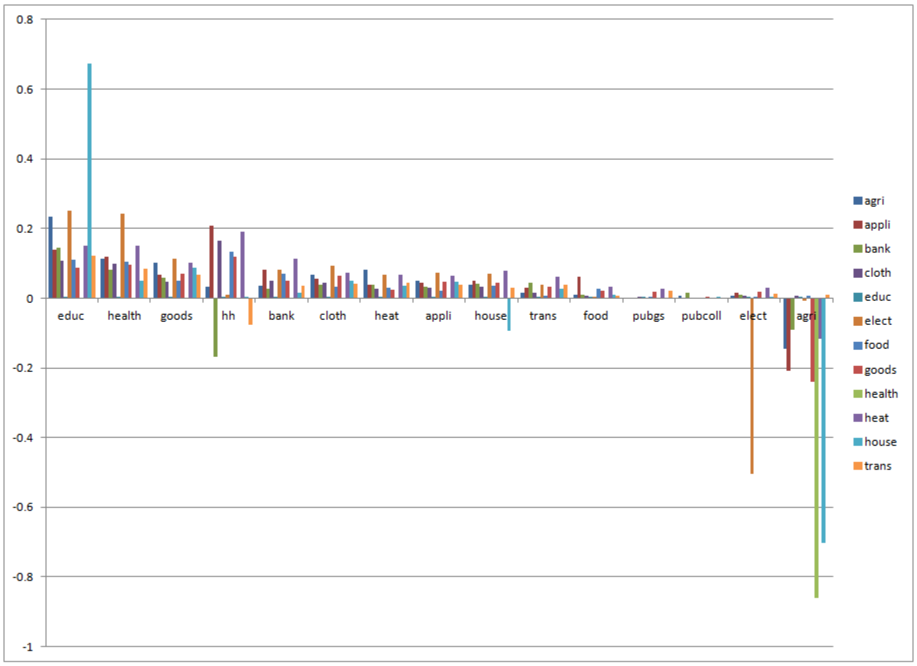


As is somewhat standard with the literature on expenditure shares, our poorest income decile, *hh1*, has a slightly larger share of aggregate expenditure than its relatively richer counterpart, *hh2* (similar to (Grainger and Kolstad 2010)). This can be rationalized by noting that many individuals in this income group are retirees, students or temporarily employed. This means that many people with low stated annual income have either saved income or indirect income from wealthier family members.

5.3 Benchmark Taxes and the Marginal Cost of Funds

Before considering our main policy experiment using the computable general equilibrium model, we first consider the benchmark taxes in place. Figure 15 denotes the implied tax rates paid by each aggregated sector in the model for intermediate inputs.

Figure 15: Benchmark Tax Rates on Intermediate Inputs



As can be seen from Figure 15, the agricultural and electricity sectors both have significant subsidies already in place. Specific to this study (and the motivator for the subsequent policy experiments described below), the electricity sector pays a negative tax rate for use of electricity and thus will not be targeted in the reduction in electricity taxes. Moreover, the effective electricity tax paid by the single household in the data is almost zero which reflects the current policy environment.

While reflecting on benchmark taxes can be potentially informing, another useful exercise concerns computing the *marginal cost of funds (MCF)*. That is, we want to think about the relative change between household consumption and governments revenues if a given tax rate is increased by a marginal amount (the numerical equivalent of a derivative). Such simulation would provide useful information concerning where policy makers could expect the least distortionary policies to exist. As a benchmark, if the computed value is greater than unity, the relative consumption change for the household is greater relative to the government income changes. This case would correspond to a detrimental policy (raising the intermediate input tax for a particular sector grouping) as increases in government revenues do not offset reductions in household consumption. Consider Table 5 for the matrix of computed values. We've computed the MCF for all tax rates sufficiently far enough away from zero (the cutoff is 0.001%).

Table 5: Marginal Cost of Funds

	agri	appli	bank	cloth	elect	food	goods	heat	house	trans
agri	0.961	0.957	0.943		0.948	0.935	0.961	0.960		0.909
appli	1.121	1.118	1.121		1.121		1.066	1.122	1.121	1.106
bank		1.041	1.040		1.036		1.038	1.037		
cloth	1.088	1.048	1.090	1.095	1.094	1.056	1.097	1.065		0.786
educ		0.632	1.163		0.874	3.718	0.906	0.831		
elect		0.963	1.043		1.050		1.019	1.051		
food	1.037	1.039	1.034		0.907	1.043	1.037	1.034		1.028
goods		1.105	1.105	1.085	1.106	1.104	1.107	1.106	1.105	1.096
health		1.206		1.142	1.297	0.941	1.293	1.804		
heat					1.300		0.610	1.275		
house		1.081	1.079		1.072		1.060	1.081	1.079	1.079
trans		1.083	1.084	1.080	1.083	1.082	1.083	1.084		1.083

Particular attention needs to be given to the electricity sector row of Table 5. Our policy experiment in later sections will concern changing the effective tax rates on industry for electricity use in the production process. With the exception of household appliances, the marginal cost of raising the input tax for electricity use is greater than one, indicating that the decrease in household consumption is greater than the increase in government revenues. However, the difference is fairly small indicating that more analysis is warranted.

5.4 Policy Experiment

Our policy experiment consists of reductions in the benchmark taxes paid by each sector for electricity use. Note that we exclude changes in the taxes paid by the electricity sector for use of its own output since the data is suggestive of large subsidies in place for the electricity sector, indicating that tax reductions need not apply here. The main simulation considers a 40% reduction in the taxes paid for electricity. By all accounts, such reduction would eliminate the likely distortions already in place within the Belarusian economy. Sensitivity analysis is employed to compute results for a range of reductions around 40% (30, 35, 45, and 50 percent reductions) to explore the nonlinearities around our solution. Indeed, as the next two sections expose, results are quite similar across reductions.

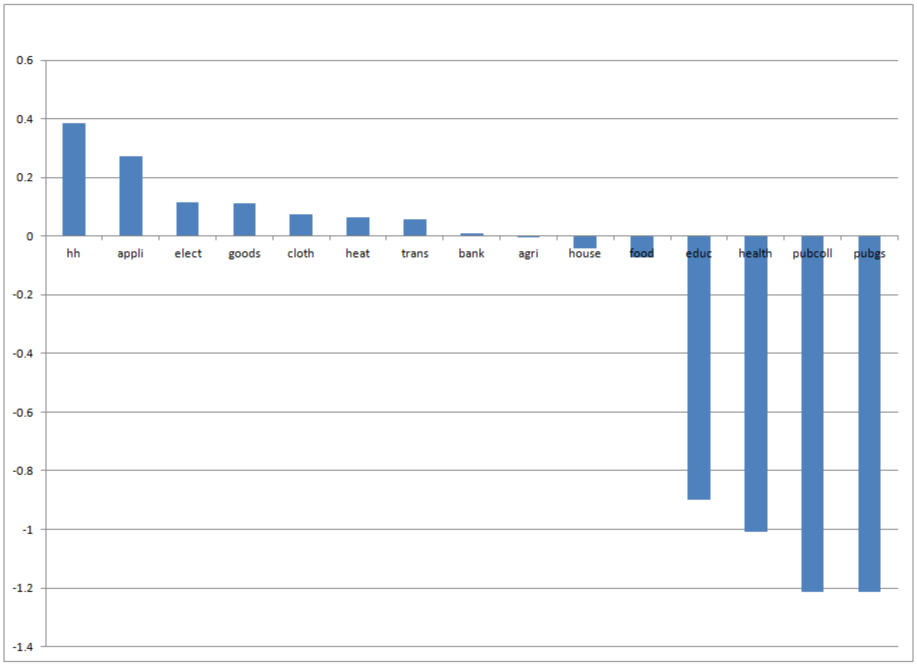
5.5 Results

As indicated above, our policy simulations concerned changing the tax on electricity input use. As such the shock entered on the production side of the model, making production relatively cheaper. Without any notion of general equilibrium effects, one would assume producers are unambigously better off due to the availability of relatively cheaper inputs to production. However, because we are focused on general equilibrium, certain sectors may not be as well off considering consumer behavior and the effects of reshuffling in the factor and input markets. The consumer side of the problem is more complex due to competing factors. On the one hand, consumers benefit from input tax reductions because prices are likely to be lower given the firm's ability to pass through any imposing tax. However, because the government levies the tax, and in the benchmark returns tax revenue via lump sum transfers to the representative agents, consumers have less tax revenue available. Thus, on the production side of the problem, we would expect electricity intensive industries to produce more relative to non-electricity intensive industries because electricity prices initially fall.

Considering previous exposition of the input output and consumer expenditure data, the most electricity intensive industry is the utilities and energy sector itself. As previously mentioned, however, this sector is not subject to the new policies in our model experiment. Other notable intensive industries are goods and services, housing, household articles, and education. Consider Figure 16 for the expected percentage change in production as a result of a 40% reduction in electricity taxes.

As is evident from Figure 16, fairly large production increases are experienced in the aggregate household good, general goods and services, electricity and the clothing sector on the order of half a percent. Large decreases are shown in the education sector and other public sectors of the order of 1 percentage point. Production trends tend to follow the theory above

Figure 16: % Change in Production



on electricity intensity. That is, the relative more electricity intense industries see increases in production while those less energy intense see decreases. To further substantiate the results, consider Figure 17 for percentage change in local output prices (relative to foreign exchange).

Consistent with the input output results, all price changes are (roughly) non-positive. While this is always the case in input output modeling with tax decreases (due to a linear pricing scheme), it is not in the case of general equilibrium modeling. Moreover, as is consistent with the literature, input output results are larger than those of the CGE model. This is largely driven by unlimited factor and input supplies and fixed price assumptions embedded in the model. While general magnitudes accord well with the IO results, computed CGE price changes follow different trends. For example, prices for education and public sectors decrease the most with changes to other sectors being much smaller. Note that this is driven by the fact that electricity taxes are highest in the educational sector. Other differences are given by the ability that firms have to substitute inputs to production and re-optimize given changing conditions.

Figure 18 provides the percentage change in the returns to capital. Given the previous

Figure 17: % Change in Local Output Price

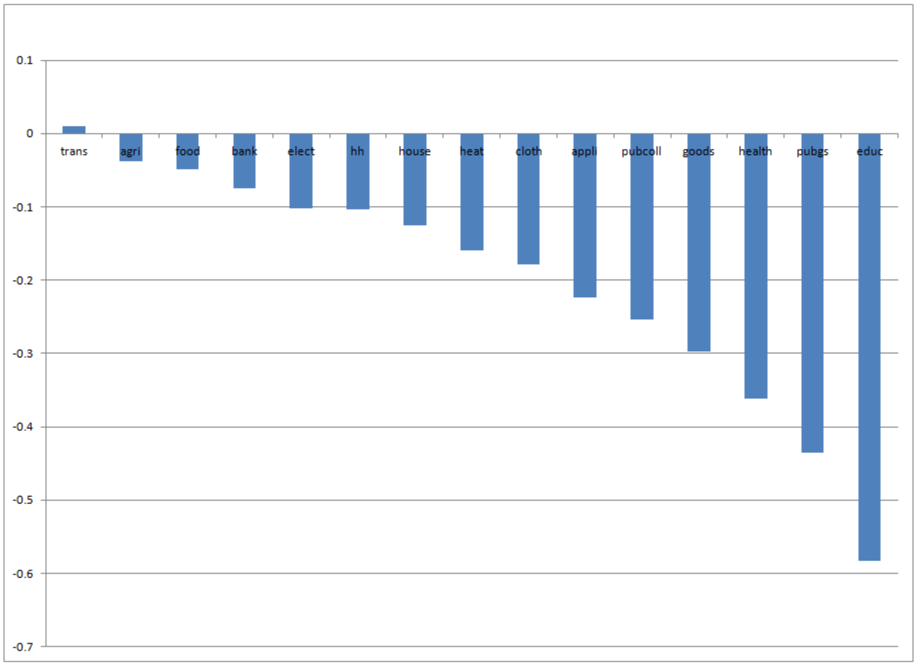
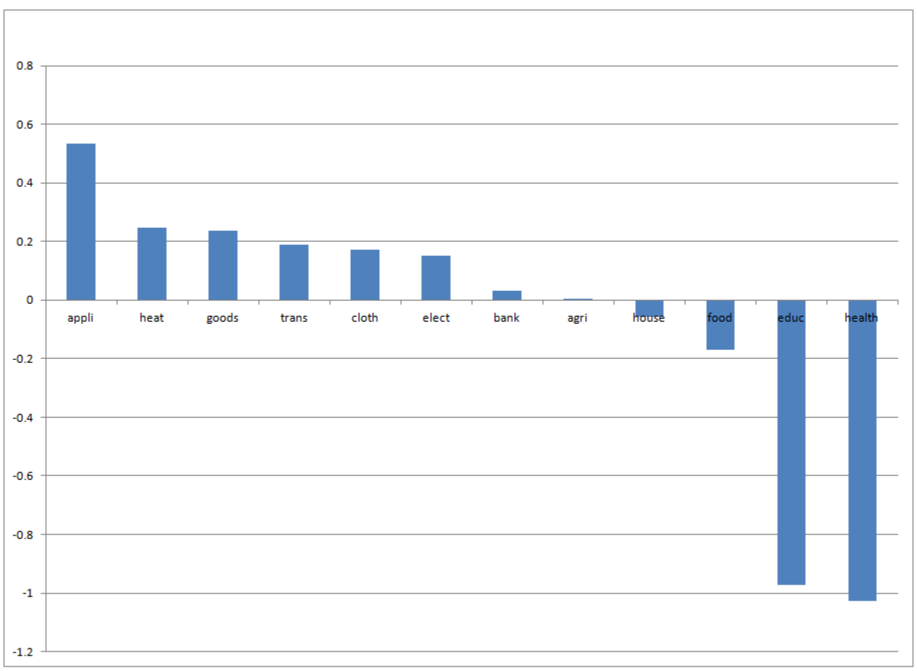
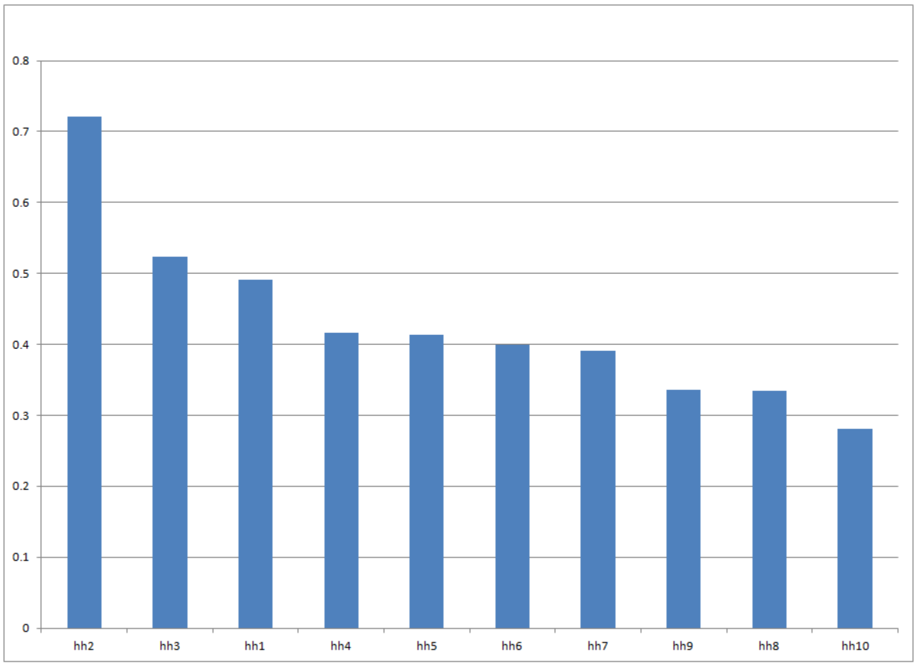


Figure 18: % Change in the Returns to Capital



results detailing changes in production and prices, changes in capital returns are unsurprising and follow the same general trend as production. The largest increase in capital returns is seen in the appliances and heat sectors. By decreasing the effective price of electricity for firms, capital intensive sectors which rely on electricity as an essential input to production experience increases in their relative rate of return of approximately 0.2-0.5%.

Figure 19: % Change in Household Welfare



The sector-level impacts roughly follow the patterns in the input-output section of this paper. The sectors that most benefit from a reduction in the electricity price are those that are the most electricity-intenstive. Perhaps the most interesting results are on the demand side of the model. By incorporating heterogeneous consumers based on income deciles in the consumer expenditure data, we can calculate the Hicksian Equivalent Variation as a measure for welfare changes due to the tax change on the production side of the model. Such a measure tracks the change in expenditures before and after the price change given new utility levels. Consider Figure 19 for the distributional impacts of the tax policy in question. These results strongly suggest that the reduction in supply -side electricity prices is a strongly *progressive* policy. That is, such tax changes benefits poorer households (as a fraction of income) more so than their richer counterparts.[6] Given these results, it appears that the reduction in output prices dominated the negative effects of less transfer income

[6]One exception to the progressivity is the relative gain to the lowest income decile, *hh1*. This is driven by the expenditure shares observed in the consumer expenditure data. As previously noted, the poorest income group, *hh1*, actually has *larger* expenditures than *hh2* which are comparable with *hh2*. Therefore,

from the government. That is, reductions in distortionary taxes actually *benefits* consumers, even though electricity prices rise as a result.

One measure of the progressivity of the policy is simply to compare the change in welfare (i.e. benefits or costs), as a share of income, across deciles. The increase in welfare for the seconde decile is roughly 0.72%, compared to 0.28% for the top decile. This suggests that the bottom income groups' welfare increases roughly two-and-a-half times as much as the top income group. Moreover, the increase in welfare is unambiguously positive across income groups, meaning not only that the policy is progressive, but it is welfare-improving at all income levels.

5.6 Sensitivity Analysis

As a robustness check, we do similar simulations but with varying tax reductions (30, 35, 45, and 50 percentage points). Results are given for percentage changes in output prices and equivalent variation for households. For a distribution of relative output price changes, consider Figure 20. As can be seen, our initial solution is quite stable across different tax reduction schemes, and therefore any worries of nonlinearities that may be around our main results are alleviated.

Just as in the case for price changes, the distribution of welfare changes is given in Figure 21 and follow similar patterns. Nonlinear effects are not a problem here, and while the magnitude of the result depends on the tax reduction amount, the impact trends do not. Such robustness exists for all results.

6 Discussion

In order to examine the question of how the elimination of cross-subsidization between industrial electricity prices and residential heating affects different sectors and household groups, we use both input output and general equilibrium methods. Our analysis serves two important purposes. First, it serves as an interesting example of how input output results can overestimate more theoretically consistent general equilibrium results, but do offer longer

the percentage change in welfare is actually greatest for the second and third income decile.

Figure 20: Sensitivity Analysis: % Change in Local Output Price

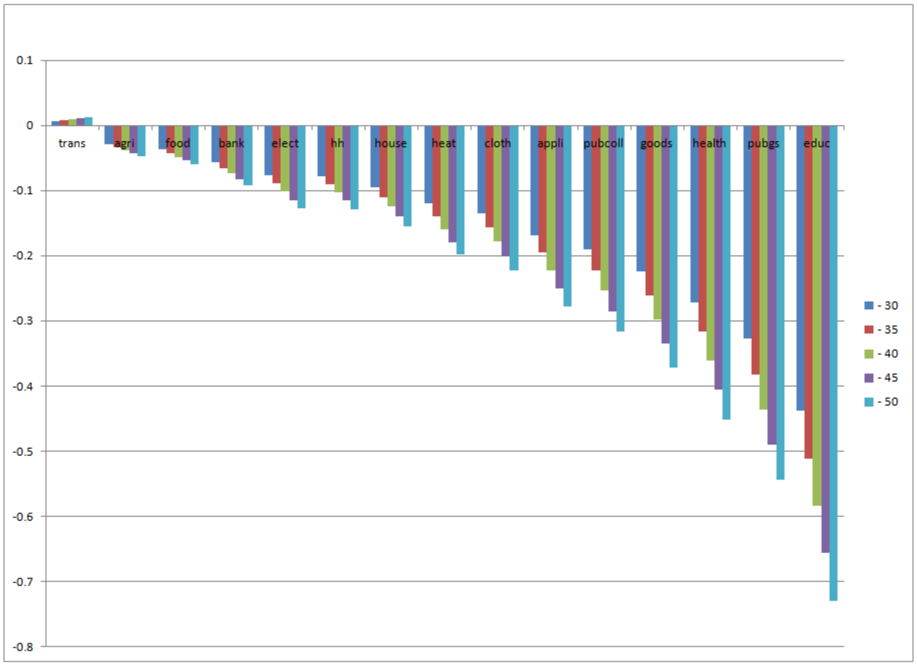
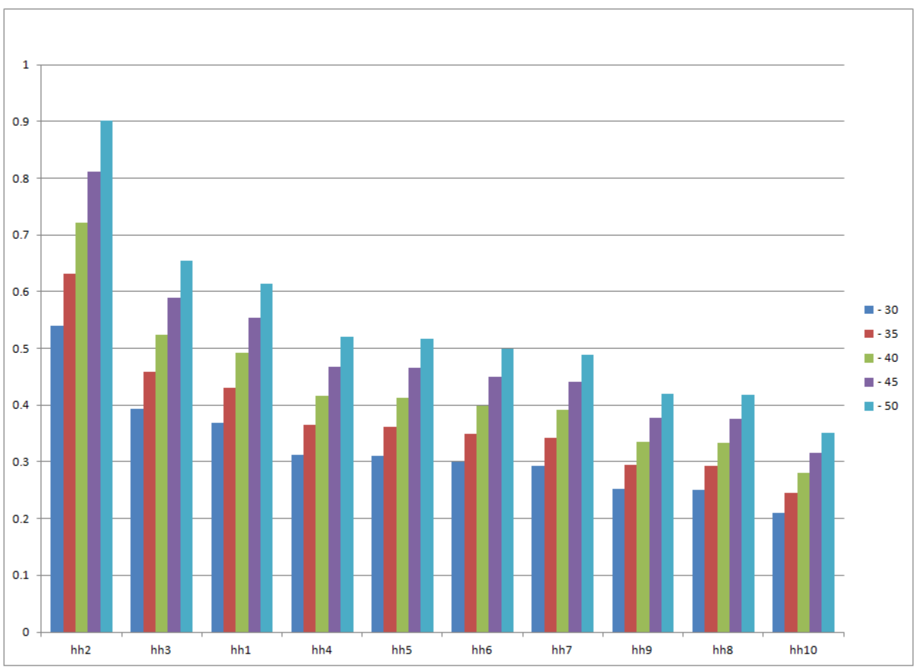


Figure 21: Sensitivity Analysis: % Change in Household Welfare



run trends and intuition on the likely effects of the policy in question. Secondly, our analysis serves to fuse consumer expenditure data into a standard single consumer input output table to impose consumer heterogeneity in a general equilibrium model. By doing so, we expose the expected *progressiveness* that the policy in question would have in the Belarusian economy. As such, the reduction in electricity prices on the production side not only has the effect of making production relatively less costly, it also increases consumer welfare in a manner which benefits poorer households relatively more so than richer households. This is due to the expenditure patterns found in the CEX data and computed relative price changes. By linking such patterns with the interconnected relations explicitly denominated in input-output data, we are able to expose such effects.

This type of cross-subsidy is common in the region, though few studies have looked at the general equilibrium distributional impacts of reform (for studies in the Ukraine and Poland, see (Mitra and Atoyan 2012) and (Freund and Wallich 1997), respectively). Our hope is that this study will help guide the literature as reforms in this region are made.

A caveat to the above model output should be noted. We do impose perfect competition as the driving assumption of the model. However, many sectors in the Belarusian economy are state run and likely do not follow such simplifying assumptions. Therefore, the above analysis should serve as approximations for the real impacts of a tax change.

Finally, we should note that more explicit data on the tax markup experienced by industry for electricity input use is not available. Therefore, our policy simulations treat the problem with fairly blunt tax decreases assuming that the reduction would be uniform across sectors. To the extent that this is representative, it serves as a benchmark for likely policy impacts.

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A Appendix: Results using RAS

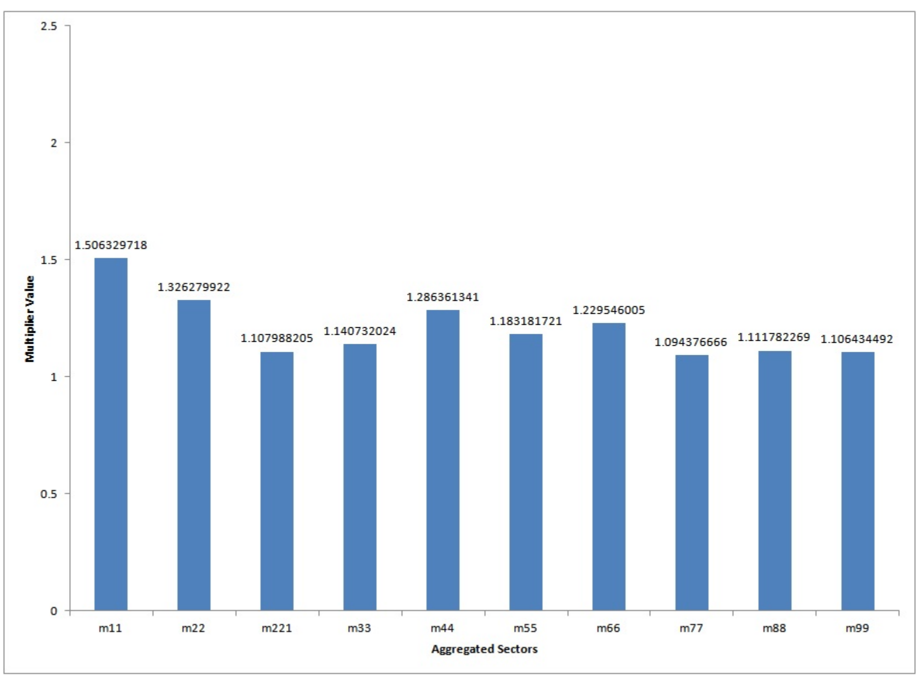
Using the same notation above for the estimated and benchmark input output tables, let ρ_i and σ_j denote multiplicative terms that assure row and column sums are as intended. Typically, via an iterative RAS approach, the loop would continue until ρ_i and σ_j are sufficiently close to one. The reason will be clear once defining the problem as:

$$
\begin{aligned}
\min_{A_{ij}} \quad & \sum_i \left(\rho_i^2 + \left(\frac{1}{\rho_i}\right)^2\right) + \sum_j \left(\sigma_j^2 + \left(\frac{1}{\sigma_j}\right)^2\right) \\
\text{s.t.} \quad & \sum_i \bar{a}_{ij} = \sum_i A_{ij} \quad \forall j \\
& \sum_i \bar{a}_{ji} = \sum_i A_{ji} \quad \forall j \\
& A_{ij} = \rho_i \bar{a}_{ij} \sigma_j \quad \forall (i,j)
\end{aligned}
$$

The last constraint denotes the typical bi-proportionate adjustments commonly associated with RAS. The clever aspect of this program concerns Rutherford's construction of the objective function. Given an iterative approach, we expect iterations to continue until ρ_i and σ_j approach unity. Therefore, by construction, the objective function is minimized in such a case (notably, bounds need to apply here). The idea is that suppose ρ_i is near zero. This then would imply its reciprocal could be quite large thus deviating from optimality.

The Leontief inverse matrix is calculated as (net of direct effects): Output Multipliers are calculated as:

Figure 22: Multipliers: RAS



Appendix: GAMS Code for Heterogeneous Consumer Model

```
$title Canonical CGE Model based on the Belarus 2011 Input-Output Table

set g Goods and final demand,
i(g) Commodities,
pub(g) Components of public demand
mrg(i) Distribution margins,
ssa Sensitivity Analysis /30,35,40,45,50/;

$gdxin belarus_ces.gdx
$loaddc g=ces i=cesi pub=cespub mrg=cesmrg

alias(i,ii);

parameters
x0(g) Exports
d0(g) Domestic supply
id0(i,g) Aggregate intermediate demand (net tax)
ld0(g) Sectoral employment
ls0 Labor supply
kd0(g) Capital earnings
t(i,g) Taxes on intermediate demand,
t0(i,g) Benchmark taxes
ty(g) Other duties,

tt0(i,i,g) Trade and transport margins,
dt0(i) Domestic supply of margins,
mt0(i) Import supply of margins,

md0(i,g) Import demand
dd0(i,g) Domestic demand
m0(i) Imports,
mx0(i) Imports for re-export
xfob0(i) Exports including transport and taxes
trn0 Net transfers,
y0(g) Benchmark output
sigma(g) Elasticity of substitution
tdd0(i) Tax revenue on exogenous demand (domestic),
tmd0(i) Tax revenue on exogenous demand (imported),
ttt0(mrg) Tax revenue on exogenous demand (margins),
xdd0(i) Exogenous demand (domestic),
xmd0(i) Exogenous demand (imported),
xtt0(mrg) Exogenous demand (margins),

bopdef Balance of payments deficit
pwx Export price index /1/,
pwm Import price index /1/;

$loaddc d0=d0_ m0=m0_ x0=x0_ kd0=kd0_ id0=id0_ y0=y0_ sigma=sigma_ ty=ty_ t=t_ t0=t0_ tt0=tt0_ dd0=dd0_ md0=md0_ ld0=ld0_
$loaddc dt0=dt0_ mt0=mt0_ xfob0=xfob0_ xdd0=xdd0_ tdd0=tdd0_ xmd0=xmd0_ tmd0=tmd0_ xtt0=xtt0_ ttt0=ttt0_ ls0 trn0 bopdef

parameter BenchmarkPD;

BenchmarkPD('x0(g): Exports',' ',' ',g) = x0(g);
BenchmarkPD('d0(g): Domestic supply',' ',' ',g) = d0(g);
BenchmarkPD('id0(i,g): Aggregate intermediate demand (net tax)',' ',i,g) = id0(i,g);
BenchmarkPD('ld0(g): Sectoral employment',' ',' ',g) = ld0(g);
BenchmarkPD('ls0: Labor supply',' ',' ',' ') = ls0;
BenchmarkPD('kd0(g): Capital earnings',' ',' ',g) = kd0(g);
BenchmarkPD('t(i,g): Taxes on intermediate demand,',' ',i,g) = t(i,g);
BenchmarkPD('ty(g): Other duties,',' ',' ',g) = ty(g);
BenchmarkPD('tt0(i,i,g): Trade and transport margins,',i,ii,g) = tt0(i,ii,g);
BenchmarkPD('dt0(i): Domestic supply of margins,',' ',' ',i) = dt0(i);
BenchmarkPD('mt0(i): Import supply of margins,',' ',' ',i) = mt0(i);
```

```
BenchmarkPD('md0(i,g): Import demand',' ',i,g) = md0(i,g);
BenchmarkPD('dd0(i,g): Domestic demand',' ',i,g) = dd0(i,g);
BenchmarkPD('m0(i): Imports,',' ',' ',i) = m0(i);
BenchmarkPD('xfob0(i): Exports including transport and taxes',' ',' ',i) = xfob0(i);
BenchmarkPD('trn0: Net transfers,',' ',' ',' ') = trn0;
BenchmarkPD('y0(g): Benchmark output',' ',' ',g) = y0(g);
BenchmarkPD('tdd0(i): Tax revenue on exogenous demand (domestic),',' ',' ',i) = tdd0(i);
BenchmarkPD('tmd0(i): Tax revenue on exogenous demand (imported),',' ',' ',i) = tmd0(i);
BenchmarkPD('ttt0(mrg): Tax revenue on exogenous demand (margins),',' ',' ',mrg) = ttt0(mrg);
BenchmarkPD('xdd0(i): Exogenous demand (domestic),',' ',' ',i) = xdd0(i);
BenchmarkPD('xmd0(i): Exogenous demand (imported),',' ',' ',i) = xmd0(i);
BenchmarkPD('xtt0(mrg): Exogenous demand (margins),',' ',' ',mrg) = xtt0(mrg);
BenchmarkPD('bopdef: Balance of payments deficit',' ',' ',' ') = bopdef;

execute_unload 'BenchmarkPD.gdx' BenchmarkPD;
execute 'gdxxrw.exe i=BenchmarkPD.gdx o=BenchmarkPD.xlsx par=BenchmarkPD rng=PivotData!A2 cdim=0';

alias(g,gg);
parameter phi(g,g),
shock(g,g) Uniform policy shock;

shock(g,gg) = 0;
phi(g,gg)=1-shock(g,gg);

* Introduce heterogeneous consumers based on fixed expenditure shares;

set h Households /
hh1 'First income decile',
hh2 'Second income decile',
hh3 'Third income decile',
hh4 'Fourth income decile',
hh5 'Fifth income decile',
hh6 'Sixth income decile',
hh7 'Seventh income decile',
hh8 'Eighth income decile',
hh9 'Nineth income decile',
hh10 'Tenth income decile'/;

parameter share(h,g);

$if not exist FigureData.gdx $call 'gdxxrw.exe i=FigureData.xlsx o=FigureData.gdx par=share rng=income_shares!A1 cdim=1 rdim=1';
$gdxin 'FigureData.gdx'
$loaddc share
$gdxin

* Numbers don't add to unity;

parameter nshare(h,i) Normalized share,
tshare(i) Total household share for good i,
dshare(h,i) ;

nshare(h,i) = share(h,i)/sum(h.local,share(h,i));
tshare(i) = sum(h,share(h,i))/sum((h,i.local),share(h,i));
dshare(h,i) = share(h,i)/sum(i.local,share(h,i));

parameter agg_incomeshare(h), income(h);
income('hh1') = 809575;
income('hh2') = 1163036;
income('hh3') = 1582812;
income('hh4') = 1919941;
income('hh5') = 2237421;
income('hh6') = 2562030;
income('hh7') = 2924984;
income('hh8') = 3360679;
income('hh9') = 3959351;
income('hh10') = 5541067;

agg_incomeshare(h) = income(h)/sum(h.local,income(h));
```

```
parameter agg_expshare(h), expend(h);
expend('hh1') = 767278.9549;
expend('hh2') = 1072506.365;
expend('hh3') = 1425457.933;
expend('hh4') = 1700677.031;
expend('hh5') = 2031617.798;
expend('hh6') = 2305247.822;
expend('hh7') = 2659953.25;
expend('hh8') = 3032006.446;
expend('hh9') = 3598021.746;
expend('hh10') = 4992010.748;

agg_expshare(h) = expend(h)/sum(h.local, expend(h));

parameter xdshare,tdshare,xmshare,tmshare,xtshare,ttshare,lsshare,kdshare,trnshare;

xdshare(i) = -xdd0(i)/d0('hh');
tdshare(i) = -tdd0(i)/d0('hh');
xmshare(i) = -xmd0(i)/d0('hh');
tmshare(i) = -tmd0(i)/d0('hh');
xtshare(mrg) = -xtt0(mrg)/d0('hh');
ttshare(mrg) = -ttt0(mrg)/d0('hh');
lsshare = ls0/d0('hh');
kdshare(i) = kd0(i)/d0('hh');
trnshare = trn0/d0('hh');

parameter checkshare;

checkshare =  sum(i, xdshare(i)+tdshare(i)+xmshare(i)+tmshare(i)) +
     sum(mrg, xtshare(mrg)+ttshare(mrg))+lsshare + sum(i, kdshare(i)) + trnshare;
display checkshare;

* Convert shares to household distribution;

parameter xdshare_h, tdshare_h, xmshare_h, tmshare_h, xtshare_h,
ttshare_h, lsshare_h, kdshare_h, trnshare_h;

xdshare_h(h,i) = nshare(h,i)*xdshare(i);
tdshare_h(h,i) = nshare(h,i)*tdshare(i);
xmshare_h(h,i) = nshare(h,i)*xmshare(i);
tmshare_h(h,i) = nshare(h,i)*tmshare(i);
xtshare_h(h,mrg) = nshare(h,mrg)*xtshare(mrg);
ttshare_h(h,mrg) = nshare(h,mrg)*ttshare(mrg);
lsshare_h(h) = agg_incomeshare(h)*lsshare;
kdshare_h(h,i) = nshare(h,i)*kdshare(i);
trnshare_h(h) = agg_incomeshare(h)*trnshare;

parameter impliedexpshare(h) Implied expenditure share;

impliedexpshare(h) =  sum(i, xdshare_h(h,i) + tdshare_h(h,i) + xmshare_h(h,i) + tmshare_h(h,i)+
     kdshare_h(h,i)) + sum(mrg, xtshare_h(h,mrg) + ttshare_h(h,mrg)) +
     lsshare_h(h) + trnshare_h(h);

display impliedexpshare;

parameter hh_exp(h) Total Expenditure share;

hh_exp(h) = impliedexpshare(h)*d0('hh');

parameter d0_h(h),
xdd0_h(h,i),
tdd0_h(h,i),
xmd0_h(h,i),
tmd0_h(h,i),
xtt0_h(h,mrg),
ttt0_h(h,mrg)
ls0_h(h),
```

```
kd0_h(h,i),
trn0_h(h);

d0_h(h) = hh_exp(h);
xdd0_h(h,i) = -d0('hh')*xdshare_h(h,i);
tdd0_h(h,i) = -d0('hh')*tdshare_h(h,i);
xmd0_h(h,i) = -d0('hh')*xmshare_h(h,i);
tmd0_h(h,i) = -d0('hh')*tmshare_h(h,i);
xtt0_h(h,mrg) = -d0('hh')*xtshare_h(h,mrg);
ttt0_h(h,mrg) = -d0('hh')*ttshare_h(h,mrg);
ls0_h(h) = d0('hh')*lsshare_h(h);
kd0_h(h,i) = d0('hh')*kdshare_h(h,i);
trn0_h(h) = d0('hh')*trnshare_h(h);

parameter hh_incbal(h) Household income balance;

hh_incbal(h) =  d0_h(h) - sum(i,-xdd0_h(h,i)-tdd0_h(h,i) - xmd0_h(h,i) - tmd0_h(h,i)) -
     sum(mrg, -xtt0_h(h,mrg) - ttt0_h(h,mrg)) - ls0_h(h) - sum(i,kd0_h(h,i)) - trn0_h(h);

display hh_incbal;

$ontext
$model:belarus

$commodities:
PD(g)$d0(g) ! Domestic price
PM(i)$m0(i) ! Import price
PX(g)$x0(g) ! Export price
PT(mrg) ! Margins
P(i,g)$id0(i,g) ! Intermediate demand
RK(g)$kd0(g) ! Rental rate
PL ! Wage rate
PFX ! Foreign exchange

$sectors:
Y(g)$y0(g) ! Production and final demand
ID(i,g)$id0(i,g)! Intermediate demand
TT(mrg) ! Trade and transport margin
M(i)$m0(i) ! Import
X(i)$x0(i) ! Export

$consumers:
GOVT ! Government
HH(h) ! Households

$prod:Y(g)$y0(g)   s:sigma(g)  t:4 va:1
o:PX(g) q:x0(g) a:GOVT t:ty(g)
o:PD(g) q:d0(g) a:GOVT t:ty(g)
i:P(i,g) q:id0(i,g) a:GOVT  t:(phi(i,g)*t(i,g)) p:(1+t0(i,g))
i:PL q:ld0(g) va:
i:RK(g) q:kd0(g) va:

$report:
v:LD(g)$ld0(g) i:PL prod:Y(g)
v:KD(g)$kd0(g) i:RK(g) prod:Y(g)

$prod:ID(i,g)$id0(i,g)    s:0  dm:4
o:P(i,g) q:id0(i,g)
i:PT(mrg) q:tt0(mrg,i,g)
i:PD(i) q:dd0(i,g) dm:
i:PM(i) q:md0(i,g) dm:

$prod:TT(mrg)
o:PT(mrg) q:(dt0(mrg)+mt0(mrg))
i:PD(mrg) q:dt0(mrg)
i:PM(mrg) q:mt0(mrg)

$prod:X(i)$x0(i)
```

```
o:PFX q:(xfob0(i)*pwx)
i:PX(i) q:x0(i)
i:PM(i) q:md0(i,"exp")
i:PT(mrg) q:tt0(mrg,i,"exp")

$prod:M(i)$m0(i)
o:PM(i) q:m0(i)
i:PFX q:(m0(i)*pwm)

$demand:GOVT s:0
d:PD(pub) q:d0(pub)
e:PD("hh") q:(-trn0)
e:PFX q:bopdef
e:PD(i) q:tdd0(i)
e:PM(i) q:tmd0(i)
e:PT(mrg) q:ttt0(mrg)

$demand:HH(h)
d:PD("hh") q:d0_h(h)
e:PD(i) q:(-xdd0_h(h,i)-tdd0_h(h,i))
e:PM(i) q:(-xmd0_h(h,i)-tmd0_h(h,i))
e:PT(mrg) q:(-xtt0_h(h,mrg)-ttt0_h(h,mrg))
e:PL q:ls0_h(h)
e:RK(i) q:kd0_h(h,i)
e:PD("hh") q:trn0_h(h)

$report:
v:W(h) w:HH(h)

$offtext
$sysinclude mpsgeset belarus

belarus.iterlim = 0;
$include belarus.gen
solve belarus using mcp;

belarus.iterlim = 10000;

* Some forensic calculations to help us ascertain where the bodies are buried.
* Evaluate the marginal cost of funds from different sources:

parameter mcf_i Marginal cost of funds for industries;

alias (i,itax,jtax);
loop(jtax$y0(jtax),
  loop(itax$(round(t(itax,jtax),4)*round(id0(itax,jtax)/y0(jtax),2)),
t(itax,jtax) = t(itax,jtax) + 0.01;
$include belarus.gen
solve belarus using mcp;
mcf_i(jtax,itax) = (d0("hh")- sum(h,HH.L(h))/PD.L("hh"))/(sum(pub,d0(pub)*GOVT.L)/sum(pub,PD.L(pub)*d0(pub))-sum(pub,d0(pub)));
t(itax,jtax) = t(itax,jtax) - 0.01;
));
display mcf_i;

execute_unload 'mcf.gdx' mcf_i;
execute 'gdxxrw.exe i=mcf.gdx o=MCF_TAX.xlsx par=mcf_i cdim=0 rng=MCF!A2';

* Now run policy shock for energy taxes. I.e.
* industries would no longer be paying 40% higher taxes
* on energy;

parameter pivotdata Pivot data with model results;

loop(ssa,
shock('elect',g) = ssa.val/100;
shock('elect','elect') = 0;
phi(g,gg)=1-shock(g,gg);
$include belarus.gen
```

```
solve belarus using mcp;
pivotdata("Hicksian Equivalent Variation (Welfare)",ssa,'% change',' ',h) = 100 * (W.L(h)-1);
pivotdata("Hicksian Equivalent Variation (Welfare)",ssa,'value change',' ',h) = d0('hh') * (W.L(h)-1);
pivotdata("Real Foreign Exchange",ssa,'% change',' ',' ') = 100 * (PFX.L-1);
pivotdata("Change in Local Output Price RTFX",ssa,'% change',' ',g) = 100 * (PD.L(g)-1);
pivotdata("Change in the Wage Rate RTFX",ssa,'% change',' ',' ') = 100 * (PL.L-1);
pivotdata("Change in the Capital Returns Rate RTFX",ssa,'% change',' ',g) = 100 * (RK.L(g)-1);
pivotdata("Change in the Intermediate Input Price RTFX",ssa,'% change',i,g) = 100 * (P.L(i,g)-1);
pivotdata("Change in the Margins Price RTFX",ssa,'% change',' ',mrg) = 100 * (PT.L(mrg)-1);
pivotdata("Change in Labor Demand",ssa,'% change',' ',g)$ld0(g) = 100 * (LD.L(g)/ld0(g)-1);
pivotdata("Change in Labor Demand",ssa,'value change',' ',g)$ld0(g) = (LD.L(g)-ld0(g));
pivotdata("Change in Capital Demand",ssa,'% change',' ',g)$kd0(g) = 100 * (KD.L(g)/kd0(g)-1);
pivotdata("Change in Capital Demand",ssa,'value change',' ',g)$kd0(g) = (KD.L(g)-kd0(g));
pivotdata("Change in Production",ssa,'% change',' ',g) = 100 * (Y.L(g)-1);
pivotdata("Change in Production",ssa,'value change',' ',g) =  (Y.L(g)-1) * y0(g);
pivotdata("Change in Imports",ssa,'% change',' ',i)$m0(i) = 100 * (M.L(i)-1);
pivotdata("Change in Imports",ssa,'value change',' ',i)$m0(i) = (M.L(i)-1) * m0(i);
pivotdata("Change in Exports",ssa,'% change',' ',i)$m0(i) = 100 * (X.L(i)-1);
pivotdata("Change in Exports",ssa,'value change',' ',i)$m0(i) = (X.L(i)-1) * x0(i);
pivotdata("Change in Transport Margins",ssa,'% change',' ',mrg) = 100 * (TT.L(mrg)-1);
shock(g,gg) = 0;
phi(g,gg)=1-shock(g,gg);
);

execute_unload 'pivot_table_hetcons.gdx' pivotdata;
$if not exist GE_hetcons.xlsx execute 'gdxxrw.exe i=pivot_table_hetcons.gdx o=GE_hetcons.xlsx par=pivotdata rng=PivotData!A2 cdi
```