RICE UNIVERSITY

Tax Policy Analysis in a Flexible Computable General Equilibrium Model: Applications to Energy and Gross Receipts Taxation

by

André J. Barbé

A THESIS SUBMITTED
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE

Doctor of Philosophy

APPROVED, THESIS COMMITTEE:

George R. Zodrow, Chair
Allyn R. and Gladys M. Cline Chair of Economics

Kenneth B. Medlock, III
James A. Baker, III, and Susan G. Baker Fellow in Energy and Resource Economics

Robin C. Sickles
Reginald Henry Hargrove Chair of Economics

Robert M. Stein
Lena Gohlman Fox Professor of Political Science

Houston, Texas

May, 2014

Abstract

Tax Policy Analysis in a Flexible Computable General Equilibrium Model:
Applications to Energy and Gross Receipts Taxation

by

André J. Barbé

In this paper, I construct a new general equilibrium model of the United States economy that is better able to analyze energy and gross receipts taxes than previous models. Existing models in the energy literature fall into two groups: general equilibrium models of the entire economy with exogenous energy resource supply and partial equilibrium models of the energy sector with endogenous resource supply. I combine the main advantages of these two strains of the literature by incorporating endogenous resource supply in a computable general equilibrium model with highly disaggregated and flexible industry cost and consumer expenditure functions. My new model is able to analyze all the major inefficiencies caused by energy taxation, i.e. those related to production, consumption, resource rents, and externalities.

In addition to its application in energy, my model is also ideal for looking at gross receipts and retails sales taxes. Gross receipts and retail sales taxes are important revenues sources for most US states and share many of the same issues as energy taxes. Retail sales taxes are commonly viewed as more efficient than gross receipts taxes because the latter apply to intermediate goods and thus result in production and consumption inefficiencies. However, in reality the retail sales taxes used by the US states are not pure consumption taxes, but tax many intermediate inputs while exempting many consumption goods. My model determines whether retail sales taxes are still more efficient than gross receipts taxes when these realistic factors are included.

As an application, I use the model to analyze two tax reforms for energy or gross receipts taxes. First, President Obama's 2014 budget proposes to reform energy taxation by eliminating fossil fuel tax preferences. I find that the budget's tax increases for fossil fuels increase household welfare if the social cost of carbon emissions is over $14 per ton but otherwise reduce welfare. Second, I also use the model to examine a tax reform that replaces a typical retail sales tax with a generic gross receipts tax. Contrary to the conventional wisdom, I find that the gross receipts tax is more efficient than the retail sales tax, with an efficiency cost that is 6.8 percent of revenues less than that of the retail sales tax. These results demonstrate that the predicted impacts of the tax reforms are significantly altered by the features included in my model: general equilibrium effects, flexible substitution, resource rents, and externalities.

Acknowledgments

I cannot sufficiently express the depth of my gratitude to George Zodrow. I would not have been able to complete this project without your advice and tutelage. In addition, Robin Sickles, Kenneth Medlock III, and Peter Hartley provided indispensable help at all stages of the thesis.

Thank you to my colleagues: Jung You, Margaret McKeehan, and Stephen Wolff. You reviewed this very long paper and gave excellent feedback on it despite having no obligation to do so. I would also like to thank my parents, Donald and Deborah Barbé. Your constant encouragement during hectic times will not be forgotten.

Contents

1 Introduction **1**

2 Energy Taxation in the President's 2014 Budget **4**

2.1 Introduction 4

2.2 Individual Provisions of the Budget Proposal 6

2.2.1 Last-in, First-out (LIFO) Inventory Accounting 6

2.2.2 Domestic Manufacturing Deduction 8

2.2.3 Expensing of Intangible Drilling Costs 8

2.2.4 Percentage Depletion 9

2.2.5 Oil Spill Liability Trust Fund 11

2.2.6 Superfund Excise Taxes 13

2.2.7 Dual Capacity Rules 14

2.2.8 Geological and Geophysical Expense Amortization 16

2.2.9 Capital Gains Treatment of Coal Royalties 17

2.2.10 Expensing of Coal Exploration 18

2.3 Current Law Tax Rates 18

2.3.1 Background 19

2.3.2 Methodology 22

2.3.3 Results 23

2.4 Conclusions 25

3 A New Model of Energy Taxation **26**

3.1 Introduction 26

3.2 Literature Review 29

3.3 Model Description 31

3.3.1 Model Overview . . . 31
3.3.2 Model Parameters . . . 33
3.3.3 Firm Cost and Consumer Expenditure Functions . . . 34
3.3.4 Taxation . . . 39
3.4 Results . . . 42
3.4.1 Baseline Results . . . 42
3.4.2 Sensitivity Tests . . . 44
3.5 Conclusions . . . 48

4 The Efficiency of Gross Receipts Taxation 50
4.1 Introduction . . . 50
4.2 Literature Review . . . 53
4.3 Methodology . . . 54
4.4 Results . . . 57
4.5 Conclusions . . . 61

Bibliography 62

A Model Data 69
A.1 Jorgenson (2007) . . . 69
A.2 Other Data Sources . . . 71

B Model Equations 73
B.1 Variable Definitions . . . 73
B.2 Regression . . . 73
B.2.1 Regression Equations . . . 73
B.2.2 Regularity Conditions . . . 76
B.3 Other Cost Functions . . . 79
B.3.1 Domestic Output . . . 79
B.3.2 Imports and Composite Output . . . 80
B.4 Removing the Energy Resource From the Capital Stock . . . 82
B.5 Supply Functions . . . 82
B.5.1 Capital . . . 82
B.5.2 Labor . . . 83

B.5.3 Energy Resource 83
B.6 Demand Functions 84
B.6.1 Household Consumption Demand 84
B.6.2 Firm Intermediate Good Demand 84
B.6.3 Government Demand 84
B.6.4 Household Investment Demand 85
B.6.5 Export Demand 85
B.6.6 Household Income and Spending 85
B.7 Household Utility 85
B.7.1 Externalities 86
B.8 Government Revenue 87

C Average Effective Tax Rates by Industry and Year 88

D Cost and Expenditure Function Parameters for the Energy Model 90

E Cost and Expenditure Function Parameters for the GRT Model 121

F Full Regression Summary Statistics 150

List of Tables

2.1 Revenue Estimates of Provisions of the President's 2014 Budget for 2013-23 ($ millions) . . . 5
2.2 Total Tax Payments by Industry for 1998-2009 ($ millions, 2008) . . . 22
2.3 Firm Average Effective Tax Rates on Capital from Corporate Income Taxes by Sector for 1998-2009 (Percent) . . . 23
2.4 Average Effective Tax Rates of All Firm Taxes by Sector for 1998-2009 (Percent) 24

3.1 Selected Parameters and their Values in the Baseline Specification . . . 33
3.2 Regression R^2 Statistics . . . 37
3.3 Regression Instrumental Variable Statistics . . . 38
3.4 Tax Bases for Provisions in Budget Proposal . . . 41
3.5 Macroeconomic Effects of the Budget Proposal under Baseline Assumptions . . . 42
3.6 Industry Level Effects of the Budget Proposal . . . 44
3.7 Macroeconomic Effects of the Budget Proposal Under Alternative Assumptions . 45
3.8 Macroeconomic Effects of the Budget Proposal in the Monte Carlo Simulation . 48

4.1 Taxable and Exempt Goods under the RST . . . 56
4.2 Statutory Tax Rates Under Each Tax Regime (Percent) . . . 57
4.3 Macroeconomic Effects of Replacing an RST with a GRT . . . 60

B.1 Commodity Variable Notation . . . 74
B.2 CES Parameters . . . 74
B.3 Regression Statistics: Nonnegativity and Monotonicity . . . 78

C.1 Average Effective Tax Rates by Industry for 1998-2009 (Percent) . . . 89
C.2 Average Effective Tax Rates by for Select Industries for 1998-2009 (Percent) . . . 89

D.1 Cost and Expenditure Function Parameters for the Energy Model 91

E.1 Cost and Expenditure Function Parameters for the GRT Model 122

F.1 Full Regression Summary Statistics 151

Chapter 1

Introduction

Federal corporate income tax reform is a perennial topic of scholarly discussion among public finance economists in the US. The tax code is rife with deductions and exemptions that could be eliminated in order to broaden the tax base and lower its rate. In particular, fossil fuels have been a target of President Obama's budgets in recent years. The president's 2014 budget would eliminate $144 billion worth of provisions it identifies as tax preferences for fossil fuel production (Treasury, 2013).

The Obama administration makes a standard tax neutrality argument to justify the budget's tax changes. In general, a tax is considered neutral if it does not influence economic choices such as which inputs or technologies are used for production, how investment is allocated across assets or industries, how firms are organized, or how investments are financed. Tax neutrality is beneficial because it is necessary for production and consumption efficiency. However, experts disagree which parts of the tax code — e.g., tax credits, deductions, or tax rates — are neutral.

However, it is not the individual parts but the tax code as a whole that should be neutral. The neutrality of individual tax provisions only matters in so far as they determine the neutrality of the tax code as a whole. Therefore, in order to determine if the proposed changes increase tax neutrality, the entire code must be examined, not just these particular provisions. The true question is not merely whether these individual provisions favor fossil fuel production, but whether the tax code as a whole does.

Unfortunately, this type of descriptive analysis can only go so far before formal economic models are necessary. There are two general categories of models in the energy taxation literature. The first takes a partial equilibrium (PE) approach that models energy resource development in great detail but has a highly simplified representation of the rest of the economy. The second uses a computable general equilibrium (CGE) approach that models many production sectors in the economy but has little detail on the differences between energy extraction and other sectors. Therefore both of these methods are missing a key feature that the other has.

This paper builds a new model that combines the most important features of both approaches. My model is a computable general equilibrium model of the US economy that includes both endogenous resource supply and externalities. Moreover, l use translog cost and expenditure functions that allow for flexible substitution by firms across inputs and by consumers across goods. The resulting model allows a comprehensive analysis of the three primary areas in which energy taxes may create or reduce inefficiencies: production and consumption, resource rents, and externalities.

In addition to examining energy taxes, my model's detailed treatment of substitution allows it to answer questions that arise in other areas of taxation. Specifically, I determine the relative efficiency of gross receipt taxes (GRTs) and retail sales taxes (RSTs). Although GRTs and RSTs are important sources of revenue for US states, GRTs are widely viewed as less efficient than RSTs because GRTs tax intermediate goods. Intermediate good taxation is well known to cause productive and consumptive inefficiency. Nevertheless, the actual RSTs implemented by US states also tax intermediate goods. Which of these two taxes causes greater intermediate good taxation and social inefficiency is thus an empirical question.

The key issue for this empirical question is intermediate good taxation and the production and consumption inefficiency it causes. My model accurately analyzes these distortions for GRTs and RSTs through the flexible substitution of the translog cost and expenditure functions. The same features that enable my model to capture these inefficiencies in energy taxes also work for GRTs and RSTs. Thus, my model is able to determine if RSTs are still more efficient than GRTs when these inefficiencies are included.

The overall outline of the dissertation is as follows. In Chapter 2, I provide descriptive analysis of the fossil fuel tax changes in President Obama's 2014 budget proposal. I examine whether the provisions changed by the budget are in fact tax preferences and compare the budget's proposed changes to both current law and the tax treatment of that issue under a neutral tax system. I also analyze whether the current tax system favors fossil fuel production compared to other sectors. I look at not only corporate income taxes that have been the focus of previous research, but also at various production-based taxes. The evidence I uncover does not show that the budget proposal improves the neutrality of the tax code or that the current law tax code favors fossil fuel production more than a neutral tax system would.

In Chapter 3, I construct a computable general equilibrium model of the US economy with endogenous resource supply, flexible substitution, and externalities. I describe the model equations, the data used to parametrize these equations, and other assumptions. I then use the model to simulate the macroeconomic effects of the president's budget proposal. I find that the budget proposal will reduce domestic fossil fuel production. It will also reduce household welfare before carbon externalities are accounted for. The social cost of carbon needs to be at least $14 per ton in order for reduced carbon emissions to make up for the social efficiency costs of the budget proposal.

In Chapter 4, I examine the relative efficiency of GRTs and RSTs. I utilize a modified version of the model developed in Chapter 3 to compare a GRT and an RST with common exemptions. For the particular RST and GRT analyzed, I find that, contrary to the conventional wisdom, the gross receipts tax is more efficient than the retail sales tax. The excess burden of the GRT is 6.8 percent of revenues less than the excess burden of the equal-yield retail sales tax.

The innovations combined in my model significantly impact the estimates of these tax reforms. In regards to the president's budget proposal, a general equilibrium model without flexible substitution would overstate the proposal's reduction in carbon emissions or understate the efficiency loss from input substitution. Similarly, a model without externalities would underestimate the benefits of the proposal. By contrast, my model address both of these pitfalls. Furthermore, sensitivity tests illustrate that both my model's inclusion of an energy resource and the general equilibrium effects of import substitution also have important welfare impacts. Moreover, flexible substitution and general equilibrium effects play key roles for GRTs and RSTs as well. My model shows that once these features are included, GRTs are actually more efficient than RSTs. Taken together, the results confirm the importance of my model's inclusion of general equilibrium effects, productive and consumptive efficiency, resource rents, and externalities.

Chapter 2

Energy Taxation in the President's 2014 Budget

2.1 Introduction

President Obama's 2014 budget proposes to raise billions of dollars in tax revenue by increasing taxes on fossil fuel production. The president himself noted that "these companies pay a lower tax rate than most other companies on their investments, partly because we're giving them billions in tax giveaways every year" (Office of the Press Secretary, 2012). The budget proposal would change the taxation of fossil fuels by delaying or eliminating deductions and reinstating expired taxes. Table 2.1 lists revenue estimates of these changes, as calculated by the Treasury (2013) and the Joint Committee on Taxation (2013), hereafter JCT. The president has stated that these provisions are tax preferences and that they contribute to investment in fossil fuel production facing a lower effective tax rate than investment in other sectors of the economy.[1] The Treasury and the JCT have also stated that, under current law, the US federal income tax code contains tax preferences that favor the production of fossil fuels (Treasury, 2013; JCT, 2012).[2] Treasury argues reduced energy security[3], higher carbon emissions, and higher taxes on the rest of the economy are consequences of this distortion.

The Obama administration has invoked tax neutrality to justify the budget's tax changes.

[1]The statutory tax rate is the legally imposed rate on taxable income. Effective tax rates are a more robust measure of taxation that also includes the effect of credits, deductions, the timing of payments, etc. See Section 2.3 for more details.

[2]Although JCT (2012) analyzes the 2013 budget proposal, the proposed changes to fossil fuel taxation are virtually identical to those in the 2014 budget proposal.

[3]Treasury does not elaborate on how tax preferences that encourage domestic fossil fuel production reduce energy security.

Table 2.1: Revenue Estimates of Provisions of the President's 2014 Budget for 2013-23 ($ millions)

Provision	JCT (2013)	Treasury (2013)
Repeal LIFO inventory accounting for all sectors	78,299	80,822
Repeal the domestic manufacturing deduction for fossil fuels	19,881	17,856
Repeal expensing of intangible drilling costs	13,698	10,993
Repeal percentage depletion for oil and gas	11,118	10,723
Reinstate Superfund excise taxes[1]	8,153	8,032
Modify tax rules for dual capacity taxpayers	7,896	10,964
Increase Oil Spill Liability Trust Fund financing rate	1,863	1,058
Increase geological and geophysical amortization period	1,251	1,363
Repeal the capital gains treatment of coal royalties	603	432
Repeal percentage depletion for coal and other hard mineral fossil fuels	595	1,982
Repeal expensing of coal exploration and development	591	432
All other fossil fuel specific provisions	270	181
Total	144,218	144,838

Notes: (1) This is the revenue estimate for all 3 Superfund excise taxes combined. However, only one of the three, a tax on petroleum, is relevant to the energy industry. But from 1991-1995 this one tax accounted for 68% of the total revenue of the three taxes (Ramseur, Reisch, and McCarthy, 2008).

Tax neutrality is a useful concept because previous work has shown that under certain assumptions, neutral taxes are both social efficient and sufficient to achieve redistributive goals (Atkinson and Stiglitz, 1976; Diamond and Mirrlees, 1971).[4] In particular, tax neutrality is necessary for production and consumption efficiency.[5] Neutrality is thus a proxy for efficiency that is easier to measure. This means that in addition to the negative consequences cited by Treasury, favoritism of fossil fuels would decrease social welfare. Unfortunately, measuring neutrality is still difficult and scholars disagree over the exact traits of a neutral tax system. However, the key question is not merely whether these individual provisions favor fossil fuel production, but whether the tax code as a whole does. In this chapter, I analyze not only the neutrality of the individual provisions, but also whether fossil fuel production is favored under current law.

In order to examine this issue, I take a more comprehensive view of the current law tax system as well. The standard yardstick for measuring the aggregate effect of the entire tax code is the effective tax rate. An effective tax rate includes not only the statutory rate, but also the availability of deduction and credits. In this chapter, I review past estimates of marginal effective tax rates for fossil fuels. Unfortunately, by focusing on marginal effective tax rates on

[4] See also Hammond (2000) and Hellwig (2008).

[5] I refer to production efficiency in the same sense as Diamond and Mirrlees (1971).

investment, the literature has overlooked an extremely large amount of production based taxes. By contrast, I utilize an average effective tax rate methodology that allows me to include these taxes as well.

The organization of this chapter is as follows: in Section 2.2, I discuss each change proposed in the 2014 budget that is relevant to fossil fuel production. I examine whether the provisions changed by the budget are in fact tax preferences, and if so, whether the proposed change successfully addresses the issue. I do so by comparing the budget's proposed changes to both current law and the tax treatment of that issue under a neutral tax system. Then in Section 2.3 I take a more comprehensive view of the current tax system. I examine the current law effective tax rates facing fossil fuel production and account for both income taxes and also production-based taxes. Section 2.4 summarizes findings and concludes.

2.2 Individual Provisions of the Budget Proposal

2.2.1 Last-in, First-out (LIFO) Inventory Accounting

Last-in, First-out (LIFO) is a system of inventory accounting that determines firm tax deductions. Under current law, taxpayers are allowed to deduct the cost of acquiring the goods they sell. However, the appropriate cost becomes unclear when the firm is selling goods from an inventory containing goods acquired at different times, each of which was bought at a different price. The LIFO and FIFO methods determine which price to use in this situation.[6] Under last-in, first-out (LIFO), when a unit of a good is removed from inventory, the price of the last (most recent) unit of that good put into the inventory is used to calculate net income from the sale of the good. Under first-in, first-out (FIFO), when a unit of a good is removed from inventory, the price of the first (least recent) unit of the good put in inventory is used to calculate net income from the sale of the good.

LIFO and FIFO can give significantly different prices and deductions. When the price of an inventory item is increasing, such as due to inflation, the cost of goods sold is higher under LIFO than FIFO. A higher cost of goods sold in a period translates to lower net taxable income and thus lower taxes paid in that period. The lower cost of goods sold from the less recent period is not used until inventories are drawn down. But if inventories are never drawn down,

[6] See Congressional Budget Office (2011), hereafter CBO, for a description of LIFO, FIFO, and the "specific identification" inventory accounting methods, their interaction with "lower of cost or market" changes, and arguments for and against them.

this lower cost of goods sold is never used and those inventory items' appreciation, whether inflationary or not, is never taxed.

Although LIFO accounting is not unique to firms that produce fossil fuels, LIFO is disproportionately used by firms in the energy sector. Energy companies account for more than 82 percent of the LIFO reserves of all companies on the S&P 500 Index (Przybyla, 2011). Energy companies also use LIFO more than other firms both as a fraction of inventories and by dollar value. LIFO reserves average $2.6 billion or 199 percent of inventories for oil and gas firms that use LIFO. For firms in other sectors that use LIFO, LIFO reserves range from $13 million up to $150 million and from 2 to 28 percent of inventories (Tipton, 2012). In addition, among corporations with inventories valued at over 1 million dollars, overall only 23 percent of inventories are LIFO. But for the petroleum refining, 73 percent of inventories are LIFO (Knittel, 2009).

President Obama's 2014 budget proposal would repeal the LIFO inventory accounting method for income tax purposes, regardless of the use of LIFO on the firm's financial statement (Treasury, 2013). Taxpayers that currently use LIFO would be required to write up their beginning LIFO inventory to its FIFO value in the first taxable year beginning in 2014 (Treasury, 2013). The resulting increase in income is taken into account ratably over 10 years (Treasury, 2013).

In a neutral tax system, taxes would be imposed on real economic income, not increases that are attributable to inflation. Gains from inflation would not be taxed, but neither would an incentive be created to retain inventories. And inventory appreciation that is not due to inflation would be taxed. In contrast to the president's proposal, Treasury (1984) recommends achieving these goals by allowing firms to choose between FIFO indexed for inflation or LIFO.[7] Conversely, as previously noted, LIFO allows firms to defer taxes on the gains from their inventory appreciating by maintaining their inventory stock. So I recommend mandatory inflation-indexed FIFO as the ideal method. However, the president's proposal is for non-indexed FIFO. Without indexing, it is unclear if the FIFO requirement proposed by the president would be more or less neutral than the current system.

[7] Kleinbard, Plesko, and Goodman (2006) notes that inflation affects all capital investment, not just inventories. Therefore, they say that inflation should be dealt with in a systematic manner instead of through LIFO. They contend that LIFO is a piecemeal solution affecting only inventories and thus favors investment in inventories over other forms of investment. This argument on the theory of the second best adds another layer of ambiguity.

2.2.2 Domestic Manufacturing Deduction

The domestic manufacturing deduction was added to the tax code with the American Jobs Creation Act of 2004 with the intent of encouraging domestic investment and improving the competitiveness of US manufacturers in global markets (Blouin, Krull, and Schwab, 2007). It allows a taxpayer to deduct a percentage of their income derived from domestic manufacturing activities (Pirog, 2012). The percentage of the deduction is six percent for oil and gas production and is nine percent for other qualifying industries. The president's 2014 budget proposal would repeal the domestic manufacturing deduction for income derived from the domestic production of oil, gas, coal, and other hard mineral fossil fuels (Treasury, 2013).

There are two margins on which this change needs to be considered: which industries receive the deduction and imports versus domestic production. In regards to first issue, the change would level the playing field between fossil fuels and industries that do not receive the deduction. But it would also increase the gap between still deductible industries and fossil fuels. The second dimension of the change is the choice between domestic production and importation. Eliminating the deduction would increase the favorability of importing fossil fuels instead of domestic production. Although this paper will not attempt to weigh the merits of energy security against free trade, Treasury (2013) has mentioned improving energy security as one of the reasons for the tax changes. This provision of the budget proposal would not accomplish this goal: increasing the favorability of importing fossil would actually reduce US energy security.

2.2.3 Expensing of Intangible Drilling Costs

Intangible drilling costs (IDCs) are expenditures made in preparation of wells for the production of oil, natural gas, or geothermal energy that are not for the purchase of tangible property. For example, wages and fuel are examples of IDCs but pipelines are not (Treasury, 1984). Most taxpayers may elect to either expense or capitalize these costs. Integrated oil and gas companies, however, are not allowed to fully expense IDCs but must capitalize 30% of intangible drilling expenses over a 60-month period (JCT, 2012).[8]

The president's 2014 budget proposal repeals both the expensing and 60-month amortization of IDCs for all firms (Treasury, 2013). Intangible drilling costs instead would be capitalized as depreciable or depletable property (Treasury, 2013).[9] Although the expensing of intangible

[8]Integrated oil and gas companies refer to oil and gas producers that conduct production, refining, and retail sales activities (JCT, 2012).

[9]Typically, depreciable assets are used to recover depletable assets (JCT, 2012).

drilling costs is not exclusively for oil and natural gas but also geothermal energy, both JCT (2012) and Treasury (2013) only discuss repeal for fossil fuels, not geothermal.

Under a neutral income tax system, expenses relating to the creation of a capital asset should not be expensed, but capitalized, with the tax depreciation allowance equal to the economic depreciation rate of the capital asset produced. However, it is not clear what generally applicable rules would then apply to IDCs nor what the true rate of economic depreciation is. It is thus not possible to compare whether the old or new rates are closer to the economic rate of depreciation.[10] However, one clear advantage of this change is that it would remove the different tax treatment between firms due to organizational form since it would remove a deduction not available to integrated oil companies.[11]

2.2.4 Percentage Depletion

Depletion deductions are similar to depreciation deductions. They are both deductions taxpayers receive as capital is reduced in value as it produces income. For fossil fuels, the cost of acquiring the lease for a property's mineral rights is deductible through depletion, not depreciation (JCT, 2012). The tax code recognizes two methods for the calculation of depletion deductions: cost depletion and percentage depletion.[12]

Under the cost depletion method, each year the taxpayer deducts an amount equal to the amount of the resource recovered that year times the cost of acquiring the lease divided by the total amount of the resource in the property. Under the percentage depletion method, a constant percentage, varying from five to 22 percent (depending on the type of resource extracted) of the taxpayer's gross income from a producing property is allowed as a deduction from net income in each taxable year (JCT, 2012).[13]

A disadvantage of percentage depletion is that it does not depend on the costs of acquiring the property and thus has no direct relationship to cost recovery. Over the years 1968-2000 government revenue was decreased by a total of $82 billion in year 2000 dollars because of the

[10] There is no reference in the proposal to what the new rules are or if there even is a single set of rules which would now apply to all IDCs. It appears that expenditures that are currently grouped together under the category of IDC would have a variety of different treatments.

[11] See CBO (2011) for further discussion of this issue.

[12] Additional explanation of the two depletion methods is available in Internal Revenue Service (2011a), hereafter IRS.

[13] Other limitations on percentage depletion exist as well. For example, for non-integrated oil companies, the deduction is limited to domestic US production on the first one thousand barrels per day per well and is also limited to 65 percent of net income on that particular property. Integrated oil companies are not allowed to use the percentage depletion deduction at all (Smalling, 2012).

greater deductions available to the petroleum industry in percentage depletion compared to cost depletion (U.S. General Accounting Office, 2000). In addition, cumulative depletion deductions may be greater than the amount expended by the taxpayer to acquire the property in the first place (JCT, 2012).

The president's 2014 budget proposal would repeal the percentage depletion deduction for fossil fuels but retain it for other mining (Treasury, 2013). All properties and firms engaged in fossil fuel extraction would use the cost depletion method instead (Treasury, 2013).

In isolation, percentage depletion is non-neutral. The percentages are chosen based on non-economic criteria such as the type of resource being extracted and eligibility varies depending on firm organizational form. Percentage depletion is also not directly linked to the cost of the actual capital invested. If this tax were revised to be neutral, is unclear what the optimal deprecation rate would be. But using the rate at which minerals are removed from the property as the deprecation rate (as cost depletion does) would at least ensure that full write off only occurs when all the minerals are removed from the property. So it appears to be a more neutral method than using percentage depletion.

However, including other taxes into the analysis increases the favorability of percentage depletion. In 2011, 35 of the 50 states imposed a severance tax on the extraction of natural resources (Telles, O'Sullivan, and Willhide, 2012). These taxes are usually imposed at a flat rate per unit of the commodity (per ton of coal, per barrel of oil, etc.) (Zelio and Houlihan, 2008). As shown in Table 2.2 of Section 2.3.1, aggregate revenue from these production taxes for oil and gas extraction averages $20 billion per year. Such taxes are distortionary because they reduce the marginal revenue of additional extraction compared to its marginal cost, causing early shutdown of otherwise still productive property. A percentage depletion allowance less than or equal to the severance tax rate would be efficiency enhancing by effectively canceling out part of the severance tax and thus increasing production.[14]

In addition, the percentage depletion deduction is repealed for fossil fuel extraction but not all resources. However the arguments for and against percentage depletion in fossil fuel extraction also apply to mining for other resources, which would retain their percentage depletion deduction under the proposal. By contrast, under a neutral tax system all forms of extraction

[14] Although using percentage depletion to cancel out these taxes would mean the original purpose of the depletion deduction, recovering capital costs incurred in acquiring the property, would not be served. Additionally, this means that federal tax law is being used to eliminate inefficiencies in state tax law. Although not relevant for determining tax neutrality, the appropriateness of such a use of federal law raises important political issues.

would have uniform depletion rules that do not vary based on the resource extracted.

This means that the repeal of percentage depletion has two effects. It increases the neutrality of the code because percentage depletion is itself distortionary. But it also reduces the neutrality of the code by eliminating a deduction that offsets other distortionary taxes and through favoring non-fossil fuel resource extraction over fossil fuel extraction. It is necessary to calculate the relative size of the two components in order to determine if the net effect is efficiency enhancing or reducing. Therefore the descriptive analysis conducted so far can not determine the neutrality of this provision.

2.2.5 Oil Spill Liability Trust Fund

Currently an excise tax of 8 cents per barrel is imposed on crude oil produced in the US and crude oil and petroleum products imported into the US.[15] This tax is scheduled to increase to 9 cents per barrel during 2017 and then expire in 2018. However, the excise tax has been repeatedly extended since its creation in 1990 and is assumed to be permanent for federal budget scorekeeping purposes (JCT, 2011).

The proceeds from this excise tax are deposited in the Oil Spill Liability Trust Fund, which is used to pay for various costs resulting from oil spills and their subsequent cleanup (Treasury, 2013). The fund pays for claims that are not covered by the responsible party, up to a $1 billion per incident limit and can reimburse the responsible party for some oil spill cleanup costs if the spill was not caused by negligence or violation of federal regulations.[16] The fund also pays for government oil spill prevention and response programs (Treasury, 2013).

For the purposes of this tax, "crude oil" does not include synthetic petroleum or unconventional crudes. This means that domestically produced shale oil, refined oil, and liquids from coal, tar sands, and biomass are not taxed (JCT, 2012). Refined oil is taxed if imported because it is included under "petroleum products" but imported tar sands are not (IRS, 2011).

The president's 2014 budget proposal increases the excise tax to 9 cents per barrel for 2014-2016 and to 10 cents per barrel for 2017 and onwards (Treasury, 2013). The tax would also be extended to apply to crudes that are produced from bituminous deposits and kerogen-rich rock, e.g. shale oil (Treasury, 2013).

[15] The excise tax rate is also called the financing rate.

[16] Responsible parties are reimbursed for cleanup costs over a fixed amount that depends on the size of the vessel or facility the spill occurred at. However, Woods (2008) notes that the standards used to prove that the responsible party was not negligent can make it difficult for responsible parties to receive this reimbursement.

In the case of smaller oil spills, strict civil liability for the full costs of the oil spill is optimal as it fully internalizes both the cost of the oil spill and the cost of prevention. The main argument for a trust fund is the case of catastrophic oil spills where the damages exceed the ability of the responsible party to pay. Previous literature has advocated two solutions to dealing with catastrophic oil spills: mandatory insurance and a prospective excess liability tax (Cohen et al., 2011; Viscusi and Zeckhauser, 2011). Under a prospective excess liability tax, responsible parties would still face full strict liability but a tax would also be imposed and the federal government would pay for any damages that exceed the value of the responsible party's assets. This tax's rate would need to be actuarially fair with respect to the probability the activity causes an accident that could not be covered by the responsible party's assets.

The excise tax used to fund the Oil Spill Liability Trust Fund is much closer to a prospective excess liability tax than mandatory insurance, so that is the comparison I will make to judge the neutrality of the tax. However, the trust fund's excise tax differs from a prospective excess liability tax in two ways: it does not have an actuarially fair rate and has only limited liability. And the president's proposal to increase the excise tax rate and extend it to other forms of oil production would make the difference even larger.

The Oil Spill Liability Trust Fund excise tax differs from a prospective excess liability tax take in a number of key areas. A prospective excess liability tax has an actuarially fair tax rate equal to the expected cost to the trust fund per barrel produced. However, there is no evidence the current rate of 8 cents per barrel or the president's proposed increase to 9 cents per barrel are based on the expected cost to the trust fund. And ideally, the rate would also vary with the level of safety taken by the firm, although the benefits of a more accurate rate need to be weighed against the difficulty of administrating such a tax. Additionally, extending the tax to include unconventional deposits is problematic. Taxing onshore and offshore oil production at the same rate is not actuarially fair if catastrophic onshore oil pollution has a lower cleanup cost or likelihood than offshore. This could easily be the case because spills from the extraction of crude from oil sands onshore (or in fact, any onshore oil extraction) are easier to repair structures for and bring responders to when compared with oil spills that occur offshore like the Deepwater Horizon (Macondo).[17]

In addition, it is worth noting that the purpose of the tax is to pay for catastrophic oil

[17] Although they do not calculate cleanup costs per barrel produced, comparison of onshore cleanup costs estimated by Connor et al. (2011) and offshore costs by Kontovas, Psaraftis, and Ventikos (2010) illustrate the markedly higher price of offshore cleanup.

spills that exceed the responsible party's ability to pay, not smaller oil spills for which the responsible party can pay. Thus a neutral tax rate would also need to take into account the lower rate of default for large firms with deep pockets by charging them a lower excise tax rate on oil production. The Deepwater Horizon oil spill cost BP $42.2 billion as of February 2013, far exceeding the Oil Spill Liability Trust fund's $1 billion cap (Fontevecchia, 2013). The probability that an oil spill would exceed the roughly $100 billion assets of a major integrated oil company like BP would be extremely small, and thus the actuarially fair tax rate would be similarly small (Abraham, 2011). This is one of the few places in the tax code where different tax treatment of small firms and major integrated oil companies can be justified.

Although firms would face full strict civil liability under a prospective excess liability tax regime, under current law liability is limited in two ways. First, total payouts by the trust fund are limited to $1 billion per incident. But with this cap, the trust fund could not fully cover the damages of the Deepwater Horizon oil spill if BP had defaulted. And second, the trust fund limits the liability of responsible parties for oil spill if they were not negligent and did not break federal regulation. This creates a moral hazard for firms to follow the minimum level of oil spill avoidance required by law, instead of the socially optimal level ensured by full strict civil liability.

2.2.6 Superfund Excise Taxes

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 established the Superfund program to clean up heavily polluted locations across the US. Following the act, the Environmental Protection Agency began maintaining a list of polluted sites called the National Priorities List. For 70 percent of the sites on the list, the EPA can locate one or more potentially responsible parties (PRPs) who pay for the site's cleanup. For the remaining 30 percent of sites, either the EPA cannot locate any PRPs or the PRPs cannot afford to pay for cleanup (Ramseur, Reisch, and McCarthy, 2008). Cleanup at these "orphaned" sites are paid out of the Hazardous Substance Superfund Trust Fund (Superfund). Since the expiration of three excise and one income tax which originally funded Superfund, it is now paid for out of general revenues.[18]

The president's 2014 budget proposal would reinstate all four Superfund taxes for the years

[18]See Probst et al. (1995) for more detail on the Superfund program in general and CBO (2011) for reform options.

2014 through 2023 (Treasury, 2013). Two of the excise taxes would not apply to the energy industry while the income tax would apply to all industries. The only tax of specific relevance to the energy industry is the remaining excise tax, a 9.7 cent per barrel excise tax on domestic crude and on imported petroleum products.

The key question is how polluted site cleanup should be funded. Currently it is paid for out of the general revenue. The proposal would instead use new excise taxes. But polluted site cleanup faces the same tax neutrality issues as oil spills. I therefore propose the same solutions discussed in detail under the Oil Spill Liability Trust Fund and for the same reasons. The law should impose full civil liability for small amounts of pollution. And it should either require firms to purchase excess liability insurance or impose an actuarially fair tax on activities with the possibility for catastrophic pollution that would exceed the firm's ability to pay. Thus cleanup would be funded either by insurance payouts or an actuarially fair tax.

However, the Superfund excise tax and Oil Spill Liability Trust Fund have similar problems concerning the actuarial fairness of the taxes. The Superfund excise tax is paid by all firms who produce or import petroleum and at the same rate regardless of the care taken by any firm to avoid polluting or the firm's risk of defaulting on cleanup costs. And it creates a moral hazard for small firms with a high risk of default which does not internalize the cost of pollution. Therefore, the Superfund excise tax is not actuarially fair.

However, Superfund is less problematic than the Oil Spill Liability Trust Fund in that the excise tax is only used to pay for orphaned sites. Under current law, if PRPs can be identified and are able to pay, then the PRPs pay for cleanup at the site. But the case of orphaned sites whose PRPs cannot be identified complicate the analysis. Knowing the reasons why PRPs cannot be identified in these cases is critical. If the inability to identify any PRPs would also prevent identification of their insurance, then an actuarially fair tax would be more efficient than requiring excess liability insurance.

2.2.7 Dual Capacity Rules

The US taxes domestic corporations on the income they earn in foreign countries. However, since the host country can also impose income taxes on the income of corporations earned in that country, this can lead to double taxation of that income. To avoid double taxation, the US tax code allows firms to credit certain foreign levies against their US tax liability. A foreign levy is creditable against the firm's US tax liability if it is compulsory and is not compensation by the firm to the host nation for a specific economic benefit.[19] A "dual-capacity taxpayer" is a taxpayer who is subject to a levy by a foreign country that also receives a specific economic benefit from that country.[20]

The tax code allows taxpayers to choose between two methods to determine the portion of the levy paid by the taxpayer that is compulsory and creditable, and the portion that is compensation for a specific economic benefit and deductible.[21] [22] Under the facts and circumstances method, a levy is creditable to the extent that the taxpayer is able to prove that portion of the levy is not paid as compensation for specific economic benefits.[23] Under the safe harbor method, if the host country has a generally imposed income tax, the taxpayer may credit an amount equal to the tax payment that would result from application of the host country's generally imposed income tax (JCT, 2012). In either case, the foreign tax credit is limited to a taxpayer's US tax liability on its foreign source income (JCT, 2012).[24]

The president's 2014 budget proposal would eliminate the current safe harbor and facts and circumstances methods for determining the fraction of a levy that is creditable (Treasury, 2013). Under the new rules, dual capacity taxpayers would be able to treat as creditable the portion of a foreign levy that does not exceed the foreign levy that the taxpayer would pay if it were not a dual-capacity taxpayer (Treasury, 2013). In effect, dual capacity companies would only be able to credit an amount equal to the host nation's general corporate tax rate applicable to other industries (Pirog, 2012). This is similar to simply forcing firms to choose the safe harbor method. In addition, the special limit for oil and gas income tax credits would be removed and it would instead be treated as its own separate limitation category (Treasury, 2013).

If US dual capacity firms operating outside the US are able to use creditable royalty payments to reduce their tax rate below that faced by other US based firms operating outside the US, who have to pay for economic benefits through deductible but not credible expenses, then removing these credits enhances the neutrality of the tax code. However, it is unclear that simply forcing all firms to credit taxes using the general corporate tax rate separates the taxes that are true

[19]Treasury Regulation section 1.901-2(a)(2)(i).
[20]Treasury Regulation section 1.901-2(a)(2)(ii)(A).
[21]Treasury Regulation section 1.901-2A(c).
[22]These rules were designed because of concerns that income taxes imposed on US oil companies by foreign governments were not income taxes but disguised royalties, which are normally deductible but not creditable (JCT, 2012).
[23]Treasury Regulation section 1.901-2A(c)(2)(i).
[24]JCT (2012) explains how two additional rules also apply. The credit is restricted by the category of income, generally referred to as "separate limitation category," so that tax credits from a particular category of income can only offset tax liabilities from that same category of income. In addition to the special limitation categories, credits from oil and gas income taxes may only offset oil and gas income tax liabilities.

income taxes from the taxes that are payments for economic benefits more accurately than the nuanced calculation allowed by the facts and circumstance rule. Indeed, to the extent that it is accurately applied, the facts and circumstances method seems ideal.

Distinct from possible differentials between sectors, another issue is whether foreign source income of US based firms should be taxed at all. There are two major systems states use for the taxation (or non-taxation) of foreign source income. Under a pure residence-based tax system, countries tax their residents (and domestic firms) on their worldwide income. Alternatively, under a territorial tax or source-based tax system, a country only taxes income that is earned within its borders.

Previous literature has not come to a consensus on which system is superior.[25] However, Gravelle (2009) notes that the US is only nominally a residence-based tax system. Under current law, firms only pay taxes on income that is repatriated back to the US and are allowed to defer repatriation indefinitely. This significantly reduces the US tax they pay on foreign source income. In this case, Gravelle (2009) states that a move towards either a more pure residence or territorial tax system would enhance the neutrality of the tax code. Exempting foreign source income entirely and moving to a territorial tax system would encourage the repatriation of income by reducing its tax rate. Alternatively, the tax code could move to a more effective residence system by ending deferral, which would encourage the repatriation of income and also increase the effective tax rate on foreign source income.

The budget uses neither of these methods. By reducing deductions, the effective tax rate on repatriated foreign source income increases but non-repatriated income remains untaxed. This increases the incentive to defer repatriation of foreign source income and decreases the neutrality of the tax code.

2.2.8 Geological and Geophysical Expense Amortization

Geological and geophysical (G&G) expenses are the costs incurred for acquiring data for minerals exploration and include expenditures on geologists, seismic surveys, gravity meter surveys, and magnetic surveys (JCT, 2012). Independent producers and small integrated oil companies may amortize and deduct these costs over two years. Major integrated oil companies are required to amortize the deduction of G&G costs over seven years.

[25] Kleinbard (2007) and Gravelle (2012) advocate residence-based taxation. Desai and Hines (2004) argues in favor of territorial-based taxation. CBO (2013) reviews different policy options.

The president's 2014 budget proposal would increase the amortization period for independent producers and small integrated oil companies from two years to the same seven years as major integrated oil companies (Treasury, 2013). Major integrated oil companies would be unaffected.

Under a neutral tax system, statutory G&G depreciation would equal economic depreciation and be the same for all firms regardless of organizational form. So it is appropriate that the president's proposal is to treat independent producers, small integrated oil companies, and large integrated oil companies equally. Bureau of Economic Analysis (2003), hereafter BEA, calculates the geometric economic depreciation rate for petroleum and natural gas mining exploration, shafts, and wells at 0.0751 and lists a service life of 12 years.[26] So the increase in the amortization period for independent producers and small integrated oil companies would move their tax depreciation treatment closer to both economic depreciation and eliminate the difference in tax treatment due to firm organizational form. This change is thus neutrality enhancing.

2.2.9 Capital Gains Treatment of Coal Royalties

While in general royalties are taxed as ordinary income, royalty income from the sale of coal mined in the US and held for at least one year can be taxed instead as long-term capital gains (JCT, 2012). The president's 2014 budget proposal would repeal the capital gains treatment of gains from coal royalties under these circumstances (Treasury, 2013).

There are a variety of considerations that must be taken in dealing with the taxation of ordinary income versus capital gains in a neutral tax system to ensure that income invested and then earned again in a subsequent period is not double taxed. However, in this case these concerns can be safely sidestepped by focusing on the coal itself. Coal and coal royalties are not assets like property or stocks but inventories. Income from the sale of inventories is typically treated as ordinary income, not capital gains. This provision is thus neutrality enhancing.[27]

[26] A summary of the BEA depreciation table as it is relevant to the energy industry is available in Table A1 in the Appendix of Metcalf (2009).

[27] Although it brings coal in line with the current law treatment of other inventories, the budget proposal does still deviate somewhat from a neutral system, which would allow inflationary gains to be deducted from income. This point is explained in greater detail in Section 2.2.1.

2.2.10 Expensing of Coal Exploration

Exploration is the process of determining if there are sufficient minerals in an area to justify mining. Under current law, taxpayers may elect to expense (immediately deduct) exploration costs in all types of mining, not just coal. Unlike other organizational forms of firms, corporations may only expense 70 percent of the exploration expenses and must amortize over a 60-month period the remaining 30 percent (Treasury, 2013). This deduction is subject to recapture by disallowing percentage depletion deduction on the property for which exploration costs were expensed until "adjusted exploration expenditures" are re-included in income (JCT, 2012).[28]

The president's 2014 budget proposal would repeal the option to expense and amortize over 60-months exploration and development costs for coal (including lignite) and certain types of oil shale (Treasury, 2013). The costs would instead be capitalized and recovered through depreciation or depletion deductions, as appropriate (Treasury, 2013). Other forms of mining would retain the option to expense and amortize exploration costs.

Under a neutral tax system, a taxpayer would be allowed to deduct capital costs based on the economic rate of depreciation. Exploration costs for a mine that is found to have insufficient quantity or quality of ore to justify mining should be immediately expensed since they will provide no future benefit. However, for a productive mine, they should be deducted at their economic depreciation rate. As was stated before, BEA (2003) calculates the geometric economic depreciation rate for petroleum and natural gas mining exploration, shafts, and wells at 0.0751 and a service life of 12 years, a longer lifetime than the 60-month amortization allowed now. Retaining the deduction for other forms of mining would make the tax system less neutral in regards to which type of mining to invest in but would make the system more neutral for the choice of what type of capital to employ in coal mining.

2.3 Current Law Tax Rates

The provisions and their neutrality are only truly relevant through their effect on the entire tax system. Therefore, the individual tax changes proposed by President Obama need to be considered in the context of the existing taxes and subsidies faced by fossil fuel producers. Trea-

[28] Adjusted exploration expenditures are the amounts for which the taxpayer claimed an exploration deduction that would have been included in the basis of the property reduced by the excess of the percentage depletion over the depletion allowable had the expenses been capitalized instead (JCT, 2012).

sury (2013) has stated that tax preferences encourage more investment in fossil fuel production than would occur under a neutral tax system. Nonetheless, research in recent years on the tax rates faced by the energy sector have displayed mixed results.

However, both previous research and the president's budget have focused on firm level capital taxes. Yet in addition to these capital taxes, production taxes (e.g. severance, excise, and property taxes) are also imposed on the extraction and refining of fossil fuels. These production taxes on fossil fuels are a larger source of revenue than corporate income taxes, but have received comparatively little attention.

In this section, I review the taxes and tax rates facing consumers, producers, capital, and labor involved with fossil fuels and compare them to those faced by the economy as a whole. I examine the issues raised by the Obama administration regarding firm capital taxes, but I also include other agents (e.g. labor and consumers) and other taxes (e.g. severance, excise, and property). I review previous work on estimating the effective rate imposed by these taxes on fossil fuel producing sectors and how their rates compare to those of the rest of the economy. I then calculate additional effective tax rates of my own that include both firm production and capital taxes.

However, there are multiple methods to measure effective tax rates. Upon reviewing the effective tax rate measures that have been used by the literature, I find that although the marginal effective tax rate (METR) measure is the gold standard, the less used average effective tax rate (AETR) method is more appropriate in this circumstance.[29] I then calculate effective tax rates for the sector using the AETR methodology.

2.3.1 Background

The main taxes imposed on capital income are state and federal corporate income taxes and personal income taxes on capital gains and dividends. The effect of these taxes on the pre-tax and post-tax rates of return can be summarized through the marginal effective tax rate (METR) on investment. The marginal effective tax rate on investment is the rate by which capital taxes reduce the pre-tax rate of return on investment. For example, if the marginal investment in a new oil well earned a pre-tax 12 percent return but taxes reduce that return to 9 percent, the marginal effective tax rate would be (12-9)/12 = 25 percent. An effective tax rate differs from the statutory tax rate in that it applies to the income earned over the lifetime

[29]The average effective tax rate is also known simply as the average tax rate.

of an investment and is able to account for the effects of inflation, the difference between tax and economic depreciation, and the difference in the taxation of returns to debt and equity.

The marginal investment is the investment that earns a rate of return exactly equal to the cost of capital. The marginal investment is the critical one for determining the aggregate level of investment because a firm will invest in all investments opportunities with higher post-tax rates of return than the breakeven rate and not invest in any with lower. Reducing the rate of return of an investment that is currently at the breakeven rate would cause the firm to no longer undertake the project and thus reduce aggregate investment.

The literature has produced many estimates of the marginal tax rate for different types of capital assets in CBO (2005), Mackie (2002), Ernst & Young (2007), and Metcalf (2009). However, there is large variation between estimated rates and no consensus on whether fossil fuel production is more or less taxed than other sectors.

CBO (2005) calculates the METR from federal taxes for a wide variety of very broad asset categories.[30] They find the overall METR on capital assets from all businesses is 24.2 percent and the METR on corporations is 26.3 percent. But the METRs for C corporation assets in the fossil fuel industry vary from 9.2 to 24.9 percent.[31] However, note that these results are for particular assets used only by energy industries, not the industry as a whole.

Mackie (2002) also calculates METRs for assets but then aggregates them over industries as well. He finds a high METR on energy assets such as mining and oil field machinery (33.5 percent) and a lower METR on mining, shafts, and wells (16.9 percent). When aggregated at the industry level, crude petroleum and gas has an METR of 24.6 percent while petroleum refining's METR is 35.6. By comparison, the METR for the corporate sector is on average 32.2 and the METR for the entire economy is 19.8 percent.

Other papers have calculated the METR for the energy sector but did not include estimates for other sectors. Ernst & Young (2007) looks at the energy sector specifically but only includes the federal corporate income tax in their calculation. They find a 21.6 percent METR for petroleum refining, which is much lower than that of Mackie (2002). Metcalf (2009) provides another calculation of the METR of assets used in fossil fuel production. Metcalf's calculation includes some tax credits, but the only taxes included are the federal corporate income tax and

[30]The taxes included in the CBO analysis are federal taxes on corporate profits, dividends, long-term capital gains, short-term capital gains, interest income, mortgage interest deductions, unincorporated business income, and distributions from non-qualified annuities. See CBO (2005) Table A-4 for more details.

[31]C corporations are corporations that are taxed separately from their owners. The corporate income tax applies solely to C corporations.

the average state corporate income tax. His results show significant variation in the METR faced by different capital assets in the energy sector, with METRs ranging from a high of 27.0 percent for other natural gas pipelines to a low of -13.5 percent for oil drilling by non-integrated firms. However, his METRs for oil drilling by integrated firms, petroleum refining, and natural gas gathering pipelines are all in the range of 15.2 to 19.1 percent. These papers provide some perspective but are less helpful in determining the relative tax burdens of fossil fuel production and other sectors since they do not present comparable economy-wide average METRs using the same methodology.

However, capital taxes are not the only taxes that apply to producers of fossil fuels. Fossil fuel production also faces a large number of other taxes such as sales, property, severance, and excise taxes. As seen in Table 2.2, total payments for these taxes, less subsidies, by fossil fuel producing sectors exceed payments for corporate income taxes.[32] However, to the best of my knowledge, these taxes have not been combined and summarized, either with each other or with capital taxes, the way the METR literature has done for taxes on capital investment.

I utilize average effective tax rates (AETRs), as opposed to marginal effective tax rates (METRs), in order to aggregate the effects of these taxes. Collins and Shackelford (1995) and Fullerton (1984) discuss each measure and their advantages and disadvantages. METR calculations are designed to measure the tax cost on marginal incentives to hire labor or employ capital. However, they are calculated formulaically using the net present value of income, tax credits, and tax deductions. Because of this they require numerous assumptions about firm financing, asset purchase decisions, and depreciation (Collins and Shackelford, 1995).[33] In addition, the calculation must explicitly choose which provisions of the tax code (i.e., which deductions and tax credits) to include and how to model them. As a practical matter, this will cause METRs to miss the cumulative effect of numerous small or difficult to model features that are not included.

AETRs are calculating empirically by dividing taxes paid by the base of economy activity taxed. Because it is calculated from actual tax payments, it avoids the problems METR calculations face of having to make numerous assumptions and being forced to pick and choose the features of the tax code to include. However, the AETR measures the average tax rates on all investments as opposed to finding the tax rate on the marginal investment. It thus reflects the

[32]Both corporate income tax statistics and the other production tax statistics include all such taxes at the federal, state, and local levels.

[33]See CBO (2006) for a more detailed description of the general method used to calculate METRs.

total burden of taxation instead of marginal incentives (Collins and Shackelford, 1995).[34]

Table 2.2: Total Tax Payments by Industry for 1998-2009 ($ millions, 2008)

Sector	Corporate Income Taxes	Other Production Taxes
Oil and Gas Extraction	42,715	227,965
Petroleum and Coal Products Manufacturing	213,416	29,153
Pipeline Transportation	4,249	20,723
Fossil Fuel Production[1]	260,381	277,842
All Sectors	4,107,379	11,075,086

Source: Author's calculation from BEA US Input-Output Accounts and NIPA Table 6.18D.
Notes: (1) Fossil fuel production is defined as oil and gas extraction, petroleum and coal products manufacturing, and pipeline transportation.

2.3.2 Methodology

In this analysis, I calculate tax rates using the AETR method. I do so because the information required to credibly calculate METRs simply does not exist for two critical areas: the types of capital whose tax treatment are changing in the budget and the production taxes such as excise, severance, and sales taxes. But a problem which remains in the AETR method is the distribution of the tax burden. If producers are able to forward shift the burden onto consumers, then tax payments should be divided by total consumer payments, the total value of output. Alternatively, if a tax would be backwards shifted onto labor or capital, payments to those factors are the base that should be used. But who bears the burden of a tax cannot be answered without using a general equilibrium model. So I leave that analysis to Chapter 3 and here present results under both assumptions, one using the total value of output assuming full forward shifting, and one using total factor payments assuming full backwards shifting.

My two main data sources are the Use of Commodities by Industries after Redefinitions tables for 1998-2009 in the US Input-Output accounts from the Bureau of Economic Analysis (BEA) and two tables from the National Income and Product Accounts (NIPA), also by the BEA.[35] I use table 3.4ES: Current-Cost Depreciation of Private Fixed Assets by Industry and table 6.18D: Taxes on Corporate Income by Industry. The average effective tax rate for a selection of energy sectors and the whole economy is calculated by dividing total tax payments

[34]The AETR method is certainly not without its own drawbacks. See Fullerton (1984) for a discussion of the problems of AETRs.

[35]In an alternative specification, I instead use corporate income tax data from the Internal Revenue Service Statistics of Income Tax Stats on the Returns of Active Corporations by Minor Industry. These results show a smaller difference between all industries and the selected fossil fuel producers, but still indicate a lower tax rate for other industries than fossil fuels. However, this data set does not include state and local income taxes and has one less year of data. Full results are available upon request.

by both the value of output and factor payments. The average effective tax rate on firm capital for those same sectors is calculated by dividing corporate income tax payments by sector capital income.

There are a number of important definitions and assumptions related to the calculation of AETRs. Total tax payment equals taxes on production and imports plus state, local, and federal corporate income taxes minus subsidies.[36] Taxes on production and imports include taxes on the product delivery or the sale of products and taxes on the ownership of assets used in production, such as federal excise, state and local sales taxes, and local real estate taxes. Corporate income taxes include those taxes at the federal, state, and local level. Factor payments are equal to net operating surplus plus compensation of employees, plus taxes on production and imports, less subsidies. Due to data limitations, capital taxes include firm level taxes but do not include individual level capital income taxation such as that on capital gains, dividends, or income from pass-through entities.

2.3.3 Results

Table 2.3 presents AETRs on capital for firms in selected sectors averaged over the years 1998-2009. Firm capital tax rates for oil and gas extraction and pipeline transportation are lower than the economy average but much higher for petroleum and coal products manufacturing. Firm capital AETRs for fossil fuel production as a whole are higher than those of other sectors because petroleum and coal products manufacturing has more capital and faces higher tax rates than the other fossil fuel producing sectors.

Table 2.3: Firm Average Effective Tax Rates on Capital from Corporate Income Taxes by Sector for 1998-2009 (Percent)

Sector	Capital AETR
Oil and Gas Extraction	4.5
Petroleum and Coal Products Manufacturing	21.1
Pipeline Transportation	6.1
Fossil Fuel Production	12.8
All Sectors	7.5

Source: Author's calculation from BEA US Input-Output Accounts and NIPA Tables 3.4ES and 6.18D.

Table 2.4 presents AETRs of all taxes for energy and other sectors averaged over the years

[36]Taxes on production and imports, subsidies, net operating surplus, and compensation of employees are defined in `http://www.bea.gov/national/pdf/chapters1-4.pdf` pages 2-8 to 2-9. Corporate income tax is defined in `http://www.bea.gov/scb/pdf/naTIOnaL/NIPA/Methpap/methpap2.pdf` on page 3.

1998-2009. This table includes all firm level taxes, i.e. not just capital taxes but production taxes as well. Since these taxes could be forward shifted onto consumers or backwards shifted onto factors, or somewhere in between, I calculate AETRs under both assumptions. The factor income base assumes full backward shifting onto factors and divides total firm taxes paid by labor and capital income. The value of output base assumes full forward shifting onto consumers and divides total firm taxes paid by the value of output.

As before, AETRs for fossil fuel production are higher than those of other sectors on both a factor income base and a value of output base. Additionally, this result obtains not just for fossil fuel production as a whole, but the fossil fuel producing subsectors individually as well. With the exception of petroleum and coal products manufacturing on a value of output base, AETRs are higher for all fossil fuel producing firms than the economy as a whole.

Table 2.4: Average Effective Tax Rates of All Firm Taxes by Sector for 1998-2009 (Percent)

Sector	Factor Income Base	Value of Output Base
Oil and Gas Extraction	19.3	12.1
Petroleum and Coal Products Manufacturing	20.0	5.2
Pipeline Transportation	16.7	7.5
Fossil Fuel Production	19.5	7.4
All Sectors	10.8	5.9

Source: Author's calculation from BEA US Input-Output Accounts and NIPA Tables 3.4ES and 6.18D.

This analysis shows that the AETR on fossil fuels producing firms is higher than the AETR for firms in other sectors under all three specifications.[37] So for this measure of taxation, fossil fuel production is more heavily, not less, taxed than other sectors.

However, it needs to be emphasized that this is a single measure of taxation and not a full account of all ways in which fossil fuel production could be favored. For example, the income and taxes used in the AETR calculation do not only come from corporations. But the proposed tax changes deal primarily with corporations. This analysis does not rule out the possibility that corporate form firms are less taxed than other sectors, while non-corporate firms and the average fossil fuel firm is more taxed. In addition, although the AETR includes all firm level taxes, some firms, (e.g., sole proprietorships and partnerships) actually have their income taxed at the personal level. These tax payments are not included in this measure of AETR.

[37]Appendix C investigates if these results are driven by a particular industry or year but concludes that they are not.

2.4 Conclusions

President Obama has proposed raising taxes on fossil fuel production in order to make the tax code more neutral. In this chapter, I examine evidence for this claim both in the proposed tax changes and in current law average tax rates. Descriptive analysis of the budget proposal's provisions shows that the effects of the proposal on tax neutrality are mixed. Some provisions move the tax code towards neutrality, while others move it away, but the effects of most provisions are unclear. In addition, previous studies calculating marginal effective tax rates on capital employed in fossil fuel production have produced contradictory results. However, I discovered that the average effective tax rate on capital for fossil fuel producing firms is 5.3 percentage points higher than the economy-wide rate. Moreover, when taxes on production are included, current law firm level taxes on fossil fuel production are 1.5 to 8.7 percentage points higher than the economy-wide rate. This particular evidence does not support the claim that the current tax code favors fossil fuel production or that the the budget proposal makes the tax code more neutral.

Chapter 3

A New Model of Energy Taxation

3.1 Introduction

Current models in the energy taxation literature fall into two general categories. The first takes a partial equilibrium (PE) approach that models energy resource development in great detail but has a highly simplified representation of the rest of the economy. The second uses a computable general equilibrium (CGE) approach that models many production sectors in the economy but has little detail on the differences between energy extraction and other sectors. This paper builds a general equilibrium model with the most important features of both approaches: my model has endogenous supply of the energy resource in a general equilibrium model that allows for flexible substitution by firms across inputs and by consumers across goods. My model allows a comprehensive analysis of the three primary areas in which energy taxes may create or reduce inefficiencies: production and consumption, resource rents, and externalities.

First, energy taxes can cause production and consumption inefficiencies because they violate the principle of tax neutrality, which states that taxes should not distort choices between economic activities.[1] If tax rates differ between different goods, firms and consumers who use these goods will substitute to use less of the more taxed good and more of the less taxed good. Substitution will minimize the firm or consumer's post-tax private costs but will increase their pre-tax or social costs. This leads to productive and consumptive inefficiency.

Because energy taxes create inefficiencies via substitution, accurate modeling of input and consumer substitution is critical for understanding the effects of energy taxation. Nevertheless,

[1] The principle of tax neutrality requires that no externalities exist. However, since there are many externalities to fossil fuel consumption, I must also consider the effect of externalities when determining the efficiency of energy taxes.

almost all partial equilibrium models assume exogenous energy prices and therefore cannot include any of these three efficiency effects (Lund, 2009). But the treatment of energy taxes in most CGE (computable general equilibrium) models is also problematical. CGE models such as Zodrow and Diamond (2013) that utilize constant elasticity of substitution (CES) or Cobb-Douglas functions for consumer expenditure constrain the substitutability between all goods to be the same (Uzawa, 1962).[2] By comparison, Altig et al. (2001), Fullerton and Rogers (1993), and other models with fixed coefficients do not allow consumer substitution at all. Moreover, these papers' firm production functions also have the same problems because those functions are CES, Cobb-Douglas, or fixed coefficient as well. Limiting the possibilities for input substitution will overestimate the impact of energy taxes on firm costs. Therefore neither PE nor CGE models accurately model substitution. Jorgenson and Yun (2001) is a notable exception that informed my model. Jorgenson and Yun (2001) and my model both use a highly flexible translog functional form for the firm cost functions (and consumer expenditure function) that allows varying degrees of substitutability between different pairs of inputs (consumer goods).[3]

The second source of energy tax inefficiency is the tax treatment of resource rents. If the energy resources (i.e., the coal, oil, or gas in the ground) have perfectly inelastic supply, then their factor payments would be economic rents and taxing them would be non-distortionary. In such a case, non-distortionary resource rent taxes would be more efficient than distortionary taxes on other sectors. In order to determine if rents exist, a model must determine whether changes in energy taxation affect the supply of energy resources. The partial equilibrium literature contains many such models of energy supply. For example, the PE approach developed initially by Hotelling (1931) is commonly used to model the decision to develop and extract energy resources. Dasgupta, Heal, and Stiglitz (1981) extended the Hotelling (1931) framework to show how taxation affects resource extraction. Some stylized general equilibrium models, such as Solow and Wan (1976), have featured similar resource modeling. However, firm resource supply decisions are usually much simpler in CGE models than in PE models, if resource supply is modeled at all in the CGE model. Some CGE models have exogenous supply of the resource that is invariant to price (Babiker et al., 2008; Paltsev et al., 2005). Other CGE models do not include an energy resource at all (Altig et al., 2001; Fullerton and Rogers, 1993; Jorgenson

[2]Nested CES can be used to add some flexibility. However, this is typically used only at the top level with fixed coefficient functional forms at lower levels. Substitution remains inflexible for any inputs which are not nested and the resulting substitutability is not invariant to the nesting structure (Sato, 1967).

[3]See Section 3.3.3 for a detailed description of the translog cost function.

and Yun, 2001; Zodrow and Diamond, 2013). By contrast, my model is a CGE model and yet includes endogenous energy resource supply. By varying the own price elasticity of energy resource supply, my model can determine the impact of the taxation of resource rents on the efficiency of energy taxes.

The third way that energy taxes lead to economic inefficiency is the treatment of externalities. Fossil fuels are associated with externalities relating to air pollution, climate change, and energy security. By definition, externalities are not internalized in the private costs borne by the producers and consumers of a good that creates an externality. Pigouvian taxes on externalities can internalize the social costs they create, leading market participants to choose the socially optimal level of the activity. Of the models listed so far, only Paltsev et al. (2005) and Babiker et al. (2008) incorporate these externalities. My model does as well by including disutility from fossil fuel externalities in the utility function.

In this chapter, I construct a CGE model of US energy taxation that includes all three sources of tax inefficiency. My model contains a number of features that allow it to capture each of the three issues. In order to accurately model both consumer substitution across goods and producer substitution across inputs, I utilize a highly disaggregated cost and expenditure functions with transcendental logarithmic (translog) functional forms. There are 22 production sectors, with each producing a single output using capital, labor, and all of the 22 outputs as inputs. These outputs are also all used for the final consumer goods. The translog form allows for varying degrees of substitutability between inputs (capital, labor, energy, and other goods) in the production and consumption of each good.

Because the cost and expenditure function parameters are so critical to the model, I take several steps to ensure that they are accurate. The parameter values are estimated from five decades of data using regression analysis, not calibrated, so that my results are not driven by the idiosyncrasies of the specific year used for calibration. I perform a number of statistical tests on the data to confirm that the regression specification is appropriate. Moreover, I ensure the parameter values make economic sense by testing for the concavity and monotonicity of the ensuing cost function. To investigate the sensitivity of model efficiency estimates to these parameters, I also calculate efficiency estimates using a number of alternate specifications and perform Monte Carlo analysis to calculate confidence intervals for the model's predictions.

As previously discussed, energy production in the model requires energy resources. The model assumes a constant elasticity of supply of energy resources. This elasticity of supply can be varied to change the responsiveness of the energy resource to changes in rents. I vary this supply elasticity from 0.1, where resource supply is relatively unresponsive to changes in rents, to 1.0, where the energy resource is more responsive to own price changes than capital is. And finally, negative externalities from fossil fuel production are included in the utility function.

Beyond these innovations for improved modeling of energy taxation, my CGE model follows the existing CGE literature. All goods and inputs are supplied endogenously. The aggregate demand for exports and supply functions for capital and labor are assumed to be isoelastic, which facilitates the use of parameter values found in previous empirical research.[4] The ratio of imports to domestic production is determined by their relative prices through a constant elasticity of substitution cost function. Existing government taxes on capital, labor, and production are modeled explicitly.

Once my model is constructed, I assess it by analyzing energy tax changes in President Obama's fiscal year 2014 budget proposal. Supporters state that president's budget will make the tax code more neutral by eliminating tax preferences for fossil fuel production. However, thus far the only analysis of these changes are descriptive judgments based on principles of neutral taxation. I use my model to estimate the actual economic effects of the proposal, which were previously unknown.

The organization of this chapter is as follows: in Section 3.2, I review previous literature on modeling energy policy with an emphasis on differences between the literature and my model. In section 3.3, I present the details of my general equilibrium model: the equations used to define the supply and demand of commodities, the data used to parametrize these equations, and other assumptions. Then in Section 3.4, I use the model to estimate the effects of the president's budget proposal. Section 3.5 summarizes my findings on both the effects of the budget proposal and the importance of the features combined in my model.

3.2 Literature Review

There are two general classes of models in the energy taxation literature: partial equilibrium (PE) and computable general equilibrium (CGE) models.[5] PE models focus on resource supply decisions by firms and take a large number of different approaches. These approaches include neoclassical (Dasgupta, Heal, and Stiglitz, 1981; Hotelling, 1931), contingent claims (Blake and

[4]An isoelastic function has the form $f(x) = kx^r$ and has elasticity r.

[5]See Lund (2009) or Smith (2012) for comprehensive reviews of the literature on modeling energy taxation.

Roberts, 2006; Lund, 1992), scenario (Hogan and Goldsworthy, 2010; Kemp, 1987), decline curve (Peaceman, 1977), and reservoir simulation models (Adelman, 1973).

Although the different methods are able to examine many issues far better than the model developed in this paper, the critical issue for energy tax modeling is that these methods determine an elasticity of energy resource supply. It is this elasticity which determines the existence of resource rents, and thus makes taxing the income earned by resources less distortionary than other sources of revenue. The model in this paper contains such an elasticity parameter and therefore can determine the impact of a given level of resource rents. Despite their advantages, PE models are, by construction, unable to capture the effects of resource taxes on the entire economy. However, these deficiencies are not shared by the second approach, CGE models of energy taxation.[6]

Although broadly similar to each other, CGE models differ in their treatment of key details. Paltsev et al. (2005) and Babiker et al. (2008) examined climate change policies using CGE models with an exogenously supplied energy resource. And although Goulder and Hafstead (2013) does not explicitly feature an energy resource, in that model total factor productivity for fossil fuel extraction decreases with cumulative extraction. These specifications are able to address intertemporal issues. However, because the resource is exogenously supplied or only interacts with total factor productivity, these models are not able to consider the impact of economic rents for the energy resource. By contrast, Jorgenson and Yun (2001) and Wilcoxen (1988) have no energy resource at all, but these models do have flexible substitution. They feature translog producer cost functions and consumer expenditure functions whose parameters are estimated with regression analysis.

The model I construct combines the advantages of the CGE and PE literatures. Specifically, input substitution is modeled following Jorgenson and Yun (2001) and Wilcoxen (1988) but with an energy resource component broadly similar to that of Babiker et al. (2008). However, the energy resource in my model is not exogenously supplied; it instead has a simple constant elasticity supply function that reflects a reduced form representation of the effects analyzed in the partial equilibrium literature.

[6] A rich literature of non-energy focused CGE models exists but they are typically designed to model fundamental tax reform and thus lack any details unique to the energy sector (Altig et al., 2001; Fullerton and Rogers, 1993; Zodrow and Diamond, 2013).

3.3 Model Description

3.3.1 Model Overview

Overall, the model is a 22 sector steady-state CGE model of the US economy. The model features flexible substitution across both production inputs and consumer goods and also endogenous resource supply. These features combine the advantages of the CGE and PE methods of energy tax analysis and allows the model to incorporate the three main efficiency effects of energy taxation. In this section, I summarize the most important features of the model including the baseline parameter values, the translog cost and expenditure functions, and the modeling of taxation. The remaining details are presented in Appendixes A and B.

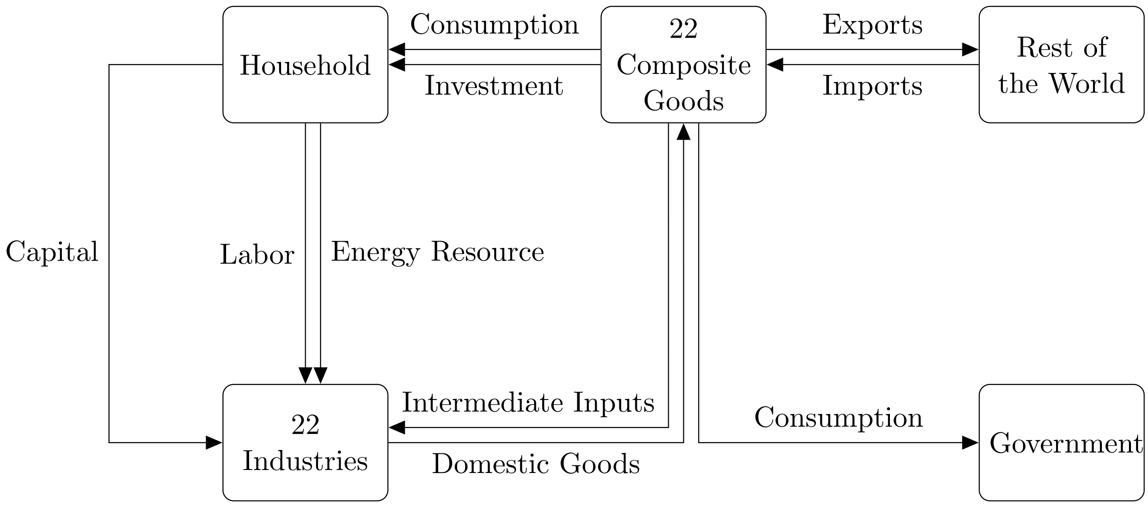
In the model, the cost function for an industry (e.g., manufacturing, health care, and oil and gas extraction) relates the cost of producing the industry's output to the cost of the industry's inputs. These inputs are capital, labor, and all the outputs of the industry cost functions. The model utilizes a translog cost function for each industry, following Jorgenson and Yun (2001) and Wilcoxen (1988). Although the functional form of the translog cost function is quite complex, its key features can be described simply: it allows different degrees of substitution between all inputs and it also also technological progress to change total factor productivity and the relative importance of particular inputs over time. Moreover, the parameters of the cost function are estimated separately for each of the 22 industries and for households. All industries are assumed to be perfectly competitive with constant returns to scale, which allows the determination of output price from firm costs.

The relationships between the various parts of the model are summarized in Figure 3.1. Purchases of goods are made by a government sector, a representative household, the industries, and the rest of the world through imports and exports. Exports are also isoelastically demanded. Conversely, the demand for imports is determined by a constant elasticity of substitution cost or expenditure function between domestic and imported inputs.

Standard assumptions are made for the supply of capital and labor and the demand for goods. Capital, labor, and the energy resource are assumed to be perfectly mobile between sectors and in the aggregate have isoelastic supply functions. There are no supplier price differentials across sectors for capital or the energy resource but, following Wilcoxen (1988), post-tax wage differentials across sectors are fixed at the ratios that occur in the data.[7]

[7]Note that this assumption is made implicitly in any model that aggregates all workers into a single type of labor.

Figure 3.1: The Model's Commodity Flows



I perform a series of regressions to estimate the values of the parameters that define the cost functions. Regression estimation of cost function parameters has important advantages over calibrating the model to values taken from a single year. In particular, calibrated parameter values are sensitive to the idiosyncratic conditions of the year of calibration. By contrast, my regression parameters are determined from five decades of data. However, endogeneity is an issue for the regressions since prices, a right hand side variable, are dependent on cost shares, a left hand side variable. Additionally, since the cost shares of all the inputs must sum to one, the error terms of the regressions are correlated. Both of these problems are solved by performing the regressions using iterated three-stage least squares.

The data used in this regression and subsequent model simulations come from several sources. The first is a system of US national accounts covering the years 1960 to 2005 compiled by Jorgenson (2007). These data include the quantity and price of output produced by all industries and all inputs purchased by all industries. Additional data come from the BEA (Bureau of Economic Analysis) Tables of the Use of Commodities by Industries for 1997-2010 and the BEA Gross Output Price Index for 1987-2010. The older Jorgenson (2007) data are converted to the same industrial classification system as the BEA data using the 1997 Economic Census's Bridge between NAICS (North American Industrial Classification System) and SIC (Standard Industrial Classification).

In order to determine the economic effects of the president's budget proposal, I compare two tax regimes. The first is current law, which includes a tax on capital, a tax on labor, a tax on energy reserves, and production taxes on output. In the second tax regime, the energy

Table 3.1: Selected Parameters and their Values in the Baseline Specification

Symbol	Definition	Value	Source
$\theta_{capital}$	Elasticity of capital supply with respect to capital rental rate	0.5	Gunning, Diamond, and Zodrow (2008)
θ_{labor}	Elasticity of labor supply with respect to wage rate	0.2	McClelland and Mok (2012)
$\theta_{resources}$	Elasticity of resource supply with respect to resource price	0.5	See Section 3.3.2
θ_{Arm}	Armington elasticity of substitution between domestic and imported fossil fuels[1]	23	Balistreri, Al-Qahtani, and Dahl (2010)
θ_{Arm}	Armington elasticity of substitution between domestic and imported goods for goods other than fossil fuels[1]	4	Rutherford and Paltsev (2000)
θ_{export}	Own price elasticity of export demand	-1	Senhadji and Montenegro (1999)
θ_{r}	Elasticity of substitution between resource and KLEM	4	See Section 3.3.2
$\tau_{capital}$	Effective tax rate on capital	Varies	See Section 3.3.4
τ_{labor}	Effective tax rate on labor	0.316	CBO (2005)
$\tau_{resources}$	Effective tax rate on energy resource	Varies	See Section 3.3.4
$\tau_{production}$	Effective tax rate on production	Varies	See Section 3.3.4

Notes: (1) Fossil fuel producing sectors are oil and gas extraction, petroleum and coal products manufacturing, and pipeline transportation.

portions of the president's fiscal year 2014 budget proposal are implemented, raising tax rates on fossil fuel producers. In addition, capital tax rates are lowered uniformly on all sectors under the second regime. The rate of this capital tax decrease is chosen in order to make the budget proposal regime revenue neutral with current law.

3.3.2 Model Parameters

The values used for the model parameters have one of three sources: regression analysis, previous literature, or raw data. The cost and expenditure function parameters are estimated by a series of regressions. These regressions are described in Section 3.3.3 and the parameter values they generate are listed in Appendix D. By contrast, literature and data parameters are taken from scholarly literature or my estimates from raw data, respectively. These literature or data parameters and their sources are described in this section. Table 3.1 lists the elasticity and tax parameters that define the responsiveness of capital, labor, resources, imports, and exports to price changes.

A few of the parameters in Table 3.1 need additional explanation. The first is the Armington elasticity of substitution. I assume a world market for energy products exists because previous literature has found high substitutability of imported and domestic fossil fuels (Balistreri, Al-Qahtani, and Dahl, 2010). Therefore, the model uses a higher Armington elasticity of substitution for fossil fuel production than for other sectors.

The second parameter of note is the elasticity of substitution between KLEM output and the energy resource. This parameter that has not been estimated in the literature. I use as a baseline the value 4, which equals the Armington elasticity of substitution for the cost equation that nests it. However, because of the uncertainty in this parameter's value, I conduct a sensitivity test using an alternative value for this parameter in Section 3.4.

The third noteworthy parameter is the elasticity of energy resource supply. Varying this elasticity determines the responsiveness of resource supply to changes in economic rents. A value of zero indicates that changes in rents do not affect resource supply. A value of 0.5 is the same as the elasticity for capital, and indicates that the resource has the same responsiveness to changes in rents as capital does to changes in price. Mohn (2010) estimates a price elasticity of over 0.9 for oil supply so a high value of 1.0 is used. In the sensitivity analysis, this parameter is varied from 0.1 to 1.0 to examine the importance of resource rents.

3.3.3 Firm Cost and Consumer Expenditure Functions

Functional Forms

This section details the firm cost and consumer expenditure functions that are the source of the model's flexible substitution. Both consumer expenditure and firm cost functions have the same general form, so only firm costs function will be mentioned in areas where they are the same and any differences will be explicitly pointed out.

In the model, there is not just one single cost function for an entire industry but, following Jorgenson and Yun (2001) and Wilcoxen (1988), production is in each industry characterized by a series of nested cost functions, each with the translog form.[8] The tier structure used to nest the cost functions for each industry is shown in the tree in Figure 3.2.

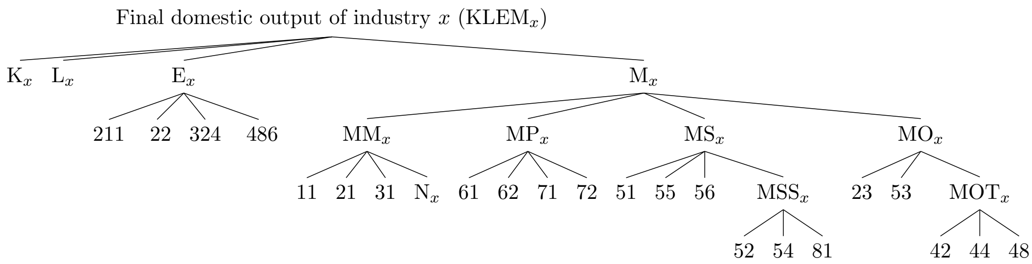
An aggregate output and its components inputs will be called a "node" of the structure. The top translog node has each sector's KLEM output created from capital (K), labor (L), energy (E), and materials (M). The KLEM output is the sector's domestic output, e.g., KLEM for the manufacturing sector is domestic manufacturing output.[9] Lower nodes are aggregates of particular energy and material inputs.[10] For example, the aggregate output MO is made from

[8]Nesting the cost functions is necessary to reduce the quantity of parameters to be estimated to a manageable number. Nesting reduces parameters by limiting the number of inputs at each node of production and increasing the number of nodes since the number of parameters at a node is of order N^2.

[9]For industries that do not produce fossil fuels, KLEM cost is exactly the domestic cost. However, for fossil fuel producing industries, KLEM must be combined with the energy resource to produce the domestic good. See Figure B.1 of Appendix B.3 for addition details.

[10]The KLEM output is not the final output used by consumers or firms. Section B.3 details how KLEM is

Figure 3.2: Tiers for the Translog Cost Function for Firm Production



Notes: K is capital, L is labor, and N is non-competing imports. KLEM$_x$ is the top tier output for the translog cost function for industry x but it is not final composite output good x. See Appendix B.3 for details on how KLEM is combined with the energy resource or imported goods to produce the composite good. Numbers give the NAICS code of the respective sector's output. All other letters are the names of aggregate outputs.

the inputs MOT, input 23 (construction), and input 53 (real estate and rental and leasing). All aggregate outputs are also used as inputs for the next higher stage of the production process. For example, MOT is itself also an aggregate output made from inputs 42 (wholesale trade), 44 (retail trade), and 48 (transportation and warehousing). At the lowest level, the inputs used are capital, labor, the 22 sector final composite outputs. Note that the prices of the final composite outputs are the same across all industries at a particular time but the prices of capital, labor, and aggregate inputs like energy will vary across industries in the same time period.

For each aggregate output (node) o and each industry x, the translog cost function is

$$ln(c_{xot}) = \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N}\beta_{xij}^{substitution} ln(p_{xit}) ln(p_{xjt}) + \sum_{i=1}^{N}\beta_{xi}^{share\,constant} ln(p_{xit}) + \sum_{i=1}^{N}\beta_{xi}^{share\,trend} ln(p_{xit})t + \beta_{xo}^{cost\,trend} t + \beta_{xo}^{cost\,constant} \quad (3.1)$$

where $ln(c_{xot})$, the log of the cost of producing output o for industry x at time t, is a function of the log of the input prices $ln(p_{xit})$ of the N inputs.[11] $ln(p_{xit})$ is the log of the price of input i at time t to industry x and t is measured in years. The variables $\beta_{xij}^{substitution}$, $\beta_{xi}^{share\,constant}$, $\beta_{xi}^{share\,trend}$, $\beta_{xo}^{cost\,trend}$, and $\beta_{xo}^{cost\,constant}$ for the inputs i and j are the parameters to be estimated at this node by the regression.

Intuitively, $\beta_{xij}^{substitution}$ defines how use of input i responds to changes in the price of input j for industry x. The variable $\beta_{xi}^{share\,constant}$ is an intercept that gives the value share of input i for industry x at this node when time and all log input prices are zero. The variable $\beta_{xi}^{share\,trend}$

combined with the energy resource and imports to get the final composite output.

[11]The value of N, the number of inputs used to make an output, ranges from one to four and is defined for a particular node according to Figure 3.2. It varies across nodes but is the same at any particular node across industries.

defines how much the value share of input i changes in one year for industry x if input prices do not change. The variable $\beta_{xo}^{cost\,trend}$ is a productivity parameter that defines how much the cost of output changes over time for industry x. The variable $\beta_{xo}^{cost\,constant}$ is the constant term of the cost function. It is the cost of output at time 0 when all input prices are 1. Because the cost of all outputs except for KLEM is unobservable, I cannot estimate the parameters $\beta_{xo}^{cost\,trend}$ or $\beta_{xo}^{cost\,constant}$ when $o \neq$ KLEM. I therefore constrain them to be 0 when $o \neq$ KLEM. However, these parameters are not independently identified from $\beta_{xo}^{share\,trend}$ and $\beta_{xo}^{share\,constant}$ in the next higher node of the tier structure, so my assumption does not affect results.

The household consumption expenditure function follows the same general format as the firm cost functions: a translog expenditure function that is nested into tiers. However, there are two differences. First, the following goods are not bought by consumers: 23 (construction), 212 (mining - except oil and gas), 55 (management of companies and enterprises), 211 (oil and gas extraction), 213 (mining support activities), capital, and labor. And because the cost of the final consumption good is not observed, I cannot estimate the parameters $\beta_{xo}^{cost\,trend}$ or $\beta_{xo}^{cost\,constant}$ for consumers even at node KLEM. I therefore constrain them to be 0 for consumers at all nodes.

Regressions for Cost and Expenditure Function Parametrization

In this section, I estimate the parameter values of Equation 3.1 for each output and industry through a series of regressions. The preferred specification of the regression is iterated three-stage least squares with one-year lagged prices used as instruments. Appendix B.2.1 presents additional details of the regressions and their exact functional forms. This is the preferred regression specification because it accounts for both endogeneity of prices and cost shares and correlation between cost shares. However, the use of instrumental variables can introduce new problems if the instruments are weak. Therefore, I test the overidentifying restrictions to see to what extent the instruments are weak. In order to determine the effect of the instruments on the model, I also estimate two alternative specifications and perform a Monte Carlo simulation. These sensitivity tests indicate that model results are not significantly affected by the choice of instruments or the fact that some excluded instruments are weakly correlated with the included endogenous variables.

Table 3.2 describes the regression results. Due to the extremely large number of parameters, Table 3.2 presents the mean and standard deviation of regression R^2 statistics instead of all

Table 3.2: Regression R^2 Statistics

Commodity	Mean	Standard Deviation
11	0.480	0.276
21	0.253	0.254
211	0.166	0.190
22	0.579	0.246
23	0.635	0.220
31	0.486	0.239
324	0.594	0.227
42	0.388	0.305
44	0.383	0.326
48	0.335	0.309
486	0.705	0.268
51	0.483	0.227
52	0.370	0.273
53	0.573	0.329
54	0.401	0.274
55	0.266	0.204
56	0.364	0.310
61	0.337	0.246
62	0.831	0.162
71	0.379	0.374
72	0.836	0.066
81	0.393	0.258
E	0.537	0.254
K	0.410	0.249
L	0.567	0.159
M	0.458	0.232
MM	0.671	0.212
MO	0.671	0.306
MOT	0.239	0.247
MP	0.868	0.126
MS	0.787	0.185
MSS	0.544	0.254
N	0.494	0.198
KLEM[1]	0.993	0.008

Notes: (1) For commodity KLEM, the mean and standard deviation of the R^2 values from the cost equation are presented and no cost share equation exists. For all other commodities, the mean and standard deviation of the R^2 values of the cost share equation are presented and no cost equation exists.

Table 3.3: Regression Instrumental Variable Statistics

	Under ID P-Value (%)		Weak Stat	
Commodity	Mean	Standard Deviation	Mean	Standard Deviation
E	3.5	16.3	4.923	1.047
M	3.5	15.6	7.364	2.754
MM	3.2	14.7	4.113	1.109
MO	0.1	0.3	11.864	3.832
MOT	2.0	3.3	2.025	0.335
MP	1.6	7.4	4.564	0.947
MS	1.0	4.3	2.868	0.532
MSS	0.2	0.9	9.273	1.722
KLEM	10.9	12.2	2.538	3.310

parameter estimates and their associated standard errors.[12] [13] For most commodities, the R^2 values of the cost share equation are presented because no cost equation exists. However, the R^2 is calculated differently for commodity KLEM than for the others. For commodity KLEM, the R^2 values from the cost equation are presented and no cost share equation exists. The average R^2 value is 0.993 for KLEM. Because KLEM is essentially the final domestic cost for a sector, this high R^2 shows that the predictive power of the system of cost functions as a whole is quite high.

I test the validity of the instrumental variable specification using both underidentification and weak identification tests. Results of these tests are presented in Table 3.3. A Lagrange multiplier version of the Anderson canonical correlation test statistic is calculated in order to test for underidentification (Anderson, 1951).[14] The p-value of this test statistic is reported in column 1 of Table 3.3. Except for output KLEM, on average all regressions reject underidentification at either the 1 or 5 percent level of statistical significance. However, underidentification for commodity KLEM cannot be rejected at even the 10 percent level. In addition, there is high variance in some of the p-values. Appendix F indicates that these p-values are very high for consumers but very low for industries. Therefore underidentification may be a problem for the regression specification.

Results for the second tests also suggests that the instruments are weak. For this test, I

[12]Full regression parameter estimates are presented in Appendix D. Full summary statistics are presented in Appendix F.

[13]Note that the typical method of calculating the total sum of squares, the sum of the regression and residual sum of squares, is incorrect because instrumental variables are used. Instead, $R^2 = \rho^2_{Y,\hat{Y}}$ where Y and $\hat{Y}$ are the actual and predicted values of the dependent variable and $\rho_{Y,\hat{Y}}$ is the correlation coefficient between them.

[14]As explained in Baum, Schaffer, and Stillman (2002), "The test is essentially the test of the rank of a matrix: under the null hypothesis that the equation is underidentified, the matrix of reduced form coefficients on the L1 excluded instruments has rank=K1-1 where K1=number of endogenous regressors. Under the null, the statistic is distributed as chi-squared with degrees of freedom=(L1-K1+1). A rejection of the null indicates that the matrix is full column rank, i.e., the model is identified."

calculate the Cragg-Donald statistic in column 3 (Cragg and Donald, 1993). Stock and Yogo (2002) calculate a variety of critical values of this test statistic but not for the exact configuration used here: 4 instruments and 4 endogenous regressors. However, for 5 instruments and 3 endogenous regressors, the critical value is 4.30.[15] This is significantly larger than the test statistic for MOT and most importantly, KLEM, suggesting that the instruments may be weak.

However, further investigation shows that weak instruments are not problematic for the model results. Two alternative regression specifications are used to investigate the significance of weak instruments. First, instead of using one-year lagged values of the input prices as instruments, I use two-year lagged values. Second, instrumental variables are dropped completely and instead of iterated three-stage least squares, the regression is performed with seemingly unrelated regressions. The results of the model's simulation under these alternative specifications are presented in Table 3.7 of Section 3.4.2. However, these alternative specifications give very similar predictions to the baseline for all economic variables. Additionally, Monte Carlo methods are used to assess the effect of any instability in parameter estimates resulting from weak instruments. Results of this analysis are shown in Table 3.8 of Section 3.4.2. These specifications show that any such instability does not affect qualitative results and could even decrease the benefits of the budget proposal.

To summarize, the statistics presented here give a positive appraisal of the regression specification. The R^2 of the KLEM output equation is nearly 1. Additionally, I find evidence of weak identification but determine that alternative instruments, no instruments at all, and the instability in parameters results from weak instruments all do not affect qualitative results. Therefore, I conclude that the regression provides robust parameter values to the model.

3.3.4 Taxation

This section describes the tax rates used in the model, both for current law and under the budget proposal. In order to accurately analyze the effect of the budget proposal, the model includes government taxes on capital, labor, energy resources, and production under both current law and the budget proposal. The tax rates for production are determined from empirical data while the tax rate for labor is taken from the literature. By contrast, the rates for capital and resource taxes are determined partly from data and partly from the literature. Under

[15] This value is for the test based on two-stage least squares bias and a 0.30 maximal bias of instrumental variables relative to ordinary least squares.

the budget proposal, the tax rate changes for each provision of the proposal are determined by first assigning a base to each provision. The provision's tax rate change is then calculated by dividing the projected revenue increase from that provision by that base. The effect of the entire budget proposal is calculated by summing the rate changes for each provision for their respective tax base.

Current Law Tax Rates

Current law tax rates are calculated using data from a number of sources. The tax rate on labor income is set equal to 31.6 percent following CBO (2005). The production tax rate for each industry's output is equal to the the AETR of all production taxes on a value of output base calculated as described in Section 2.3.2 and presented in Section 2.3.3.

The capital tax rate is equal to the sum of the firm and personal-level capital tax rates. The rates for the firm-level capital taxes vary by industry and are taken from the relevant average effective tax rate (AETR) results calculated using the methodology in Section 2.3.2. Due to data limitations, this AETR includes firm level taxes but does not include individual level taxes such as those on capital gains, dividends, or income from pass-through entities. I include the aggregate effect of these taxes by setting all sectors' personal level capital taxes equal to 12.5 percent. This value causes total firm and personal capital taxes for the entire economy to average 20 percent as found in Mackie (2002). Unfortunately, this method ignores any variation in individual level capital tax rates between sectors. However, in order for individual level capital taxes to lower taxes for fossil fuel production relative to other sectors, individual taxes would need to vary systematically by industry and with negative correlation to the rates calculated in Section 2.3.3.[16] To reduce the effect of outliers, a ceiling of 35 percent, the maximum statutory federal corporate rate, is set on the current law firm capital tax rates used in the model. The tax rate for the energy resource is based off of the capital tax rate for fossil fuel producers: $\tau_{resource}$ is equal to the value of $\tau_{capital,x}$ where $x =$ the oil and gas extraction industry.

Budget Proposal Tax Rate Increases

In order to model the budget proposal, the provisions of the proposal must be expressed in a method conformable with the model's variables. This is done by assigning each budget provision to a particular tax base (capital or production) for a particular sector or set of sectors,

[16]Since I cannot disprove this possibility, additional results are presented in Section 3.4 using METRs instead of AETRs

Table 3.4: Tax Bases for Provisions in Budget Proposal

Provision and *Industry Base*	Factor Base
All fossil fuel production[1]:	
Repeal the domestic manufacturing deduction for fossil fuels	Capital
Modify tax rules for dual capacity taxpayers	Capital
All other fossil fuel specific provisions	Capital
Petroleum and coal products manufacturing:	
Repeal LIFO inventory accounting for all sectors	Capital
Reinstate Superfund excise taxes	Output
Increase Oil Spill Liability Trust Fund financing rate	Output
Mining:	
Repeal the capital gains treatment of coal royalties	Capital
Repeal percentage depletion for coal and other hard mineral fossil fuels	Output
Repeal expensing of coal exploration and development	Capital
Oil and gas extraction:	
Repeal expensing of intangible drilling costs	Capital
Repeal percentage depletion for oil and gas	Output
Increase geological and geophysical amortization period	Capital

Notes: (1) Fossil fuel production is defined as oil and gas extraction, petroleum and coal products manufacturing, and pipeline transportation.

as shown in Table 3.4. The tax rate this provision applies to these bases and sectors is calculated by dividing the proposal's average yearly revenue from JCT (2013) by the 2009 tax base of these sectors. In order to calculate the effect of the budget proposal as a whole, the tax rates implied by each provision for each base for each sector are added together to provide a cumulative rate for all provisions.

However, LIFO complicates this calculation. The LIFO change includes both a permanent increase in tax rates due to the taxation of future inventory appreciation and also a one-time tax payment from the taxation of current LIFO reserves. In addition, the LIFO change applies to all industries, not just fossil fuel extraction. However, the JCT (2013) revenue estimate does not disaggregate all these effects. Therefore instead of using JCT (2013), I calculate the revenue increase of the LIFO inventory change using JCT (2014a)'s estimate of the revenue increase of removing LIFO from 2016-2018, which is equal to the permanent tax rate increase of removing LIFO (JCT, 2014b). Because Przybyla (2011) indicates that 82 percent of LIFO reserves are held by energy companies, I allocate 82 percent of this tax increase to petroleum and coal products manufacturing, and the other 18 percent to all other sectors.

Table 3.5: Macroeconomic Effects of the Budget Proposal under Baseline Assumptions

Variable	Percent Change in Variable
Welfare	-0.50
Capital Stock	-0.04
Employment	-0.01
Consumption	-0.17
Output	-0.13
Capital Rental Rate[1]	-0.09
Labor Wage Rate[1]	-0.06
Variable	**Value ($/ton)**
Social Cost of Carbon	14

Notes: (1) Wage and capital rental rates are the post-tax rates expressed using the price of consumption as a numéraire.

3.4 Results

In this section, I use the computable general equilibrium model described in Section 3.3 to examine the impact of the changes to fossil fuel taxation proposed in the president's 2014 budget. I calculate how economic variables would change if the proposal were implemented. I find that the budget proposal reduces fossil fuel production and also reduces social welfare before externalities are taken into account. Sensitivity tests show that these results are robust to a variety of changes to the model. The results confirm the importance of general equilibrium modeling, flexible substitution, and endogenous energy resource supply.

3.4.1 Baseline Results

Table 3.5 illustrates the macroeconomic effects of implementing the budget proposal. The economic efficiency of the proposal is first measured using the welfare of the representative household, excluding carbon externalities. Under the budget proposal, household welfare would decrease by 0.50 percent. In addition, other economic variables such as the capital stock, employment, household consumption, domestic output, wages, and the capital rental rate would also all decrease under the budget proposal.

The explanation for the decrease in welfare (excluding externalities) can be traced to these other economic variables. I then follow the changes in these variables back to their original source. The decrease in welfare is caused by the decrease in consumption, which is caused by the decrease in income. The decrease in income is in turn caused by the decrease in the capital and labor prices and quantities. The decrease in capital and labor prices also lead to the decrease in quantities supplied. Therefore, the decrease in capital and labor prices are the root cause.

Recall that the three pathways by which energy taxes can lead to efficiency changes are production and consumption, resource rents, and externalities. The baseline results are driven by the first issue, production and consumption inefficiency. The budget proposal decreases the efficiency of the allocation of capital and labor across industries, lowering their productivity, and thus also lowering their price.[17]

Industry level effects of the budget proposal are similar to the macroeconomic effects. Table 3.6 presents the effects of the budget proposal on each industry's output price, the quantity of output the industry produces, and the capital and labor employed by the industry. In general, all of these variables decrease. In particular, since the proposal increases capital taxes on fossil fuel producing sectors, the capital stock in these sectors falls. The capital stock in oil and gas extraction falls the most, by 7.34 percent. Perhaps surprisingly, the capital and labor employed by these industries decreases far more than their output falls. However, this is because capital and labor are relatively unimportant in these industries. Together capital and labor are only 12% of costs for petroleum and coal products manufacturing and 11% for oil and gas extraction.

The reduction in fossil fuel production leads to the primary benefit of the proposal: a reduction in carbon emissions. I compare the benefits of the reduction in carbon emissions to the cost of reduced household welfare, before carbon emissions are taken into account. I do so by calculating the budget proposal's implied social cost of carbon: the cost of carbon for which the budget proposal has zero net effect on household welfare. This implied social cost of carbon is equal to the equivalent variation that households would pay to avoid the budget proposal divided by the change in carbon emissions due to the proposal.[18] If the total social cost of carbon from all externalities is $14, the budget proposal gives households the same welfare as under current law. For higher carbon costs, the budget proposal increases household welfare. For lower costs, it reduces welfare. By comparison, the Interagency Working Group on Social Cost of Carbon (2013) lists mean estimates of the marginal social costs of carbon for 2015 ranging from $11 to $52, depending on the discount rate used.[19]

In total, these results highlight the importance of the features of my model relating to general

[17] I refer only to productive efficiency and inputs here because the arguments are exactly the same for consumptive efficiency and goods.

[18] See Appendix B.7.1 for an explanation of how the change in carbon emissions is calculated.

[19] The social cost of carbon estimated by the Interagency Working Group on Social Cost of Carbon (2013) apparently does not include energy security externalities since this category is not explicitly listed.

Table 3.6: Industry Level Effects of the Budget Proposal

Industry	Percent Change in Consumer Price	Output	Capital Stock	Employment
Accommodation and Food Services	-0.05	-0.09	0.02	-0.07
Administrative and Waste Management	-0.05	-0.10	0.05	-0.05
Agriculture, Forestry, Fishing, and Hunting	0.01	-0.06	-0.02	-0.01
Arts, Entertainment, and Recreation	-0.02	-0.10	-0.06	-0.07
Construction	0.00	-0.02	-0.04	0.03
Educational Services	-0.05	-0.10	0.01	-0.09
Finance and Insurance	-0.08	-0.01	0.05	-0.01
Health Care and Social Assistance	-0.03	-0.13	-0.06	-0.13
Information	-0.05	-0.01	0.07	-0.01
Management of Companies and Enterprises	-0.08	0.08	0.09	0.09
Manufacturing	-0.03	0.00	0.14	0.03
Mining	0.20	-0.21	-0.18	-0.22
Oil and Gas Extraction	0.52	-2.65	-7.34	-14.52
Other Services	-0.06	-0.07	0.03	-0.07
Petroleum and Coal Products Manufacturing	0.92	-2.40	-3.61	-6.94
Pipeline Transportation	0.45	-0.62	-0.77	-0.71
Professional, Scientific, and Technical Services	-0.03	-0.03	0.03	-0.04
Real Estate and Rental and Leasing	-0.06	-0.04	0.01	-0.03
Retail Trade	-0.04	-0.12	0.00	-0.09
Transportation and Warehousing	0.18	-0.21	-0.12	0.00
Utilities	0.09	-0.29	-0.18	-0.12
Wholesale Trade	-0.04	-0.01	0.08	0.02

equilibrium modeling, flexible substitution, and externalities. A partial equilibrium model could not determine that the budget proposal reduces household welfare, excluding externalities. Additionally, a model without flexible substitution would not predict the large drop in fossil fuel capital relative to the drop in output. This would lead the model to either overstate the reduction in carbon emissions or understate the efficiency loss from input substitution. And finally, a model without externalities would underestimate the benefits of the proposal. All three play a role in accurately determining the effects of the budget proposal. In the next section, I perform sensitivity tests and also evaluate the role of the last issue: resource rents.

3.4.2 Sensitivity Tests

I test the robustness of the baseline results presented thus far with a number of alternative model specifications. These alternative specifications change parameters or assumptions from those in the baseline and then examine how results respond. Recall that in the baseline specification, $\theta_{capital} = 0.5$, $\theta_{labor} = 0.2$, $\theta_{resource} = 0.5$, $\theta_r = 4$, and $\theta_{Arm}^{FossilFuelProduction} = 23$. In addition, in the baseline specification the energy resource is separate from capital and the average effective tax rates (AETRs) calculated in Section 2.3.3 are used for the capital tax rates.

Table 3.7: Macroeconomic Effects of the Budget Proposal Under Alternative Assumptions

	Parameter Values[1]	Percent Change in: Welfare[2]	Capital Stock	Employment	Consumption	Social Cost of Carbon ($/ton)
1	Baseline	-0.50	-0.04	-0.01	-0.17	14
2	$\theta_{capital} = 1$	-0.25	-0.09	-0.01	-0.14	16
3	$\theta_{capital} = 0.2$	-0.40	-0.02	-0.01	-0.42	13
4	$\theta_{labor} = 0.3$	-1.03	-0.05	-0.02	-0.18	15
5	$\theta_{labor} = 0.1$	-0.28	-0.04	-0.01	-0.16	12
6	$\theta_{resource} = 1$	-0.54	-0.05	-0.01	-0.18	15
7	$\theta_{resource} = 0.1$	-0.46	-0.04	-0.01	-0.15	13
8	$\theta_r = 0.1$	-0.63	-0.06	-0.01	-0.21	17
9	$\theta_{capital} = 1, \theta_{labor} = 0.3,$ $\theta_{resource} = 1$	-0.36	-0.10	-0.02	-0.16	19
10	$\theta_{capital} = 0.2, \theta_{labor} = 0.1,$ $\theta_{resource} = 0.1$	-0.85	-0.01	-0.01	-0.42	11
11	$\theta_{Arm}^{FossilFuelProduction} = 4$	-0.24	0.00	-0.01	-0.09	7
12	Energy resource treated as capital	-0.76	-0.09	-0.02	-0.25	21
13	Mackie (2002) capital METRs	-0.70	-0.05	-0.01	-0.19	13
14	Regression: 2 period lags for IV	-0.25	-0.03	-0.01	-0.10	19
15	Regression: no instruments	-1.24	-0.05	-0.01	-0.20	13

Notes: (1) Except for the changes explicitly noted under "parameter values," all specifications use the same parameter values and methods as the baseline (specification 1).
(2) Because household utility can be negative, percentage change values can be misleading. Therefore I present the absolute percent change so that positive percents represent increases in welfare while negative numbers represent decreases in welfare.

Furthermore, the translog cost function parameters are estimated using iterated three-stage least squares with one year lagged prices used as the first-stage instrumental variables. All of these parameters or assumptions are changed in at least one sensitivity test. While the baseline uses values that represent the average of the literature, the alternative specifications utilize the high and low extremes of the values which are credibly supported by the literature. My results are robust to the removal of any of these assumptions.

Economic variables do not change markedly under the various alternative specifications. Table 3.7 presents the changes in welfare, capital stock, employment, or consumption caused by the budget proposal under all alternative model specifications. The table also lists the different social costs of carbon necessary for the budget proposal to have zero net effect on household welfare. Specification 1 is the baseline, while specifications 2 through 7 vary the price elasticities of supply for capital, labor, and energy resources. However, under these specifications all variables retain the same sign as the baseline and have similar magnitudes.

Specifications 6 and 7 are especially noteworthy because they deal with the elasticity of energy resource supply. Recall that energy resource supply is better modeled by partial equilibrium models than general equilibrium models. However, these specifications have very similar results, which indicates that the exact value used for the elasticity of the energy resource is not important. This finding suggests that the advantage of partial equilibrium models in this area may not be important for final results.

Other changes are also considered. Specification 8 changes the elasticity of technical substitution for the energy resource, while specifications 9 and 10 change multiple elasticities at once to all be high or low. However, again, results are similar to the baseline. Specifications 11 though 15 consider more fundamental changes that have larger impacts on results than varying elasticity parameters. In specification 11, I reduce the Armington elasticity substitution of imported and domestic fossil fuels to 4 (from 23 in the baseline simulation). This greatly reduces the welfare loss of the proposal and the social cost of carbon necessary to justify it, while also providing the one change in sign of any variable: the budget proposal now has no effect on aggregate capital stock. This indicates that import assumptions significantly impact results: if importation of fossil fuels were as difficult as the importation of a typical good (i.e. an elasticity of 4 instead of 23), then raising taxes on fossil fuels would be less inefficient. It also shows that models that do not allow for substitution toward imported fossil fuels, such as partial equilibrium models or CGE models that assume inelastic import demand, underestimate the negative effects of energy taxes.

One of the primary goals of this paper has been to incorporate endogenous resource supply into a general equilibrium model. The importance of endogenous resource supply can be evaluated by considering a specification without it, specifically, by including the energy resource as part of the capital stock instead of as a separate factor of production. This is considered in specification 12. Compared to the baseline, the effects of the proposal on the social cost of carbon increase to the highest level of any specification. This indicates that including the energy resource as a separate input meaningfully impacts results and that models without an energy resource would overestimate the efficiency costs of the budget proposal. In addition, comparison of this specification to specifications 6 and 7 show that including an energy resource has a large effect on the carbon price necessary to justify the proposal but exactly how the model includes the energy resource is much less important.

In specification 13, I consider model sensitivity to alternative tax rates. Although Section 2.3.2 mentions a number of advantages the AETR has over the METR in this situation, the METR is still the standard method of measuring tax rates. In order to examine if results are driven by the use of AETRs, specification 13 uses the capital METR calculated by Mackie (2002) instead of my calculated capital AETRs. However, the effects of the proposal under this specification are still negative and similar in size to the baseline.

Additionally, I consider several alternative specifications of the regression used to parametrize the translog consumer expenditure and firm cost functions.[20] In the baseline, iterated three-stage least squares was used to parametrize the cost function. Intuitively, three-stage least squares can be thought of as instrumental variables (two-stage least squares or IV) followed by seemingly unrelated regressions (SUR). The ideal sensitivity test would be to perform this regression first with only the IV portion of the regression, then with only the SUR portion, and finally by ordinary least squares. However, it is not possible to perform the regression without the SUR portion. Recall that in order to ensure that the translog cost function I estimate is a legitimate cost function, I must impose cross equation restrictions on the parameter values. Therefore, it is not possible to remove the SUR part of the regression without relaxing these restrictions.[21]

Instead, I perform sensitivity tests only on the IV portion of the regression. This is done in specifications 14 and 15. In the baseline specification, the instruments used for the first-stage are the one year lagged values of the input prices. In specification 14, the 2 year lagged values are used instead. In specification 15, no instruments are used at all. In both cases the proposal has a negative impact on all economic variables. Recall that Section 3.3.3 showed evidence that the baseline specification may be using weak instruments. These sensitivity tests show that the results on welfare, capital stock, employment, consumption, and the social cost of carbon are not driven by the choice of instruments.

In addition to these sensitivity tests, I examine the translog cost function's parameters as a whole as well. Varying individual parameter values is an effective method of determining the sensitivity of model predictions to a small set of parameters. Unfortunately, this method cannot be used to evaluate the entire translog cost function because of the large number of parameters involved. However, Monte Carlo methods can handle large numbers of parameters as long as their distribution is known. I use a Monte Carlo simulation to test the robustness of results to the estimated parameters of the translog cost and expenditure functions. New parameter values β are drawn from the multivariate distribution

$$\beta \sim \mathcal{N}(\beta^*, \Sigma^*) \tag{3.2}$$

[20]For brevity, I refer only to the firm cost function as it is treated identically to the consumer expenditure function in theses tests.

[21]See Appendix B.2.2 for a list of what these restrictions are and how they are imposed.

Table 3.8: Macroeconomic Effects of the Budget Proposal in the Monte Carlo Simulation

Variable	Percentile of Percent Change in Variable 5%	50%	95%
Welfare	-0.52	-0.43	-0.27
Capital Stock	-0.05	-0.04	-0.04
Employment	-0.01	-0.01	-0.01
Consumption	-0.18	-0.16	-0.11
Output	-0.13	-0.13	-0.11
Capital Rental Rate[1]	-0.10	-0.09	-0.07
Labor Wage Rate[1]	-0.06	-0.06	-0.05

Variable	Percentile of Variable 5%	50%	95%
Social Cost of Carbon	19	15	12

Notes: (1) Wage and capital rental rates are the post-tax rates expressed using the price of consumption as a numéraire.

where β^* and Σ^* are from the seemingly unrelated regressions portion of the iterated three-stage least squares regression. β^* is the vector of estimated parameter values and Σ^* is the estimated variance-covariance matrix for the parameter estimates. 20 draws from this distribution are taken for each variable. The cost function parameters resulting from each draw are used to run a new simulation, with all other model parameters as shown in the baseline specification.

Table 3.8 presents the results of the Monte Carlo simulation. The distribution of the macroeconomic effects of the proposal estimated by the Monte Carlo simulation are consistent with those in the baseline specification. Even at the 95^{th} percentile, all macroeconomic variables decrease under the budget proposal and the budget proposal needs a social cost of carbon of $12 to enhance social efficiency. Taken together, the Monte Carlo simulation and the other sensitivity tests demonstrate that my baseline results are not purely products of my assumptions but would occur under a broad class of model specifications and elasticity values.

3.5 Conclusions

In this chapter, I construct a computable general equilibrium model of the United States economy. My model includes endogenous resource supply, flexible substitution among consumer goods and production inputs, and externalities associated with energy use. I then use this model to examine proposed fossil fuel tax increases in President Obama's 2014 budget proposal. This research has two main conclusions regarding the effects of the proposal and how energy taxes should be modeled.

First, the budget proposal will reduce domestic fossil fuel production and will also reduce household welfare before carbon externalities are accounted for. The budget proposal discourages the investment in and the production of fossil fuels. The movement of economic activity out of fossil fuels worsens the allocation of consumption, labor, and capital across sectors of the economy and leads to lower productivity and household consumption. The social cost of carbon needs to be at least $14 per ton in order for reduced carbon emissions to make up for the social efficiency costs of the budget proposal.

Second, the innovations in my model significantly impact the estimates of the proposal's effects. A partial equilibrium model could not analyze the efficiency costs of the proposal. Additionally, a general equilibrium model without flexible substitution would overstate the proposal's reduction in carbon emissions or understate the efficiency loss from input substitution. Similarly, a model without externalities would underestimate the benefits of the proposal. Sensitivity tests further expose the limitations of the aforementioned approaches. These tests illustrate that both the inclusion of an energy resource and the general equilibrium effects of import substitution have important welfare impacts. By contrast, factors more accurately modeled by partial equilibrium models have little effect on welfare estimates. Therefore these results confirm the importance of considering general equilibrium effects, productive and consumptive efficiency, resource rents, and externalities.

Chapter 4

The Efficiency of Gross Receipts Taxation

4.1 Introduction

Retail sales taxes (RSTs) and gross receipts taxes (GRTs) are important revenue sources for most US states. In 2011, 42 states relied on RSTs or GRTs for at least 20 percent of their tax revenues, and these taxes accounted for over 50 percent of revenues in Texas, Hawaii, Tennessee, South Dakota, Florida, and Washington (Tax Policy Center, 2013). In total, these taxes raised $374 billion, or 31 percent of total own-state revenues (Tax Policy Center, 2013; US Census Bureau, 2012). Although RSTs are more common in the United States, there has been a recent resurgence of interest in GRTs. Various forms of broad-based GRTs have recently been enacted in Ohio, Texas, and Kentucky and GRTs have long been in place in Delaware and Washington.[1] [2]

The primary difference between these two types of taxes is that, in principle, an RST applies only to all final sales to consumers and exempts from taxation all sales of intermediate inputs to businesses. By comparison, a GRT in principle taxes all sales of all businesses, including both retail sales to consumers and sales of intermediate inputs to businesses. Because GRTs tax the sales of intermediate inputs, they are widely viewed as highly inefficient tax instruments.

[1] In some cases, the dividing line between RSTs and GRTs can be blurry. For example, Mikesell (2007) notes that several states have taxes that are legally GRTs but from an economic perspective are effectively RSTs. Such states include Arizona, California, Connecticut, Hawaii, Kentucky, Michigan, Nevada, New Mexico, North Dakota, South Dakota, Tennessee, and Wisconsin.

[2] In this paper, I consider only broad-based GRTs that apply to most sales in the economy and do not examine narrow GRTs that apply only to particular industries or activities.

Intermediate good taxation result in "tax cascading," or multiple applications of the statutory GRT rate at various stages of the production process (Mikesell, 2007; Pogue, 2007). Tax cascading in turn causes at least four types of economic inefficiency.[3]

The four types of economic inefficiency caused by intermediate good taxation relate to production, tax competition, consumption, and vertical integration. First, intermediate input taxation leads to productive inefficiency. In the absence of full forward shifting of all taxes on all inputs into consumer prices, taxing intermediate inputs altering input prices and thus distorts business decisions regarding input mix. According to the well-known Diamond and Mirrlees (1971) production efficiency theorem, such production distortions are generally undesirable.[4] Second, taxation of business inputs increases production costs within a state and creates incentives for businesses to locate in other states with a less burdensome tax structure. Third, a large fraction of input taxes is likely to be shifted forward onto consumption. As a result, the final effective tax rate on a taxed consumption good or service will be higher than the statutory rate, with arbitrary differential effective tax rates across consumer goods. These effective tax rates will vary depending on the number of taxed stages in the production process and will inefficiently distort consumption decisions. Fourth, because the final tax burden under a cascading tax depends on the number of stages in the production process, cascading creates a tax incentive for inefficient vertical integration. For all of these reasons, most observers argue that a gross receipts tax is highly inefficient. In particular, a GRT is widely viewed as a less efficient tax instrument than a well-designed RST (Pogue, 2007).[5]

Although the RST is thus in principle a more efficient tax than the GRT, RSTs in practice fall far short of an ideal consumption-based tax that is applied to all final consumer goods and services while exempting all production inputs (McLure, 2005). In particular, real RSTs often

[3]As discussed below, additional sources of inefficiency unrelated to tax cascading arise because the typical GRT, like the typical RST, does not tax all consumption goods, exempting some goods for social reasons, others on administrative grounds, and largely exempting remote sales, including electronic commerce. The typical GRT, however, taxes consumption much more comprehensively than the typical RST. See footnote 10 for an example.

[4]Note that the production efficiency theorem requires that a full set of commodity taxes be available and set optimally and that any positive economic profits be taxed at a rate of 100% (Diamond and Mirrlees, 1971). If these conditions are not satisfied, differential tax treatment of intermediate inputs may be desirable (1) to indirectly tax final goods that are under-taxed relative to the optimum, or (2) to indirectly tax production inputs that earn above-normal profits. It seems unlikely that the pattern of differential taxes required for efficiency in these cases would correspond to the pattern that occurs under a GRT. However, that possibility cannot be ruled out without an empirical investigation of the actual GRT and industry structure in any given state. As will be discussed below, a similar issue arises under retail sales taxes, which also tax intermediate inputs. For example, Hawkins (2002) shows that sales taxation of inputs is generally disproportionately high in service industries that are largely exempt from sales taxes (even though sales of services to final consumers should in principle be fully taxed), so that the taxation of intermediate inputs can be efficiency-enhancing in this case.

[5]Indeed, one of the main reasons for the widespread adoption of the VAT in Europe was the desire to eliminate the gross receipts or "turnover" taxes that preceded it (Bird and Gendron, 2007, p. 20).

tax intermediate inputs and thus suffer from tax cascading. Indeed, Ring (1999) estimates that as much as 40 percent of RST revenues are attributable to taxes on intermediate inputs.[6] As a result, all of the inefficiencies that plague the GRT also arise to some extent under the RST. In addition, RSTs — to a greater extent than GRTs — typically are not assessed uniformly on all consumption goods, as exemptions for health care, education, food, and other "merit goods" are more common than under GRTs. Many services are also exempt from tax, and the taxation of remote sales is haphazard, especially for sales of consumer goods over the Internet.[7] All of these factors further reduce the efficiency of RSTs. Thus despite the common perception that GRTs are relatively inefficient tax instruments when compared to RSTs, it is not clear in practice which of the two taxes is preferable on efficiency grounds.

I examine the relative efficiency of the two taxes in this paper within the context of a computable general equilibrium model of a representative state economy. Specifically, I compare the relative efficiency costs of equal revenue yield versions of a generic GRT and a generic RST, typical of those enacted in the various states. The analysis takes into account both the taxation of production inputs that leads to tax cascading and exemptions for items such as health care and education as well as many services. It also considers the extent to which the taxation of business inputs reduces total state output. I am not, however, able to examine differential tax effects on vertical integration within the context of the model.

Given the focus on tax cascading under both the GRT and the RST, accurate modeling of both firm production and consumer choices is essential. Firm production technologies need to include variations in the number of stages, as well as in the production process for different industries and in the extent of firm substitution among intermediate inputs. Consumer choices also need to allow for substitution among different consumption goods and services. Two features of the model ensure that it has such flexibility: the number of goods and the cost functions that describe how they are used.

First, I allow for a relatively large number of intermediate and consumer goods. Production is disaggregated into 21 different industries to analyze tax cascading within and across many

[6] Ring (1999) does not distinguish between revenues attributable to intermediate inputs and those attributable to purchases of consumer goods by out-of-state tourists.

[7] The arguments for excluding internet sales from sales taxes are not particularly compelling (Zodrow, 2006). In addition, numerous factors have combined to increase the sales taxation of electronic commerce significantly in recent years and have increased the prospects that a much larger fraction of remote sales to consumers will eventually be subject to tax. These factors include the passage of so-called "Amazon laws," voluntary agreements between Amazon and various states, and the efforts of the states participating in the Streamlined Sales Tax Agreement.

different sectors. The outputs of these production sectors are then combined to produce final consumption goods to analyze the efficiency costs of distortions in consumer prices.

Second, in order to capture substitution across production inputs and consumer goods precisely, I use highly flexible firm cost and consumer expenditure functions. Specifically, for production, I assume a translog functional form for the firm cost functions in each industry, following the work of Jorgenson and various associates, especially Jorgenson and Slesnick (2008) and Wilcoxen (1988). The translog function is preferable to the more commonly used and more tractable constant elasticity of substitution (CES) production function, which assumes the elasticities of substitution between all inputs used in a given cost function are the same. By comparison, the translog function allows these elasticities to vary across different combinations of inputs. Similarly, the effects of consumption distortions under the two taxes are captured by using the translog functional form for the consumer expenditure function, which again allows more flexible modeling of substitution than the often-used CES utility function. The translog functional form also allows for technological progress and changes in the importance of particular inputs over time.

The paper proceeds as follows. I begin in the following section with a short review of the literature and then outline my methodology in Section 4.3. The simulation results are presented in Section 4.4, while the final section offers some concluding observations.

4.2 Literature Review

Although I am not aware of any previous studies that have examined the relative efficiency properties of state GRTs and RSTs, several previous analyses have examined the efficiency of state sales tax reforms. The studies that are most relevant to this paper are Russo (2005) and Hawkins (2002), both of which are reviewed by Fox and Luna (2006).

Russo (2005) compared several sales tax reforms within the context of an infinite horizon general equilibrium model with two consumption goods and one intermediate good. These tax reforms included broadening the base of the sales tax, replacing the sales tax with a true consumption tax, and replacing the sales tax with higher income taxes. He found that broadening the sales tax base and converting the sales tax base to include all consumption expenditures increases economic efficiency, while replacing sales taxes with an income tax reduces efficiency. In addition, Russo concluded that even partial sales tax base broadening could produce sizable efficiency improvements. This finding provides an interesting perspective on comparisons of the GRT and RST because the GRT can be described as an RST with its base broadened to include both more final goods (which increases efficiency) and more intermediate inputs (which reduces efficiency).

Hawkins (2002) conducted another analysis of the taxation of production inputs under a sales tax. He used a partial equilibrium model to analyze the effect of pyramiding due to the taxation of intermediate goods on the efficiency of state sales taxes. Hawkins does not model production explicitly but uses the Almost Ideal Demand System to model consumer demand (which is broadly similar to my translog expenditure functions) in order to evaluate the efficiency cost of tax distortions of consumer purchasing decisions under different sales tax structures. His results generally indicate that uniform taxation of consumption goods promotes efficiency. One result that is particularly relevant for this paper is that the input taxes he considers indirectly fall heavily on price-inelastic and RST-exempt goods and thus tend to improve economic efficiency.

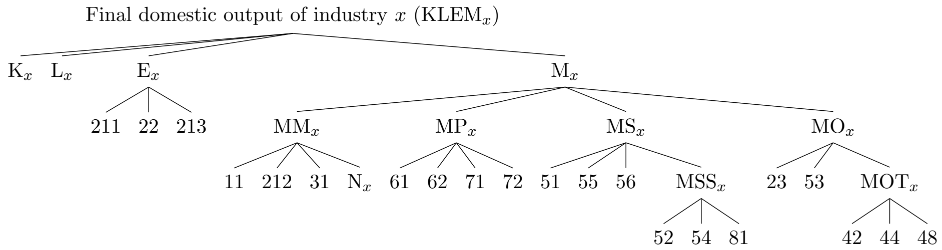
My analysis extends this literature by using a much more detailed production and demand structure within a fully specified general equilibrium model. For example, Hawkins (2002) does not explicitly model production and thus does not consider production inefficiency. Moreover, compared to the two consumption goods and one intermediate good modeled by Russo (2005), my model contains 21 production goods, all of which can be used as either consumption goods or intermediate inputs, and also utilizes much more flexible cost and expenditure functions. Both of these features allow for a more accurate analysis of the production inefficiencies caused by tax cascading due to the taxation of intermediate goods under the GRT and the RST.

4.3 Methodology

This analysis utilizes a modified version of the general equilibrium model of the US economy previously described in Chapter 3. These modifications are designed to adjust the model for differences between federal energy taxation and the analysis of gross receipts and retail sales taxes in a representative US state. The modified model is then used to compare a GRT and an equal revenue RST. In this section, I describe the changes to the model compared to the version used in Chapter 3. I also briefly describe the exact features of the GRT and RST analyzed using the model.

The state version of the model used in this chapter differs from that of the previous chapter in a small number of ways.[8] Some changes focus the model on gross receipts taxation instead of energy. In this version of the model, the representative state government only collects gross receipts or retail sales taxes. The model ignores all other taxes, i.e. those on capital and labor. In addition, this model uses the tier structure of production shown in Figure 4.1 which has less detail on fossil fuel production.

Figure 4.1: Tiers for the Translog Cost Function for Firm Production in the State Model



Notes: K is capital, L is labor, and N is non-competing imports. $KLEM_x$ is the top tier output for the translog cost function for industry x but it is not final composite output good x. See Appendix B.3 for details on how KLEM is combined with imported goods to produce the composite good. Numbers give the NAICS code of the respective sector's output (see Table 4.1). All other letters are the names of aggregate outputs.

I also adjust the model to differences between the entire US and a single representative US state. I assume the population of households within the taxing state and their aggregate labor supply are fixed. And by contrast, I assume that the state can be modeled as small open economy in the capital market; the supply of capital to the state is perfectly elastic. One notable variable I do not change is the Armington elasticity of substitution. I do not change it because its current value of 4.0 is broadly similar to that used in the CGE models of the US states. Specifically, Thaiprasert, Faulk, and Hicks (2013) use a value of 2 and Despotakis and Fisher (1988) use values that range from 0.25 to 6.0. In addition, the state model does not include an energy resource.

I use this model to compare two tax regimes: an RST and a GRT. The RST is typical of those used by the states because its base includes some business inputs and it also exempts certain goods (see Table 4.1). In order to implement these features, the RST is split into two portions. The first is a consumption tax that falls only on taxed final goods. The second is an intermediate goods tax that falls only on taxed intermediate goods. Based on the results in Ring (1999), I assume that 40 percent of RST revenues come from the tax on intermediate goods.[9] Specifically, I set the final good tax rate equal to 1 percent and solve for the intermediate good

[8]Any features not mentioned are the same in both versions of the model.

[9]Recall that this is an overestimate because Ring (1999) included tourist purchases of consumer goods in his calculation of the amount of intermediate inputs in the sales tax base.

Table 4.1: Taxable and Exempt Goods under the RST

NAICS Code	Output Exempt?	Industry
72	No	Accommodation and Food Services
11	No	Agriculture
71	No	Arts, Entertainment, and Recreation
23	No	Construction
61	Yes	Educational Services
52	Yes	Finance and Insurance
62	Yes	Health Care and Social Assistance
51	Yes	Information
55	Yes	Management
31	No	Manufacturing
212	No	Mining - Except Oil and Gas
211	No	Mining - Oil and Gas
213	No	Mining Support Activities
81	Yes	Other Services
53	Yes	Real Estate
44	No	Retail Trade
54	Yes	Technical Services
48	No	Transportation
22	No	Utilities
56	No	Waste Disposal
42	No	Wholesale Trade

tax rate such that intermediate good tax revenue is equal to 40 percent of the combined revenue of the two components of the RST.

The second tax regime consists of a GRT on all sales by in-state firms, both of intermediate and final goods, with no exempt industries.[10] The GRT tax rate is chosen to be revenue neutral with the RST. In order to compare revenues as the prices of goods change, total state government revenue under both the RST and GRT scenarios must be sufficient to purchase the same number of units of the consumer composite consumption good. Under both the RST and GRT, all tax revenue is returned to consumers as a lump sum rebate.

For both the GRT and RST, the degree of tax cascading for each good is endogenously determined by the input mix used by the industry that produces that good. Industries using inputs that are characterized by limited tax pyramiding or inputs that are tax exempt (under the RST) will produce outputs that have relatively little tax pyramiding, and vice versa. The translog cost function determines the input mix used by each industry and thus the degree of

[10] Although GRTs do not necessarily apply to all sales, exemptions for particular industries or goods do not seem to be a common feature. For example, the Ohio GRT applies to schools, health providers, and services if they are provided by for-profit organizations with at least $150,000 of taxable gross receipts. By comparison, these activities are almost always exempt from RSTs.

Table 4.2: Statutory Tax Rates Under Each Tax Regime (Percent)

Classification Under the RST	RST	GRT
Exempt Intermediate Goods	0	0.414
Non-exempt Intermediate Goods	0.643	0.414
Exempt Final Goods	0	0.414
Non-exempt Final Goods	1.000	0.414

tax pyramiding, as well as the ability of firms to substitute among inputs in response to the different tax regimes analyzed.

4.4 Results

I begin by characterizing the initial equilibrium in the model. I set the tax rate on intermediate goods under the RST (which is assumed to be the same for all intermediate goods) so that 40 percent of RST revenues are attributable to the taxation of intermediate goods when the tax rate on final goods is 1 percent. This results in a tax rate on intermediate goods of 0.643 percent. By contrast, moving to a GRT broadens the tax base to include all final consumption and intermediate goods (now taxing those exempt under the RST) and thus lowers the necessary tax rate, to 0.414 percent (see Table 4.2). Surprisingly, the RST actually taxes intermediate goods more than the GRT. The GRT only receives 33.7 percent of its revenue from the taxation of business inputs, as opposed to 40 percent for the RST. This is because the base broadening that occurs under the GRT, relative to the RST, falls less heavily on intermediate goods than the original RST base did.

Figure 4.2 shows the change in the price of each industry's output that would occur if the RST were replaced with a GRT. Industries that were previously exempt face nominal price increases of about 0.8 percent, while industries that were previously taxed face price increases of less than 0.2 percent. Figure 4.3 shows the change in the output of each sector that would occur with a move to a GRT. These results reflect the price changes shown in Figure 1, as previously non-exempt industries increase their output and previously exempt industries decrease their output.

My methodology also allows me to compare the efficiency cost of the RST relative to that of an equal-yield GRT. I calculate the excess burden of the RST using an equivalent variation measure — the amount households would be willing to pay under the GRT regime to avoid moving to the RST regime, expressed as a fraction of the revenue raised under the GRT. By

Figure 4.2: Price Change Due to Moving to a Gross Receipts Tax from a Retail Sales Tax, by Sector

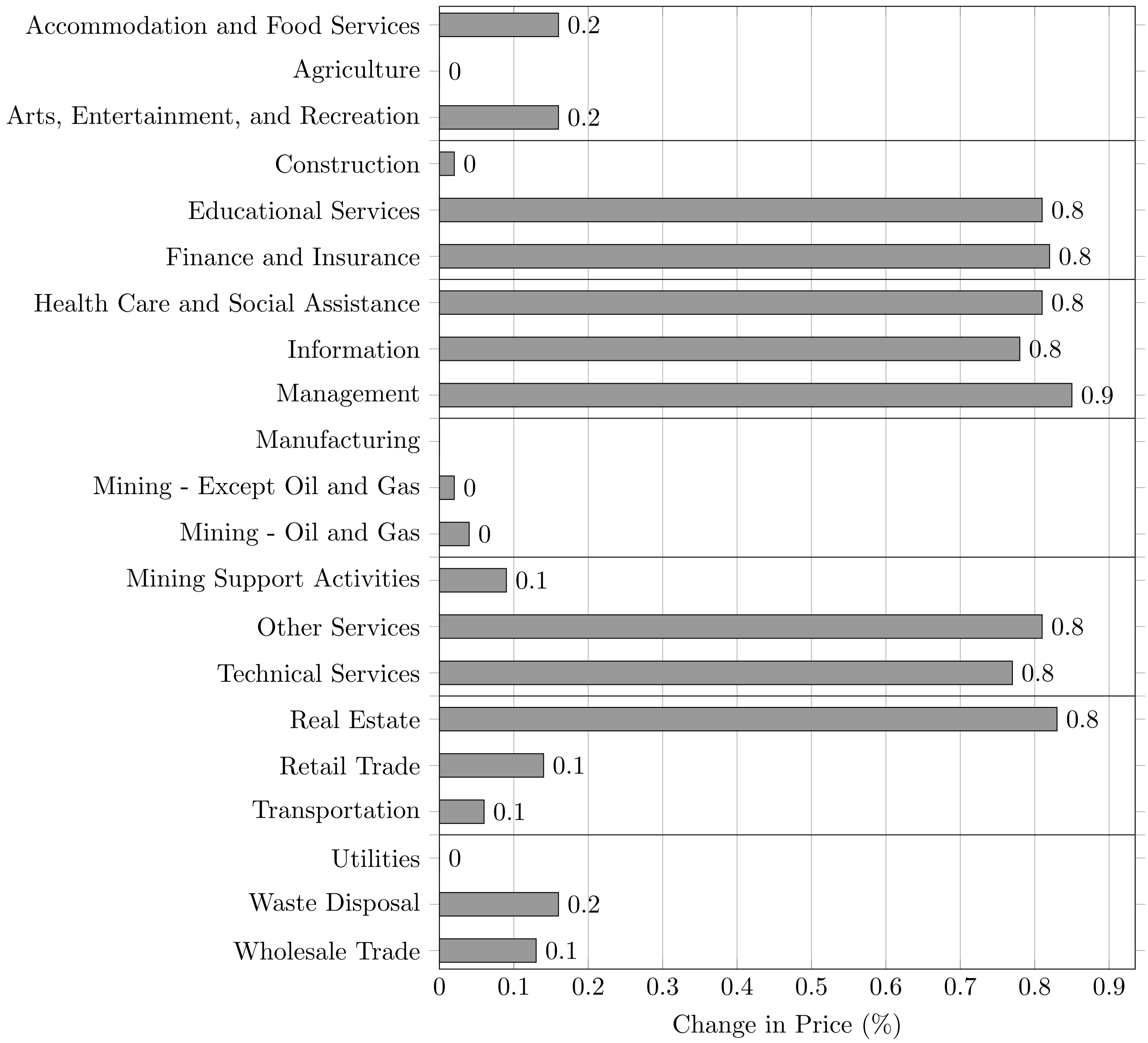


Figure 4.3: Producer Output Quantity Change Due to Moving to a Gross Receipts Tax from a Retail Sales Tax, by Sector

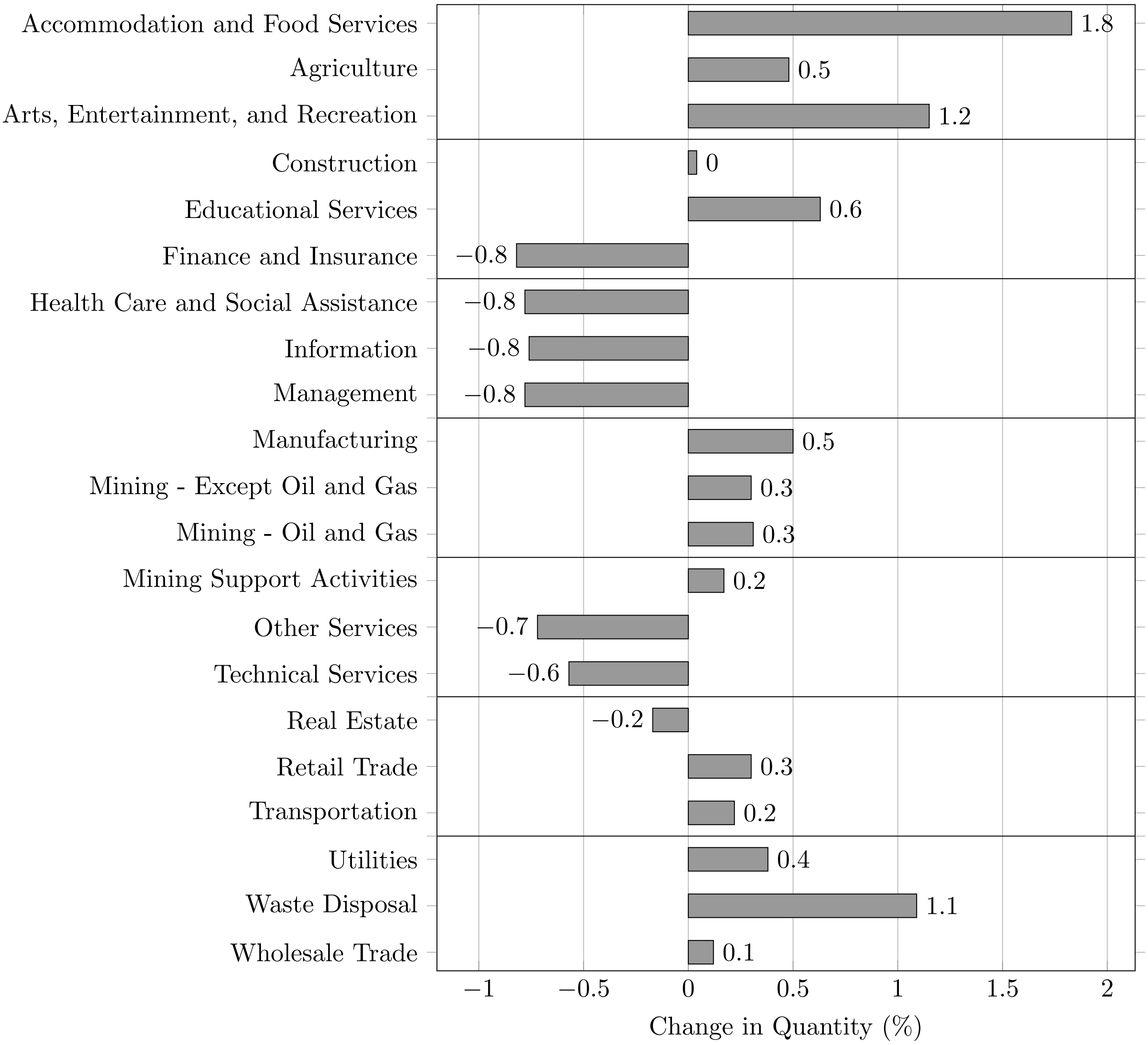


Table 4.3: Macroeconomic Effects of Replacing an RST with a GRT

Variable	Change
Output (Nominal) (% Change)	0.293
Output (Real) (% Change)	-0.016
Private Investment (% Change)	-0.075
Price of Consumption Good (% Change)	0.309
Capital Rental Rate[1] (% Change)	-0.001
Labor Wage Rate[1] (% Change)	0.042
Excess Burden of Taxation (Percentage Point Change)	-6.82

Notes: (1) Wage and capital rental rates are the rates expressed using the price of consumption as a numéraire.

this measure, the efficiency loss of moving to a RST equals 6.8 percent of revenues. That is, the revenue raised under the RST results in an excess burden that is higher by 6.8 percent of revenues than the excess burden that arises from raising the same amount of revenue under a GRT.

I can also calculate the absolute efficiency costs of the RST and the GRT, compared to an equilibrium in which neither tax is imposed. The absolute excess burden, the equivalent variation consumers would be willing to pay to avoid having any tax imposed at all, is 25.9 percent of revenues for the RST. This excess burden is significantly higher than that found by Hawkins (2002), who found that a sales tax with a 1.76 percent statutory rate, pyramiding, and exemptions for most services and home foods had an excess burden of 17.9 percent of revenues. By contrast, I find that the GRT's excess burden is 19.1 percent of revenues, or 6.8 percentage points less than under the RST. Thus, contrary to the conventional wisdom described in the introduction, the GRT is more efficient than the RST in this simulation. Note, however, that my comparison understates the efficiency cost of the GRT to some extent because I assume that it taxes all consumption goods with no exemptions.

Table 4.3 examines additional economic effects of replacing the RST with a GRT. Nominal output and the wage rate are larger under the GRT. However, real output, private investment, the price of the consumption good, and the real capital rental rate (as well as the efficiency costs of the tax discussed above) are smaller. An important reason for the relative efficiency of the GRT is that it results in an improved allocation of labor, which leads to higher labor productivity, higher wages, and higher household income. The real labor wage rate is 0.042 percent higher under the GRT. The increase in labor income is partially offset by a reduction in private investment, which falls by 0.075 percent. However, because the income share of labor is 66 percent, the net effect of moving to a GRT is to increase total real household income by

0.036 percent.

My results on the relative efficiency of the RST and GRT are not what might be expected based on the existing literature, but are not surprising when examined in detail. Although the GRT is often viewed to be an undesirable tax instrument because it results in tax cascading, in reality both taxes suffer from this problem. In my comparison of a generic RST and a generic GRT, the RST actually gets a larger fraction of its revenues from taxes on intermediate goods. Intermediate good taxation leads to inefficient substitution by firms and consumers, and results in inefficiencies in production and consumption. More generally, because my model has a more detailed production and consumption structure, it is better able to estimate the excess burdens of RSTs and GRTs than previous models.

4.5 Conclusions

Retail sales taxes are commonly viewed as significantly more efficient than gross receipts taxes because the latter apply to intermediate goods and thus result in tax cascading. However, the retail sales taxes used by the US states are not pure consumption taxes, but in fact tax many intermediate inputs while exempting more consumption goods than the typical gross receipts tax does. In this paper, I analyze the relative efficiency of a generic gross receipts tax and a generic retail sales tax while taking these factors into account. I find that substitution in production and consumption, as well as general equilibrium effects, play key roles in determining the relative efficiencies. For the particular retail sales tax and gross receipts tax analyzed, my model shows that, contrary to the conventional wisdom, the gross receipts tax is more efficient than the retail sales tax, with an efficiency cost that is 6.8 percent of revenues less than that associated with an equal-yield retail sales tax. In addition, the retail sales tax actually receives a larger fraction of its revenue from intermediate good taxation than the gross receipts tax does.

Bibliography

Abraham, Kenneth S. (2011). "Catastrophic Oil Spills and the Problem of Insurance". In: *Vanderbilt Law Review* 64.6, pp. 1769–1791.

Adelman, M.A. (Jan. 1973). *The World Petroleum Market*. Baltimore: Johns Hopkins University Press.

Altig, David et al. (2001). "Simulating Fundamental Tax Reform in the United States". English. In: *The American Economic Review* 91.3, pp. 574–595. ISSN: 00028282. URL: http://www.jstor.org/stable/2677880.

Anderson, Theodore Wilbur (Sept. 1951). "Estimating linear restrictions on regression coefficients for multivariate normal distributions". In: *The Annals of Mathematical Statistics* 22.3, 327351. URL: http://www.jstor.org/stable/10.2307/2236620 (visited on 08/28/2013).

Atkinson, Anthony Barnes and Joseph E. Stiglitz (1976). "The design of tax structure: Direct versus indirect taxation". In: *Journal of Public Economics* 6.1-2, pp. 55–75. URL: http://EconPapers.repec.org/RePEc:eee:pubeco:v:6:y:1976:i:1-2:p:55-75.

Babiker, Mustafa MH et al. (2008). *A forward looking version of the MIT emissions prediction and policy analysis (eppa) model*. Tech. rep. MIT Joint Program on the Science and Policy of Global Change.

Balistreri, Edward J., Ayed Al-Qahtani, and Carol A. Dahl (2010). "Oil and Petroleum Product Armington Elasticities: A New-Geography-of-Trade Approach to Estimation." In: *Energy Journal* 31.3, pp. 167–179. ISSN: 01956574.

Baum, Christopher F., Mark E. Schaffer, and Steven Stillman (Apr. 2002). *IVREG2: Stata module for extended instrumental variables/2SLS and GMM estimation*. Published: Statistical Software Components, Boston College Department of Economics. URL: http://ideas.repec.org/c/boc/bocode/s425401.html.

Bird, Richard Miller and Pierre-Pascal Gendron (2007). *The VAT in developing and transitional countries*. Vol. 244. Cambridge University Press Cambridge.

Blake, Andon J. and Mark C. Roberts (2006). "Comparing petroleum fiscal regimes under oil price uncertainty". In: *Resources Policy* 31.2, pp. 95–105. ISSN: 0301-4207. DOI: http://dx.doi.org/10.1016/j.resourpol.2006.08.001. URL: http://www.sciencedirect.com/science/article/pii/S0301420706000316.

Blouin, Jennifer L., Linda K. Krull, and Casey Schwab (2007). "The Effect of the Domestic Manufacturing Deduction on Corporate Payout Behavior". In: Working Paper.

Bureau of Economic Analysis (Sept. 2003). *Fixed Assets and Consumer Durable Goods in the United States, 1925-97*. Washington, DC: U.S. Government Printing Office.

Cohen, Mark A. et al. (2011). "Deepwater Drilling: Law, Policy, and Economics of Firm Organization and Safety". In: *Vanderbilt Law Review* 64.6, pp. 1853–1916.

Collins, Julie H. and Douglas A. Shackelford (1995). “Corporate Domicile and Average Effective Tax Rates: The Cases of Canada, Japan, the United Kingdom, and the United States”. In: *International Tax and Public Finance* 2.1, pp. 55–83.

Congressional Budget Office (Nov. 2005a). *Effective Marginal Tax Rates on Labor Income*. Tech. rep. Washington, DC: Congressional Budget Office. URL: http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/68xx/doc6854/11-10-labortaxation.pdf (visited on 08/05/2013).

— (2005b). *Taxing Capital Income: Effective Rates and Approaches to Reform*. Tech. rep. Washington, DC: Congressional Budget Office.

— (Dec. 2006). *Computing Effective Tax Rates on Capital Income*. Tech. rep. Washington, DC: Congressional Budget Office.

— (2011). *Reducing the Deficit: Spending and Revenue Options*. Tech. rep. Washington, DC: Congressional Budget Office. URL: http://www.cbo.gov/publication/22043 (visited on 07/16/2013).

— (Jan. 2013). *Options for Taxing U.S. Multinational Corporations*. Tech. rep. Washington, DC: Congressional Budget Office. URL: http://www.cbo.gov/publication/43764 (visited on 07/16/2013).

Connor, John A. et al. (2011). “Nature, frequency, and cost of environmental remediation at onshore oil and gas exploration and production sites”. In: *Remediation Journal* 21.3, 121144. ISSN: 1520-6831. DOI: 10.1002/rem.20293. URL: http://dx.doi.org/10.1002/rem.20293.

Cragg, John G. and Stephen G. Donald (1993). “Testing Identifiability and Specification in Instrumental Variable Models”. English. In: *Econometric Theory* 9.2, pp. 222–240. ISSN: 02664666. URL: http://www.jstor.org/stable/3532477.

Dasgupta, Partha, Geoffrey Heal, and Joseph E. Stiglitz (1981). *The Taxation of Exhaustible Resources*. NBER Working Papers 0436. National Bureau of Economic Research, Inc. URL: http://EconPapers.repec.org/RePEc:nbr:nberwo:0436.

Department of the Treasury (1984). *Tax Reform for Fairness, Simplicity, and Economic Growth: The Treasury Department Report to the President, November 1984*. Tech. rep.

— (2013). *General Explanations of the Administration’s Fiscal Year 2014 Revenue Proposals*. Tech. rep. URL: http://www.treasury.gov/resource-center/tax-policy/Documents/General-Explanations-FY2014.pdf.

Desai and Hines (2004). “Old Rules and New Realities: Corporate Tax Policy in a Global Setting”. In: *National Tax Journal* 57.4, pp. 937–960.

Despotakis, Kostas A. and Anthony C. Fisher (1988). “Energy in a regional economy: A computable general equilibrium model for California”. In: *Journal of Environmental Economics and Management* 15.3, pp. 313–330. ISSN: 0095-0696. DOI: http://dx.doi.org/10.1016/0095-0696(88)90005-8. URL: http://www.sciencedirect.com/science/article/pii/0095069688900058.

Diamond, Peter A. and James A. Mirrlees (1971). “Optimal Taxation and Public Production I: Production Efficiency”. In: *The American Economic Review* 61.1, pp. 8–27. URL: http://www.jstor.org/stable/1910538?seq=17 (visited on 05/05/2010).

Fontevecchia, Agustino (Feb. 2013). *BP Fighting A Two Front War As Macondo Continues To Bite And Production Drops*. URL: http://www.forbes.com/sites/afontevecchia/

2013/02/05/bp-fighting-a-two-front-war-as-macondo-continues-to-bite-and-production-drops/ (visited on 03/12/2014).

Fox, William F. and Le Ann Luna (2006). "How Broad Should State Sales Tax Bases Be? A Review of the Empirical Literature". In: *State Tax Notes* 41, p. 639.

Fullerton, Don (1984). "Which Effective Tax Rate?" In: *National Tax Journal* 37, pp. 23–41.

Fullerton, Don and Diane Lim Rogers (1993). *Who bears the lifetime tax burden?* Brookings Institution Press.

Goulder, Lawrence H. and Mark A.C. Hafstead (Oct. 2013). *A Numerical General Equilibrium Model for Evaluating U.S. Energy and Environmental Policies*. URL: http://www.rff.org/Documents/WP-Numerical-General-Equilibrium-Model.pdf (visited on 03/08/2014).

Gravelle, Jane G. (2009). "International Corporate Income Tax Reform: Issues and proposals". In: *Florida Tax Review* 9.5, pp. 469–496.

— (July 2012). *Moving to a Territorial Income Tax: Options and Challenges*. CRS Report for Congress R42624. Congressional Research Service. URL: http://www.fas.org/sgp/crs/misc/R42624.pdf.

Gunning, Timothy S., John W. Diamond, and George R. Zodrow (2008). "Selecting Parameter Values for General Equilibrium Model Simulations". In: *The James A. Baker III Institute for Public Policy, Rice University, mimeograph*. URL: http://128.42.204.130/publications/parameter_values_final.pdf (visited on 08/22/2013).

Hammond, Peter J (2000). "Reassessing the Diamond-Mirrlees Efficiency Theorem". In: *Incentives, Organization, and Public Economics: Papers in Honour of Sir James Mirrlees: Papers in Honour of Sir James Mirrlees*. Ed. by Peter J Hammond and Gareth Myles, p. 193.

Hawkins, Richard R. (Dec. 2002). "Popular Substitution Effects: Excess Burden Estimates for General Sales Taxes". In: *National Tax Journal* 55.4, pp. 755–770. URL: http://www.jstor.org/stable/41789639 (visited on 02/16/2010).

Hellwig, Martin (Dec. 2008). *A Generalization of the Atkinson-Stiglitz (1976) Theorem on the Undesirability of Nonuniform Excise Taxation*. Working Paper Series of the Max Planck Institute for Research on Collective Goods 2008_47. Max Planck Institute for Research on Collective Goods. URL: http://ideas.repec.org/p/mpg/wpaper/2008_47.html.

Hogan, Lindsay and B Goldsworthy (2010). "International minerals taxation: experience and issues". In: *The Taxation of Petroleum and Minerals: Principles, Problems and Practice*. Ed. by Philip Daniel, Michael Keen, and Charles McPherson. London: Routledge.

Hotelling, Harold (1931). "The economics of exhaustible resources". In: *The Journal of Political Economy* 39.2, 137175. URL: http://www.jstor.org/stable/10.2307/1822328 (visited on 08/31/2013).

Interagency Working Group on Social Cost of Carbon (May 2013). *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*. Tech. rep. URL: http://www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf (visited on 09/02/2013).

Internal Revenue Service (2011a). *Publication 535 (2011), Business Expenses*. URL: http://www.irs.gov/publications/p535/ch09.html.

— (Jan. 2011b). *TAM-142671-10*. URL: http://www.irs.gov/pub/irs-wd/1120019.pdf.

Joint Committee on Taxation (2011). *Present Law And Background Information On Federal Excise Taxes*. JCS-1-11. Washington, DC: U.S. Government Printing Office.

— (2012). *Description of Revenue Provisions Contained in the Presidents Fiscal Year 2013 Budget Proposal*. JCS-2-12. Washington, DC: U.S. Government Printing Office.

— (2013). *Estimated Budget Effects of the Revenue Provisions Contained in the President's Fiscal Year 2014 Budget Proposal*. JCS-11-13. Washington, DC: U.S. Government Printing Office.

— (2014a). *Estimated Revenue Effects of the "Tax Reform Act of 2014"*. JCX-20-14. Washington, DC: U.S. Government Printing Office.

— (2014b). *Technical Explanation of the Tax Reform Act of 2014, a Discussion Draft of the Chairman of the House Committee on Ways and Means to Reform the Internal Revenue Code: Title III Business Tax Reform*. JCX-14-14. Washington, DC: U.S. Government Printing Office.

Jorgenson, Dale and Daniel T. Slesnick (2008). "Consumption and labor supply". In: *Journal of Econometrics* 147.2, pp. 326–335. URL: http://www.sciencedirect.com/science/article/pii/S0304407608001474 (visited on 11/19/2010).

Jorgenson, Dale W. (1986). "Econometric Methods for Modelling Producer Behavior". In: *Handbook of Econometrics*. Vol. 3. Elsevier Science Publishers, pp. 1842–1915.

— (2007). *35 Sector KLEM*. URL: http://hdl.handle.net/1902.1/10684 (visited on 09/12/2011).

Jorgenson, Dale W. and Kun-Young Yun (2001). *Lifting the Burden: Tax Reform, the Cost of Capital, and U.S. Economic Growth*. Vol. 3. Cambridge, MA: MIT Press.

Kemp, Alexander G (1987). *Petroleum rent collection around the world*. IRPP.

Kleinbard, Edward D. (Feb. 2007). "Throw Territorial Taxation from the Train". In: *Tax Notes* 114, pp. 547–564.

Kleinbard, Edward D., George A. Plesko, and Corey M. Goodman (Oct. 2006). "Is it Time to Liquidate LIFO?" In: *Tax Notes* 113.3, pp. 237–253. (Visited on 08/14/2012).

Knittel, Matthew (Mar. 2009). "How Prevalent is LIFO? Evidence from Tax Data". In: *Tax Notes* 122, p. 1587. (Visited on 08/14/2012).

Kontovas, Christos A., Harilaos N. Psaraftis, and Nikolaos P. Ventikos (2010). "An empirical analysis of IOPCF oil spill cost data". In: *Marine Pollution Bulletin* 60.9, pp. 1455–1466. ISSN: 0025-326X. DOI: http://dx.doi.org/10.1016/j.marpolbul.2010.05.010. URL: http://www.sciencedirect.com/science/article/pii/S0025326X10002110.

Lund, Diderik (1992). "Petroleum taxation under uncertainty: contingent claims analysis with an application to Norway". In: *Energy Economics* 14.1, pp. 23–31. ISSN: 0140-9883. DOI: http://dx.doi.org/10.1016/0140-9883(92)90021-5. URL: http://www.sciencedirect.com/science/article/pii/0140988392900215.

— (Oct. 2009). "Rent Taxation for Nonrenewable Resources". In: *Annual Review of Resource Economics* 1.1, pp. 287–308. ISSN: 1941-1340, 1941-1359. DOI: 10.1146/annurev.resource.050708.144216. URL: http://www.annualreviews.org/doi/abs/10.1146/annurev.resource.050708.144216 (visited on 04/12/2013).

Mackie, James B. III (2002). "Unfinished Business of the 1986 Tax Reform Act: An Effective Tax Rate Analysis of Current Issues in the Taxation of Capital Income". In: *National Tax Journal* 55.2, pp. 293–337.

McClelland, Robert and Shannon Mok (2012). *A Review of Recent Research on Labor Supply Elasticities*. Tech. rep. 2012-12. Washington, DC: Congressional Budget Office. URL: http://digitalcommons.ilr.cornell.edu/key_workplace/971/ (visited on 05/15/2013).

McFadden, Daniel (1978). "Cost, revenue, and profit functions". In: *Production Economics: A Dual Approach to Theory and Applications*. Ed. by Fuss Melvyn and Daniel McFadden. Vol. 1. Elsevier North-Holland.

McLure, Charles E (2005). "Understanding the nuttiness of state tax policy: When states have both too much sovereignty and not enough". In: *National Tax Journal* 58.3, 565–573.

Metcalf, Gilbert E. (2009). *Taxing Energy in the United States: Which Fuels Does the Tax Code Favor?* Energy Policy & the Environment Report 4. Manhattan Institute for Policy Research.

Mikesell, John L. (Jan. 2007). "Gross Receipts Taxes in State Government Finances: A Review of Their History and Performance". In: *Tax Foundation Background Paper* No. 53. URL: http://taxfoundation.org/article/gross-receipts-taxes-state-government-finances-review-their-history-and-performance.

Mohn, Klaus (2010). "Elastic Oil: A Primer on the Economics of Exploration and Production". English. In: *Energy, Natural Resources and Environmental Economics*. Ed. by Endre Bjrndal et al. Energy Systems. Springer Berlin Heidelberg, pp. 39–58. ISBN: 978-3-642-12066-4. URL: http://dx.doi.org/10.1007/978-3-642-12067-1_3.

Office of the Press Secretary (Mar. 2012). *Remarks by the President on Oil and Gas Subsidies*. URL: http://www.whitehouse.gov/the-press-office/2012/03/29/remarks-president-oil-and-gas-subsidies.

Paltsev, Sergey et al. (2005). *The MIT emissions prediction and policy analysis (EPPA) model: version 4*. Tech. rep. MIT Joint Program on the Science and Policy of Global Change. URL: http://dspace.mit.edu/handle/1721.1/29790 (visited on 05/08/2013).

Peaceman, Donald W (1977). *Fundamentals of numerical reservoir simulation*. Amsterdam, The Netherlands: Elsevier Scientific Publishing Company. ISBN: 978-0444552983.

Pirog, Robert (Mar. 2012). *Oil and Natural Gas Industry Tax Issues in the FY2013 Budget Proposal*. CRS Report for Congress R42374. Congressional Research Service. URL: http://budget.house.gov/uploadedfiles/crsr42374.pdf.

Pogue, Thomas F. (2007). "The Gross Receipts Tax: A New Approach to Business Taxation?" In: *National Tax Journal* 60.4, pp. 799–879.

Probst, Katherine N. et al. (1995). *Footing the Bill for Superfund Cleanups: Who pays and how?* Brookings Institution Press.

Przybyla, Heidi (June 2011). "Obama Wants to Scrap $72-Billion Business Tax Break as Republicans Balk". In: *Bloomberg*. URL: http://www.bloomberg.com/news/2011-06-27/obama-targets-72-billion-business-tax-break-republicans-balk.html.

Quantitative Economics and Statistics Group, Ernst & Young LLP (2007). *International Comparison of Depreciation Rules and Tax Rates for Selected Energy Investments*. URL: http://accf.org/wp-content/uploads/2007/05/internationalComparison.pdf.

Ramseur, Jonathan L., Mark Reisch, and James E. McCarthy (Feb. 2008). *Superfund Taxes or General Revenues: Future Funding Issues for the Superfund Program.* CRS Report for Congress RL31410. Congressional Research Service.

Ring, Raymond (1999). "Consumers' Share and Producers' Share of the General Sales Tax". In: *National Tax Journal* 52.1, pp. 79–90.

Russo, Benjamin (Oct. 2005). "An Efficiency Analysis of Proposed State and Local Sales Tax Reforms". In: *Southern Economic Journal* 72.2. ArticleType: research-article / Full publication date: Oct., 2005 / Copyright 2005 Southern Economic Association, pp. 443–462. ISSN: 00384038. URL: http://www.jstor.org/stable/20062121.

Rutherford, Thomas F. and Sergey V. Paltsev (2000). "GTAP-Energy in GAMS: the dataset and static model". In: *University of Colorado at Boulder, Working Paper* 00-02. URL: http://www.colorado.edu/econ/papers/papers00/wp00-2.pdf (visited on 05/15/2013).

Sato, K. (1967). "A Two-Level Constant-Elasticity-of-Substitution Production Function". English. In: *The Review of Economic Studies* 34.2, pp. 201–218. ISSN: 00346527. URL: http://www.jstor.org/stable/2296809.

Senhadji, Abdelhak S. and Claudio E. Montenegro (Sept. 1999). "Time Series Analysis of Export Demand Equations: A Cross-Country Analysis". In: *IMF Staff Papers* 46.3, pp. 259–273. ISSN: 10207635. DOI: 10.2307/3867643. URL: http://www.jstor.org/stable/3867643.

Smalling, Bill (2012). "Overview of the Petroleum Industry Positions Relative to Oil Industry Tax Issues in the Federal FY2013 Budget Proposal". In: *Texas Tax Lawyer* 39.3.

Smith, James (2012). *Issues in Extractive Resource Taxation: A Review of Research Methods and Models.* Tech. rep. Washington, DC: International Monetary Fund. URL: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2202638 (visited on 04/16/2013).

Solow, Robert M. and Frederic Y. Wan (1976). "Extraction Costs in the Theory of Exhaustible Resources". English. In: *The Bell Journal of Economics* 7.2, pp. 359–370. ISSN: 0361915X. URL: http://www.jstor.org/stable/3003261.

Stock, James H. and Motohiro Yogo (2002). *Testing for weak instruments in linear IV regression.* Cambridge, MA: National Bureau of Economic Research. URL: http://www.nber.org/papers/t0284 (visited on 08/28/2013).

Tax Policy Center (Mar. 2013). *State Tax Collection Shares by Type 2000-2011.* URL: http://www.taxpolicycenter.org/taxfacts/displayafact.cfm?DocID=404&Topic2id=90&Topic3id=92 (visited on 11/03/2013).

Telles, Rudy, Sheila O'Sullivan, and Jesse Willhide (Apr. 2012). *State Government Tax Collections Summary Report: 2011.* U.S. Census Bureau.

Thaiprasert, Nalitra, Dagney Faulk, and Michael J Hicks (2013). "A Regional Computable General Equilibrium Analysis of Property Tax Rate Caps and a Sales Tax Rate Increase in Indiana". In: *Public Finance Review* 41.4, 446472.

Tipton, Jonathan Spenser (2012). "IFRS and the Repeal of LIFO". PhD thesis. University of Tennessee. URL: http://trace.tennessee.edu/utk_chanhonoproj/1483.

US Census Bureau (Apr. 2012). *State Government Tax Collections: 2012.* URL: http://factfinder2.census.gov (visited on 11/03/2013).

U.S. Energy Information Administration (Feb. 2011). *Performance Profiles of Major Energy Producers 2009.* Tech. rep. DOE/EIA-0206(09). Washington, DC: U.S. Energy Information Administration.

U.S. General Accounting Office (2000). *Petroleum and Ethanol Fuels: Tax Incentives and Related GAO Work*. URL: http://www.gao.gov/new.items/rc00301r.pdf.

Uzawa, Hirofumi (1962). "Production Functions with Constant Elasticicities of Substitution". In: *The Review of Economic Studies* 29, pp. 291–299.

Viscusi, W Kip and Richard J. Zeckhauser (2011). "Deterring and Compensating Oil-Spill Catastrophes: The Need for Strict and Two-Tier Liability". In: *Vanderbilt Law Review* 64.4, pp. 1717–1765.

Wilcoxen, Peter (1988). "The Effects of Environmental Regulation and Energy Prices on U.S. Economic Performance". Ph.D. Dissertation. Cambridge, MA: Harvard University.

Woods, J. M. (2008). "Going on Twenty Years-The Oil Pollution Act of 1990 and Claims Against the Oil Spill Liability Trust Fund". In: *Tulane Law Review* 83, p. 1323. (Visited on 08/29/2012).

Zelio, Judy and Lisa Houlihan (2008). *State Energy Revenues Update*. URL: http://www.ncsl.org/issues-research/budget/state-energy-revenues-update.aspx (visited on 08/18/2012).

Zodrow, George R (2006). "Optimal commodity taxation of traditional and electronic commerce". In: *National Tax Journal* 59.1, 7–31.

Zodrow, George R. and John W. Diamond (2013). "Chapter 11 - Dynamic Overlapping Generations Computable General Equilibrium Models and the Analysis of Tax Policy: The Diamond-Zodrow Model". In: *Handbook of Computable General Equilibrium Modeling SET, Vols. 1A and 1B*. Ed. by Peter B. Dixon and Dale W. Jorgenson. Vol. 1. Handbook of Computable General Equilibrium Modeling. Elsevier, pp. 743–813. URL: http://www.sciencedirect.com/science/article/pii/B9780444595683000110.

Appendix A

Model Data

A.1 Jorgenson (2007)

The data used in the regressions and simulations come from several sources. The first is a system of US national accounts covering the years 1960 to 2005 compiled by Jorgenson (2007). This data includes the quantity and price of output produced by all industries, the capital and labor purchased by each industry, the price of capital and labor purchased by each industry, and all intermediate inputs purchased by each industry from each industry. However, this data uses its own unique sector classification system that is roughly based on the Standard Industrial Classification (SIC). But the SIC has been superseded by the more modern North American Industrial Classification System (NAICS) and all other data sets use the NAICS format.

In order to convert Jorgenson (2007) to NAICS, I first convert the data to SIC. I then utilize the 1997 Economic Census's Bridge between NAICS and SIC. The bridge gives the value of shipments and full-time equivalent employees in each SIC sector and how both are apportioned to the new NAICS sectors. The Jorgenson (2007) data on price, industry revenue, and input purchases are apportioned to NAICS sectors using the value of shipments in the bridge.

Input purchases by Jorgenson (2007) sectors are apportioned in three steps. First the SIC shipments in the bridge are aggregated to the level of the Jorgenson (2007) sectors:

$$Ship_y^x = \sum_{z \in y} Ship_z^x \tag{A.1}$$

where $Ship_z^x$ are the value of shipments of SIC industry z apportioned to NAICS industry x and $Ship_y^x$ are the value of shipments of Jorgenson (2007) industry y apportioned to NAICS industry

x. Note that each Jorgenson (2007) sector y contains many SIC sectors z. Jorgenson (2007) sector 35 (government enterprises) has no corresponding SIC entry in the bridge but all other Jorgenson (2007) sectors directly correspond to particular SIC sectors. No SIC sector contains more than one Jorgenson (2007) sector. The next step gives the use of Jorgenson (2007) inputs by NAICS industries with the following formula:

$$u_{xjt}^{NAICS,JORG} = \sum_{y \in JORG} \frac{Ship_y^x u_{yjt}^{JORG,JORG}}{\sum_{x \in NAICS} Ship_y^x} \tag{A.2}$$

here $u_{xjt}^{NAICS,JORG}$ is the expenditure on Jorgenson (2007) input j by NAICS industry x at time t, $Ship_y^x$ are the value of shipments of Jorgenson (2007) industry y apportioned to NAICS industry x, $u_{yjt}^{JORG,JORG}$ is the expenditure on Jorgenson (2007) input j by Jorgenson (2007) industry y at time t, and $JORG$ is the set of all sectors in Jorgenson (2007). Intuitively, Equation A.2 says that the NAICS sector which is apportioned X percent of the value of shipments of a Jorgenson (2007) sector is also apportioned X percent of that sector's Jorgenson (2007) input purchases.

However note that in Equation A.2 the input j is still a Jorgenson (2007) sector, not a NAICS sector: only the industry using the input was converted into the NAICS basis. In the second step, the inputs are converted into an NAICS basis as follows:

$$u_{xit} = \sum_{j \in JORG} \frac{Ship_j^i u_{xjt}^{JORG,NAICS}}{\sum_{i \in NAICS} Ship_j^i} \tag{A.3}$$

where here u_{xit} is the expenditure on NAICS input i by NAICS industry x at time t. This fully converts Jorgenson (2007) input purchases of Jorgenson (2007) industries to NAICS input purchases by NAICS industries.

Next the revenue data in Jorgenson (2007) must be converted. The following equation is used to convert Jorgenson (2007) industry revenue to NAICS revenue:

$$u_{xt} = \sum_{j \in JORG} \frac{Ship_j^x u_{jt}^{JORG}}{\sum_{i \in NAICS} Ship_j^i} \tag{A.4}$$

where u_{xt} is the revenue of NAICS industry x at time t and u_{xt}^{JORG} is the revenue of Jorgenson (2007) industry j at time t.

Finally, Jorgenson (2007) prices are converted to NAICS prices as follows:

$$p_{it} = \sum_{j \in SIC} \frac{u_{jt}^{SIC} Ship_j^i}{q_{it} \sum_{i \in NAICS} Ship_j^i}. \tag{A.5}$$

A.2 Other Data Sources

Additional data comes from the BEA Tables of the Use of Commodities by Industries from 1997-2010. This data set contains revenue for NAICS industries that is used for the years 2006 through 2010. In addition, this data set contains commodity demand data that is used for all years.

It is also worth noting exactly how variables such as "government investment" are defined as this variable draws from several different variables in this data set. Household consumption expenditure data by industry are taken from "Personal consumption expenditures". The private investment expenditures are equal to the sum of "Private fixed investment" and "Change in private inventories". Exports are "Exports of goods and services". Imports are "Imports of goods and services". Government investment is the sum of "Federal Government defense: Gross investment", "Nondefense: Gross investment", "State and local government education: Gross investment", and "State and local government gross investment, other". Government consumption is equal to the sum of "Federal Government defense: Consumption expenditures", "Nondefense: Consumption expenditures", and "State and local government consumption expenditures, other".

A third source of data is the BEA Gross Output Price Index from 1987-2010 which contains the price for each sector's output. For most sectors, these prices can be used directly without adjustment. However, it is worth noting that my model's sectors differ slightly from NAICS sectors. Sectors 211, 324, and 486 are not standalone sectors and are not contained in sectors 21, 31, and 48 as they normally are in the NAICS. The price of the sector (211, 324, or 486) commodity is removed from the price of commodity (21, 31, or 48) which no longer contains it as follows:

$$p_{21t} = \frac{p_{21t}^{OLD} Revenue_{21t} - p_{211} Revenue_{211t}}{Revenue_{21t} - Revenue_{211t}} \tag{A.6}$$

$$p_{31t} = \frac{p_{31t}^{OLD} Revenue_{31t} - p_{324} Revenue_{324t}}{Revenue_{31t} - Revenue_{324t}} \tag{A.7}$$

$$p_{48t} = \frac{p_{48t}^{OLD} Revenue_{48t} - p_{486} Revenue_{486t}}{Revenue_{48t} - Revenue_{486t}} \tag{A.8}$$

where p_{kt}^{OLD} is the original price of commodity k at time t in the raw BEA data where $k \in \{21, 31, 48\}$.

Note that Jorgenson (2007) also contains price data. The Jorgenson (2007) prices are used from 1960-1997. For years after 1997, the normalized BEA prices are used. This is done because the Jorgenson (2007) had to be converted from SIC and thus suffers from conversion error while the BEA data does not. This normalization is accomplished by setting prices in 1997 equal to the Jorgenson (2007) 1997 prices as follows:

$$p_{it} = \begin{cases} p_{it}^{J} & \text{if } t \leq 1997 \\ p_{it}^{BEA} \frac{p_{i1997}^{J}}{p_{i1997}^{BEA}} & \text{if } t > 1997 \end{cases} \tag{A.9}$$

where p_{it} is the price of commodity i at time t used in the regression, p_{it}^{J} is the price from Jorgenson (2007) and p_{it}^{BEA} is the price from the BEA data set.

The final data source from the BEA is BEA Table: Full-Time Equivalent Employees by Industry for the years 1998-2010 which provides the full-time equivalent employees by industry.

Data for expenditures on energy resource acquisition come from two sources. The first is T-15. Oil and Natural Gas Exploration and Development Expenditures from 1977 to 2009, which provides the expenditures by financial reporting system (FRS) companies on the acquisition of land containing oil and gas resources.[1] However, T-15 only includes FRS firms. In order to find the expenditures of all firms, reserve additions from these and non-FRS companies are taken from T-19. Oil and Natural Gas Reserves: FRS and Industry, 2008 to 1977.[2]

[1] Available online at `http://www.eia.gov/cfapps/frs/frstables.cfm?tableNumber=15&startYear=1977&endYear=2009&loadAction=Apply+Changes`.

[2] Available online at `http://www.eia.gov/cfapps/frs/frstables.cfm?tableNumber=19&startYear=2003&endYear=2009`.

Appendix B

Model Equations

B.1 Variable Definitions

Tables B.1 and B.2 define the variables used in the model, excluding the elasticity parameters of Table 3.1. Table B.1 lists the variables that refer to the price, quantity, or expenditure on various commodities. If a variable is missing a sector x subscript, then it is a vector of the prices for all sectors. The variable with a time t subscript are only used in the regression: in the simulation, the model is solved for a steady-state equilibrium in the year 2005.

Table B.2 defines the parameters used in the constant elasticity of substitution (CES) cost functions that give the price of domestic output and composite output. These parameters are determined by calibration in order to give the observed cost shares spent on imported versus domestic products for all sectors or on energy resources versus capital, labor, energy, and materials for oil and gas extraction.

B.2 Regression

B.2.1 Regression Equations

The regression which parametrizes the translog cost function in Equation 3.1 deals not only with that equation but an entire system of equations. The additional equations are the input cost shares, one for each input, given by

$$share_{xoit} = \sum_{j=1}^{N} \beta_{xij}^{substitution} ln\left(p_{xit}\right) + \beta_{xi}^{share\,trend} t + \beta_{xi}^{share\,constant} \tag{B.1}$$

Table B.1: Commodity Variable Notation

Symbol	Definition
p_{xit}	Price of input i to industry x at time t
p_{xkt}	Price of capital to industry x at time t
p_{xlt}	Price of labor to industry x at time t
p_{xrt}	Price of resource to industry x at time t
p_{xi}	Price of input i to industry x
p_k	Vector of prices of capital
p_l	Vector of prices of labor
p_r	Vector of prices of resource
p_{dom}	Vector of prices of domestic output
p_{imp}	Vector of prices of imported output
p_{com}	Vector of prices of composite import/domestic commodity
p_c	Prices of the household composite consumption good

Notes: Only the price variables are given in the table given a price variable p_z, the associated quantity is q_z and the associated expenditure is $p_z q_z \equiv u_z$.

Table B.2: CES Parameters

Symbol	Definition
α_r	Parameter for Equation B.21: Domestic output cost function
α_{KLEM}	Parameter for Equation B.21: Domestic output cost function
α_{import}	Parameter for Equation B.27: Composite output cost function
$\alpha_{domestic}$	Parameter for Equation B.27: Composite output cost function

where $share_{xoit}$ is the share of the total cost of output o for industry x at time t that is spent on input i.

However, these equations are parametrized indirectly. Because the translog cost function is not guaranteed to be concave, a Cholesky decomposition was used to ensure the concavity. The parameters of the Cholesky decomposition are those actually estimated by the regression. In addition, the requirements of homogeneity, product exhaustion, and symmetry impose further constraints on the parameters. Taking into account all these restrictions, the actual regression is performed on the following system of 3 equations (labeled Equations B.2, B.3, and B.4) when N=4 and inputs $i = \{1, 2, 3, 4\}$. For brevity $\beta_{xi}^{share\ constant} \equiv \beta_{xi}^{sc}$.

$$\begin{aligned} share_{xo1t} &= \\ \beta_{x1}^{sc} - (-\beta_{x1}^{sc} + {\beta_{x1}^{sc}}^2 + e^{2d_{x11}})ln(p_{x1t}) &- (\beta_{x1}^{sc}\beta_{x2}^{sc} + e^{d_{x11}+d_{x12}})ln(p_{x2t}) \\ -(\beta_{x1}^{sc}\beta_{x3}^{sc} + e^{(d_{x11}+d_{x13})})ln(p_{x3t}) &+ (0 + (-\beta_{x1}^{sc} + {\beta_{x1}^{sc}}^2 + e^{2d_{x11}}) \\ +(\beta_{x1}^{sc}\beta_{x2}^{sc} + e^{d_{x11}+d_{x12}}) + (\beta_{x1}^{sc}\beta_{x3}^{sc} + e^{d_{x11}+d_{x13}}))ln(p_{x4t}) &+ \beta_{x1}^{share\ trend} year + \varepsilon_{xo1t} \end{aligned} \tag{B.2}$$

$$share_{xo2t} =$$

$$\beta^{sc}_{x2} - (\beta^{sc}_{x1}\beta^{sc}_{x2} + e^{d_{x11}+d_{x12}})ln(p_{x1t}) - (-\beta^{sc}_{x2} + \beta^{sc\,2}_{x2} + e^{2d_{x12}} + e^{2d_{x22}})ln(p_{x2t})$$
$$-(\beta^{sc}_{x2}\beta^{sc}_{x3} + e^{d_{x12}+d_{x13}} + e^{d_{x22}+d_{x23}})ln(p_{x3t}) + (0 + (\beta^{sc}_{x1}\beta^{sc}_{x2} + e^{d_{x11}+d_{x12}})$$
$$+(-\beta^{sc}_{x2} + \beta^{sc\,2}_{x2} + e^{2d_{x12}} + e^{2d_{x22}}) + (\beta^{sc}_{x2}\beta^{sc}_{x3} + e^{d_{x12}+d_{x13}} +$$
$$e^{d_{x22}+d_{x23}}))ln(p_{x4t}) + \beta^{share\,trend}_{x2} year + \varepsilon_{xo2t} \tag{B.3}$$

$$share_{xo3t} =$$

$$\beta^{sc}_{x3} - (\beta^{sc}_{x1}\beta^{sc}_{x3} + e^{d_{x11}+d_{x13}})ln(p_{x1t}) - (\beta^{sc}_{x2}\beta^{sc}_{x3} + e^{d_{x12}+d_{x13}} + e^{d_{x22}+d_{x23}})ln(p_{x2t})$$
$$-(-\beta^{sc}_{x3} + \beta^{sc\,2}_{x3} + e^{2d_{x13}} + e^{2d_{x23}} + e^{2d_{x33}})ln(p_{x3t}) + (0 + (\beta^{sc}_{x1}\beta^{sc}_{x3} + e^{d_{x11}+d_{x13}})$$
$$+(\beta^{sc}_{x2}\beta^{sc}_{x3} + e^{d_{x12}+d_{x13}} + e^{d_{x22}+d_{x23}}) + (-\beta^{sc}_{x3} + \beta^{sc\,2}_{x3} + e^{2d_{x13}} +$$
$$e^{2d_{x23}} + e^{2d_{x33}}))ln(p_{x4t}) + \beta^{share\,trend}_{x3} year + \varepsilon_{xo3t} \tag{B.4}$$

where ε_{xojt} is the error term. However, not all cost function (Equation 3.1) terms are present in Equations B.2, B.3, and B.4. And note that the d_{xij} terms do not appear in the cost function at all. The remaining terms for the cost function are derived from the terms in Equations B.2, B.3, and B.4 as follows in Equations B.5 through B.16:

$$\beta^{substitution}_{x11} = -(\beta^{sc\,2}_{x1} + e^{2d_{x11}}) + \beta^{sc}_{x1} \tag{B.5}$$
$$\beta^{substitution}_{x12} = -(\beta^{sc}_{x1}\beta^{sc}_{x2} + e^{d_{x11}+d_{x12}}) \tag{B.6}$$
$$\beta^{substitution}_{x13} = -(\beta^{sc}_{x1}\beta^{sc}_{x3} + e^{d_{x11}+d_{x13}}) \tag{B.7}$$
$$\beta^{substitution}_{x14} = 0 - \beta^{substitution}_{x11} - \beta^{substitution}_{x12} - \beta^{substitution}_{x13} \tag{B.8}$$

$$\beta^{substitution}_{x22} = -(\beta^{sc\,2}_{x2} + e^{2d_{x12}} + e^{2d_{x22}}) + \beta^{sc}_{x2} \tag{B.9}$$
$$\beta^{substitution}_{x23} = -(\beta^{sc}_{x2}\beta^{sc}_{x3} + e^{d_{x12}+d_{x13}} + e^{d_{x22}+d_{x23}}) \tag{B.10}$$
$$\beta^{substitution}_{x24} = 0 - \beta^{substitution}_{x12} - \beta^{substitution}_{x22} - \beta^{substitution}_{x23} \tag{B.11}$$

$$\beta^{substitution}_{x33} = -(\beta^{sc\,2}_{x3} + e^{2d_{x13}} + e^{2d_{x23}} + e^{2d_{x33}}) + \beta^{sc}_{x3} \tag{B.12}$$
$$\beta^{substitution}_{x34} = 0 - \beta^{substitution}_{x23} - \beta^{substitution}_{x33} - \beta^{substitution}_{x13} \tag{B.13}$$

$$\beta_{x4}^{sc} = 1 - \beta_{x1}^{sc} - \beta_{x2}^{sc} - \beta_{x3}^{sc} \tag{B.14}$$

$$\beta_{x44}^{substitution} = 0 - \beta_{x14}^{substitution} - \beta_{x24}^{substitution} - \beta_{x34}^{substitution} \tag{B.15}$$

$$\beta_{x4}^{share\,trend} = 0 - \beta_{x1}^{share\,trend} - \beta_{x2}^{share\,trend} - \beta_{x3}^{share\,trend}. \tag{B.16}$$

Additionally, since prices are directly observed, not costs, I assume that the domestic price of output is equal to the cost of producing that industry's KLEM output

$$c_{x,KLEM,t} = p_{x,dom,t}. \tag{B.17}$$

B.2.2 Regularity Conditions

Not all functions are cost functions. In order for a function to be a cost function, it must be the dual representation of a well-behaved production function. This imposes the following requirements on the cost function (McFadden, 1978):

1. Positivity. The cost function is positive for positive input prices.

2. Homogeneity. The cost function is homogeneous of degree one in the input prices.

3. Monotonicity. The price function is increasing in the input prices.

4. Concavity. The price function is concave in the input prices.

Many functional forms for cost functions satisfy these 4 requirements for all parameter values. However, the translog cost function does not. For a translog cost function to satisfy the above 4 requirements, it must satisfy the following 5 conditions (Jorgenson, 1986):

1. Homogeneity. The value shares and the rate of technical change are homogeneous of degree zero in the input prices.

2. Product Exhaustion. The sum of the value shares is equal to unity.

3. Symmetry. The matrix of share elasticities is symmetric.

4. Nonnegativity. The value shares must be nonnegative.

5. Monotonicity. The matrix of share elasticities must be nonpositive definite.

The regression to parametrize the translog cost function must be implemented with these requirements in mind in order to avoid parameter values that violate them and thus lead to the use of a function which is not a cost function. The following cross equation restrictions on parameter values:

$$\sum_{i \in N} \beta_{xi}^{shareconstant} = 1 \qquad \forall x \tag{B.18}$$

$$\sum_{i \in N} \beta_{xi}^{sharetrend} = 0 \qquad \forall x \tag{B.19}$$

$$\beta_{xij}^{substitution} = \beta_{xji}^{substitution} \qquad \forall x, i, j \tag{B.20}$$

guarantee that the cost function satisfies the homogeneity (Equation B.18), product exhaustion (Equation B.19), and symmetry (Equation B.20) conditions. Nonnegativity and monotonicity cannot be guaranteed but must be checked for using the regression's estimated parameter values. This is accomplished by taking the estimated parameter values and the full data set of input prices used to estimate them and determining for what percent of these input prices the resultant cost functions are nonnegative and monotonic.

Table B.3 presents results of this calculation.[1] Almost all cost shares are positive for all input prices. The very few exceptions typically occur for industries that use little to none of a particular commodity. This would allow difference in scale between that commodity's cost share and the cost shares of the other commodities to cause negative cost shares for the less used commodity through rounding errors.

The concavity of the cost function in input prices is equivalent to the monotonicity requirement. This is determined by calculating the cost function's Hessian and determining whether the Hessian is negative semidefinite or not. However, this procedure involves calculating the Hessian's eigenvalues using both multiplication and addition. Because of this, even small rounding errors can significantly change the outcome. Therefore, I define a cost function as concave if given any eigenvalue λ of its Hessian, $\lambda \leq 10^{-16}$. 10^{-16} was chosen because the computer program used to calculate the Hessian has 16 digits of precision.

Table B.3 indicates that for the majority of input prices, the cost functions are concave. Most importantly, the top level output KLEM is concave for 68.2 percent of input prices. However, at the lower level commodities are not always concave in input prices. Concavity is a significant

[1]These are the mean values of the summary statistics averaged over all industries. See Appendix F for full results.

Table B.3: Regression Statistics: Nonnegativity and Monotonicity

Commodity	Nonnegative (%)	Monotonic (%)
11	100	na
21	100	na
211	99	na
22	100	na
23	99.7	na
31	100	na
324	99.9	na
42	100	na
44	100	na
48	100	na
486	99.9	na
51	100	na
52	100	na
53	100	na
54	100	na
55	100	na
56	100	na
61	100	na
62	100	na
71	100	na
72	100	na
81	100	na
E	100	20.6
K	100	na
L	100	na
M	100	36.2
MM	100	69.7
MO	100	48.9
MOT	100	65.6
MP	100	83.4
MS	100	89.6
MSS	100	82.6
N	100	na
KLEM	na	68.2

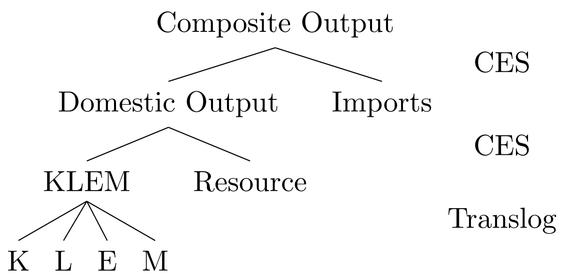
Notes: There are different numbers of entries in each column because every commodity which is an input has a cost share, which defines nonnegativity. However, only composite commodities have cost functions, which defines monotonicity.

problem for commodities E and M. I attempt to mitigate the concavity problem through the use of a Cholesky decomposition as detailed in Appendix B.2.1. But Table B.3's results are what is obtained after all efforts to improve the function's concavity have been implemented.

B.3 Other Cost Functions

The translog cost function describes how the various KLEM goods, the domestic outputs of each industry, are produced. However, the KLEM good cannot be directly used to satisfy demand for a commodity. In order to create composite output that can satisfy demand, KLEM must be combined with the energy resource to create domestic output and then domestic output must be combined with imports to produce composite output. This process is diagrammed in Figure B.1.

Figure B.1: Tiers and Cost Functions to Create Composite Output



Notes: See Section 3.3.3 for the tier structure of producing KLEM.

However, the step of combining KLEM and the energy resource only applies to the industry of oil and gas extraction. For all other industries, the energy resource is not used: $q_{x,resource} = 0$ and $p_{x,dom} = p_{x,KLEM}$ if $x \neq$ oil and gas extraction.

B.3.1 Domestic Output

Domestic output is created using a constant elasticity of substitution cost function with two inputs, KLEM, the output of the translog cost function, and the energy resource. The cost function for domestic output is

$$c_{dom}(p_{KLEM}, p_r) = \frac{1}{\phi_{dom}}(\alpha_r^{\theta_r} p_r^{1-\theta_r} + \alpha_{KLEM}^{\theta_r} p_{KLEM}^{1-\theta_r})^{\frac{1}{1-\theta_r}} \tag{B.21}$$

with

$$\alpha_{KLEM} = 1 - \alpha_r \tag{B.22}$$

and

$$\phi_{dom} = (\alpha_r^{\theta_r} p_{r2005}^{1-\theta_r} + \alpha_{KLEM}^{\theta_r} p_{KLEM,2005}^{1-\theta_r})^{\frac{1}{1-\theta_r}} / p_{dom,2005}. \tag{B.23}$$

The cost share of the resource is

$$\frac{u_r}{u_r + u_{KLEM}} = \frac{\alpha_r^{\theta_r} p_r^{1-\theta_r}}{\alpha_r^{\theta_r} p_r^{1-\theta_r} + \alpha_{KLEM}^{\theta_r} p_{KLEM}^{1-\theta_r}} \tag{B.24}$$

and the value of α_{KLEM} is calibrated for the year 2005 by solving for the α_{KLEM} that gives the 2005 cost share of the resource is

$$\frac{u_{r,2005}}{u_{r,2005} + u_{KLEM,2005}} = \frac{\alpha_r^{\theta_r} p_{r,2005}^{1-\theta_r}}{\alpha_r^{\theta_r} p_{r,2005}^{1-\theta_r} + \alpha_{KLEM}^{\theta_r} p_{KLEM,2005}^{1-\theta_r}}. \tag{B.25}$$

The assumption of perfectly competitive markets means that p_{KLEM} is equal to the cost times one plus the production tax rate

$$p_{dom} = c_{dom}(1 + \tau_{production}). \tag{B.26}$$

B.3.2 Imports and Composite Output

Like domestic output, composite output is created using a constant elasticity of substitution cost function in two variables: the price of domestic output p_{dom} and imports p_{import}.

$$p_{com} = c_{com}(p_{dom}, p_{import}) = \frac{1}{\phi_{com}}(\alpha_{dom}^{\theta_{Arm}} p_{dom}^{1-\theta_{Arm}} + \alpha_{import}^{\theta_{Arm}} p_{import}^{1-\theta_{Arm}})^{1/(1-\theta_{Arm})} \tag{B.27}$$

where

$$\phi_{com} = (\alpha_{dom}^{\theta_{Arm}} + \alpha_{import}^{\theta_{Arm}})^{1/(1-\theta_{Arm})}. \tag{B.28}$$

This value of ϕ was chosen so that if input prices are equal, they equal composite price

$$c_{com}(x, x) = x. \tag{B.29}$$

Solving for α_{import} in terms of the other variables gives

$$\alpha_{import} = \left(\frac{u_{import}}{u_{domestic} + u_{import}} \left(\frac{p_{dom}}{p_{import}} \right)^{1-\theta_{Arm}} \right)^{\dfrac{1}{\theta_{Arm}}} \tag{B.30}$$

and

$$\alpha_{import} = 1 - \alpha_{dom}. \tag{B.31}$$

p_{import} is assumed to be exogenous to the model. For convenience, I assume $p_{import} = p_{dom,2005}$ but any value of p_{import} can be used without affecting results due to the way the other parameters are defined.

In order to parametrize α_{import}, it is partially calibrated as

$$\alpha_{import} = \left(\frac{u_{import,2005}}{u_{dom,2005} + u_{import,2005}} \left(\frac{p^{*}_{dom}}{p_{import}} \right)^{1-\theta_{Arm}} \right)^{\dfrac{1}{\theta_{Arm}}} \tag{B.32}$$

where p^{*}_{dom} is the value of p_{dom} for a simulation using the model baseline specification's elasticity parameter values under current law. p^{*}_{dom} is used instead of $p_{dom,2005}$ which would calibrate α_{import} for 2005 data.

Although $p_{dom,2005}$ could be used, that would be a mistake. Because portions of the model such as the translog firm cost and consumer expenditure functions are not calibrated, 2005 prices are not equilibrium prices for the model, but differ slightly. This is important for import substitution because of the extremely high Armington elasticities involved, especially for the critically important fossil fuel production sectors. These large elasticities mean that the non-equilibrium prices of $p_{dom,2005}$ would cause imports to be very different under the model's current law equilibrium than the empirical values in the data. Calibrating α_{import} off of an equilibrium price such as p^{*}_{dom} ensures that the model's equilibrium import levels are closer to the empirical values than would be achieved with calibration to 2005 prices.

B.4 Removing the Energy Resource From the Capital Stock

Since the "other" data include energy resource acquisition expenditures as part of capital expenditures, these expenditures are subtracted as follows:

$$q_{jkt,BASELINE} = q_{jk2005} - \frac{u_{r,2005}}{p_{jk2005}}. \tag{B.33}$$

Some translog equation parameters are similarly adjusted to give the proper cost shares of each input. For any $i \in \{k, l, e, m\}$, if $x =$ oil and gas extraction

$$\beta_{xi}^{shareconstant} = \beta_{xi}^{shareconstant,OLD} + \frac{u_{x,i,BASELINE}}{u_{x,o,BASELINE}} - \frac{u_{x,i,2005}}{u_{x,o,2005}}. \tag{B.34}$$

For the same reason, the prices observed in the data set are p_{dom}, not p_{KLEM}. For most industries, the two are identical. But for oil and gas extraction where $p_{dom} \neq p_{KLEM}$, p_{KLEM} is imputed from p_{dom} as follows:

$$p_{KLEM} = p_{dom} \prod_{i \in k,l,e,m} (p_{xi2005})^{\frac{u_{x,i,BASELINE}}{u_{x,o,BASELINE}} - \frac{u_{x,i,2005}}{u_{x,o,2005}}}. \tag{B.35}$$

Note however that since AQC (defined in Appendix B.5.3) can only be calculated for a single year and not the entire data set, the regression to parametrize the translog cost function of oil and gas extraction includes resource acquisition expenditures as part of capital. This implicitly assumes that in the data, resource acquisition costs are a constant fraction of capital expenditures, either because $\frac{p_k}{p_r}$ is constant or $\theta_r = 0$.

B.5 Supply Functions

B.5.1 Capital

Total capital supply in the model is determined by the actual total capital supply in 2005 (net of resource subtraction, see Appendix B.4), the post-tax capital rental rate, and the price elasticity of capital supply as follows:

$$\sum_x q_{xk} = \sum_x q_{x,k,BASELINE} \left(\frac{(1-\tau_k)p_k/p_c}{(1-\tau_{k,2005})p_{k,2005}/p_{c,2005}} \right)^{\theta_{capital}}. \tag{B.36}$$

Capital is assumed to be perfectly mobile across industries such that for any two industries x and y:

$$(1-\tau_{xk})p_{xk} = (1-\tau_{yk})p_{yk}. \tag{B.37}$$

B.5.2 Labor

Total labor supply in the model is determined by the actual total labor supply in 2005, the post-tax wage rate, and the substitution elasticity of labor supply as follows:

$$\sum_x q_{xl} = \sum_x q_{x,l,2005} \left(\frac{(1-\tau_l)p_l/p_c}{(1-\tau_{l,2005})p_{l,2005}/p_{c,2005}} \right)^{\theta_{labor}}. \tag{B.38}$$

Labor is mobile across sectors but differential wage rates across sectors are assumed to be exogenously determined such that the relative wage rate across sectors stays fixed:

$$(1-\tau_l)p_l = \alpha(1-\tau_{l,2005})p_{l,2005} \tag{B.39}$$

for some $\alpha \in \mathbb{R}$.

B.5.3 Energy Resource

The total expenditures on the energy resource in 2005 is derived from the raw data as

$$u_{r,2005} = \sum_{t=2003}^{2005} AQC_t^{FRS} \frac{\sum_{t=2003}^{2005} R_t^{All}}{3\sum_{t=2003}^{2005} R_t^{FRS}} \tag{B.40}$$

where AQC_t^j is the expenditure by companies of type j on proved and unproved acreage in the US in year t in millions of 2009 dollars. R_t^{All} is total reserve additions of oil and gas in the US in millions of barrels of oil equivalents.[2] R_t^{FRS} is total reserve additions by Financial Reporting System (FRS) firms of oil and gas in the US in millions of barrels of oil equivalents. This method implicitly assumes FRS and non-FRS firms have the same cost of reserve additions. As suggested in U.S. Energy Information Administration (2011), three-year averages of the variables are used. $AQC_{Baseline}$ is then deflated from 2009 to 2005 dollars using the Urban

[2] 1 billion cubic feet feet of natural gas equals 0.178 million barrels of oil equivalents (U.S. Energy Information Administration, 2011).

Consumer Price Index. From this, total resource supply in the model is equal to

$$q_r = q_{r,2005} \left(\frac{(1-\tau_r)p_r/p_c}{(1-\tau_{r,2005})p_{r,2005}/p_{c,2005}} \right)^{\theta_{resource}}. \tag{B.41}$$

B.6 Demand Functions

Demand for the composite commodities comes from 5 sources: exports, government demand, household consumption demand, and household investment demand or

$$q_{final} = q_{export} + q_{government} + q_{consumption} + q_{investment}. \tag{B.42}$$

The market clearing condition of the equilibrium requires demand to equal supply:

$$q_{final} = q_{com}. \tag{B.43}$$

This section describes the various sources of final demand for the composite good in more detail.

B.6.1 Household Consumption Demand

There is no explicit functional form for the consumer demand function: it is implicitly defined by the series of nested translog expenditure functions. The price of household consumption resulting from the translog expenditure functions is p_c and the quantity of consumption is q_c.

B.6.2 Firm Intermediate Good Demand

There is no explicit functional form for the firm intermediate good demand function: it is implicitly defined by the series of nested translog cost functions.

B.6.3 Government Demand

Government demand is equal to government consumption and investment spending and equal in nominal value to its 2005 spending:

$$q_{government} = q_{government,2005} \frac{p_{com}}{p_{com,2005}}. \tag{B.44}$$

B.6.4 Household Investment Demand

Household investment demand of composite commodity is equal to:

$$q_{investment} = \frac{\sum_x q_{x,k}}{\sum_x q_{x,k,2005}} \frac{p_{com}}{p_{com,2005}} S_{inv,2005} \tag{B.45}$$

where $q_{investment}$ is vector of investment demand for the composite commodity and $S_{inv,2005}$ is equal to a vector of spending for private investment in 2005 for each industry.

B.6.5 Export Demand

Export demand is isoelastic in the price of the composite commodity:

$$q_{export} = q_{export,2005} \left(\frac{p_{com}}{p_{com,2005}} \right)^{\theta_{export}}. \tag{B.46}$$

B.6.6 Household Income and Spending

Households own all factors of production and receive income from their use. Post-tax income is calculated from the supply of capital, labor, and energy resources:

$$I_j = \sum_x q_{xk} p_{xk}(1 - \tau_{xk}) + q_{xl} p_{xl}(1 - \tau_{xl}) + q_{xr} p_{xr}(1 - \tau_{xr}) \tag{B.47}$$

where x indexes industry.

Household spending is given by:

$$S = \sum_x p_{com,x}(q_{consumption,x} + q_{investment,x}) \tag{B.48}$$

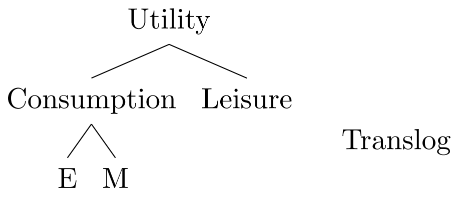
and the budget condition requires spending to equal income:

$$S = I. \tag{B.49}$$

B.7 Household Utility

A representative household maximizes utility by allocating income between consumption and leisure. This occurs in a two step process detailed in Figure B.2. The household first allocates income between leisure and composite consumption. Then the household allocates consumption spending among different consumption goods through the translog expenditure function.

Figure B.2: Household Utility



Notes: See Section 3.3.3 for the tier structure of producing KLEM. Consumers do not use capital, labor, or noncompeting imports but otherwise use the same structure as producers.

Expressed in terms of of the composite consumption good c, labor supply l, household utility is

$$U(q_c, q_l, b) = q_c - L_0 q_l^{1+1/\theta_{labor}} \tag{B.50}$$

where

$$L_0 = q_{l,2005}^{-1/\theta_{labor}} \frac{\theta_{labor}}{\theta_{labor}+1} \frac{(1-\tau_{l,2005})p_{l,2005}}{p_{c,2005}}. \tag{B.51}$$

The utility function is linear in consumption and the form of the labor term is chosen in order to generate the isoelastic labor supply of Equation B.38.

B.7.1 Externalities

The change in carbon emissions from the budget proposal is equal to

$$\Delta C = \Delta q_{min} C \tag{B.52}$$

where Δq_{min} is equal to the smallest percent decrease in output by a fossil fuel producing sector and C is the total US 2011 greenhouse gas emissions in metric tons of carbon dioxide equivalents from Table ES-2 in `http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2011.pdf`.

Greenhouse gas emissions are not the only externalities from the production or use of fossil fuels. Other sources of externalities include water use, air and water pollution, and energy security. These other externalities are not explicitly included in the model.

B.8 Government Revenue

Total government tax revenue T_{total} is equal to the sum of the revenue from all sources: capital, labor, energy resources, and production as given by the following equations:

$$T_{capital} = \sum_x q_{xk} p_{xk} \tau_{capital,x} \tag{B.53}$$

$$T_{labor} = \sum_x q_{xl} p_{xl} \tau_{labor,x} \tag{B.54}$$

$$T_{resource} = q_r p_r \tau_{resources} \tag{B.55}$$

$$T_{production} = \sum_x q_{dom,x} p_{dom,x} \frac{\tau_{production,x}}{1 + \tau_{production,x}} \tag{B.56}$$

$$T_{total} = T_{capital} + T_{labor} + T_{resource} + T_{production}. \tag{B.57}$$

Appendix C

Average Effective Tax Rates by Industry and Year

Although the AETR on capital, value of output, and total income are higher in fossil fuel production than other sectors, several readers have expressed concerns that these results may be driven by a few outlier industries or years. For example, years in the sample where oil company profits were extremely high might make the average tax rate over the entire period much higher than the median yearly rate. Tables C.1 and C.2 investigate this possibility by breaking results down by industry and year.

The most notable outliers in Table C.1 are the capital tax rates of management of companies and enterprises and real estate rental and leasing. Real estate rental and leasing is especially interesting because there is an extremely large capital stock in housing but this sector is typically non-corporate and thus would be missed in my measure of capital taxation. However, the removal of these two sectors does not change results. Removing real estate increases the capital AETR of all industries to 10.6 percent. Removing management of companies and enterprises reduces the capital AETR of all industries to 6.7 percent. In both cases, the capital AETR of fossil fuel production of 12.8 percent remains higher than the all industry average.

Table C.2 indicates that results are not driven by any particular year. AETR are higher for fossil fuel production than the all industry average on all measures and years with only one exception: capital in 1998.

Table C.1: Average Effective Tax Rates by Industry for 1998-2009 (Percent)

Industry	Capital	Value of Output	Factor Income
Management of Companies and Enterprises	138.7	12.7	22.5
Petroleum and Coal Products Manufacturing	21.1	5.2	22.2
Finance and Insurance	20.2	6.6	14.2
Retail Trade	15.8	17.4	26.2
Manufacturing	14.8	2.9	9.9
Fossil Fuel Production	12.8	7.4	28.5
Mining	9.5	5.8	15.6
Wholesale Trade	9.2	17.5	26.0
Utilities	8.9	14.4	34.0
Information	8.4	6.0	14.4
All Industries	7.5	5.9	12.3
Educational Services	7.2	3.4	6.0
Pipeline Transportation	6.1	7.5	29.1
Transportation and Warehousing	5.4	3.6	8.2
Oil and Gas Extraction	4.5	12.1	38.2
Accommodation and Food Services	4.1	7.1	13.7
Construction	3.2	1.0	2.2
Administrative, Support, and Waste Management	3.1	1.8	3.0
Health Care and Social Assistance	3.0	1.7	3.1
Professional, Scientific, and Technical Services	1.7	2.1	3.3
Arts, Entertainment, and Recreation	1.6	7.8	13.8
Other Services, Except Government	0.8	3.4	5.8
Agriculture, Forestry, Fishing, and Hunting	0.7	-2.6	-8.5
Real Estate and Rental and Leasing	0.3	8.1	14.0

Table C.2: Average Effective Tax Rates by for Select Industries for 1998-2009 (Percent)

Year	Fossil Fuel Production			All Industries		
	Capital	Value of Output	Factor Income	Capital	Value of Output	Factor Income
2009	5.8	6.3	26.7	5.4	5.8	11.7
2008	11.3	6.7	27.6	6.2	5.6	12.0
2007	15.1	7.9	31.0	9.0	6.2	13.2
2006	17.4	8.6	31.9	10.0	6.5	13.7
2005	17.4	8.9	29.6	9.3	6.3	13.2
2004	15.2	8.8	27.0	7.4	6.0	12.4
2003	9.8	7.1	23.4	6.5	5.8	11.8
2002	6.0	5.6	26.5	5.4	5.5	11.3
2001	10.7	7.0	25.0	5.9	5.3	11.0
2000	17.5	7.1	33.1	8.1	5.7	12.0
1999	10.2	6.0	32.5	8.2	5.9	12.3
1998	7.7	6.7	26.8	8.4	6.0	12.5

Appendix D

Cost and Expenditure Function Parameters for the Energy Model

This section lists the parameters estimated for the firm cost and consumer expenditure functions in the energy model. These parameters are from the baseline regression specification that uses iterated three-stage least squares with one period lagged prices as instruments.

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta_{x,48}^{share\,constant}$	$\beta_{x,42}^{share\,constant}$	$\beta_{x,48}^{share\,trend}$	$\beta_{x,42}^{share\,trend}$	$\beta_{x,48,48}^{substitution}$
11	0.98465	0.0006466	-0.0003392	0.00024872	0.0011457
21	0.98533	0.0062419	-0.00026327	0.00019132	0.010808
22	0.97148	0.011245	-0.00016707	0.00012486	0.016922
23	0.8925	0.057408	-0.00034615	0.00025872	0.086997
31	0.98154	-0.00014664	-0.00035065	0.00025857	-0.00054835
42	-0.06449	1.0637	0.00014387	-0.00025297	-0.06867
44	-0.064609	1.0637	0.00014383	-0.00025288	-0.068812
48	0.24949	0.51611	0.00028272	-0.00019139	0.18693
51	-0.014167	0.59397	0.00015868	-4.511e-05	-0.014696
52	-0.019414	1.022	0.00024859	-0.00032279	-0.019864
53	-0.046317	1.0173	0.00024212	-0.00030629	-0.048568
54	-0.097173	1.0547	0.00018556	-0.00026577	-0.1084
55	-0.01935	1.0216	0.0002495	-0.00032326	-0.019791
56	0.99485	-0.0075879	-0.00021848	0.00016333	-0.0062376
61	-0.098139	1.0543	0.00018536	-0.00026511	-0.1095
62	-0.11713	1.0683	0.00020421	-0.00027879	-0.13265
71	0.99904	-0.02599	-0.00032729	0.00024969	-0.032015
72	-0.082825	1.061	0.0001711	-0.00026407	-0.091098
81	-0.078409	1.0558	0.00018209	-0.00027071	-0.084634
211	0.9905	0.0034963	-0.00030663	0.00022212	0.0075307
324	0.99185	0.0032995	-0.0002723	0.00019682	0.0055958
486	0.25339	0.5133	0.00028104	-0.00019018	0.18885
Consumer	0.84054168	-0.080264	-0.00034917	0.00015225	0.11876

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta^{substitution}_{x,48,42}$	$\beta^{substitution}_{x,48,44}$	$\beta^{substitution}_{x,42,42}$	$\beta^{substitution}_{x,42,44}$	$\beta^{share\ constant}_{x,44}$
11	-0.0013103	0.00016457	0.00056656	0.00074372	0.014705
21	-0.006949	-0.0038588	0.0042628	0.0026862	0.0084268
22	-0.011763	-0.0051593	0.0069434	0.0048192	0.01727
23	-0.061292	-0.025706	0.042357	0.018935	0.05009
31	6.038e-05	0.00048797	-0.00026334	0.00020296	0.018607
42	0.068509	0.00016176	-0.068993	0.00048385	0.00078083
44	0.068634	0.00017829	-0.06904	0.0004062	0.00094982
48	-0.13486	-0.052069	0.096958	0.037901	0.2344
51	0.0070345	0.0076618	-0.0096726	0.0026382	0.42019
52	0.019761	0.00010272	-0.023271	0.0035095	-0.0025925
53	0.045848	0.0027195	-0.046429	0.00058097	0.029016
54	0.10089	0.0075101	-0.092946	-0.0079392	0.042512
55	0.019718	7.301e-05	-0.023161	0.0034433	-0.0022648
56	0.0072301	-0.00099247	-0.011424	0.004194	0.012742
61	0.1016	0.0079015	-0.09339	-0.0082111	0.043826
62	0.11957	0.013086	-0.10612	-0.013451	0.048876
71	0.025227	0.0067881	-0.027148	0.0019205	0.026946
72	0.085522	0.0055762	-0.082726	-0.002796	0.021799
81	0.082099	0.0025357	-0.080536	-0.0015626	0.022603
211	-0.004607	-0.0029237	0.0021674	0.0024396	0.0059991
324	-0.0034168	-0.002179	0.0022164	0.0012003	0.0048548
486	-0.13626	-0.05259	0.097977	0.03828	0.23332
Consumer	0.063152	-0.18191	-0.092752	0.0296	0.23972

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta^{substitution}_{x,44,44}$	$\beta^{share\ trend}_{x,44}$	$\beta^{share\ constant}_{x,54}$	$\beta^{share\ constant}_{x,81}$	$\beta^{share\ trend}_{x,54}$
11	-0.00090829	9.048e-05	-0.0039254	0.017602	3.976e-05
21	0.0011726	7.195e-05	-0.031025	-0.016029	8.37e-05
22	0.00034009	4.221e-05	0.079809	0.071525	9.833e-05
23	0.0067711	8.743e-05	-0.0086736	0.063695	0.00023395
31	-0.00069093	9.207e-05	-0.022623	0.002035	0.00020962
42	-0.00064561	0.0001091	0.0099605	0.048835	0.00012772
44	-0.00058449	0.00010905	0.0091167	0.0482	0.0001281
48	0.014168	-9.132e-05	0.033304	0.0056218	0.00013506
51	-0.0103	-0.00011357	0.092041	0.037291	0.00013462
52	-0.0036122	7.42e-05	0.00071496	0.014541	5.19e-05
53	-0.0033005	6.417e-05	-0.0070082	0.034377	7.607e-05
54	0.00042912	8.022e-05	0.038954	0.035845	0.00012246
55	-0.0035163	7.377e-05	0.0015531	0.014347	5.118e-05
56	-0.0032015	5.516e-05	-0.0073346	0.042446	0.00014806
61	0.00030954	7.974e-05	0.040207	0.037939	0.00012261
62	0.00036514	7.458e-05	0.039375	0.036519	0.00012306
71	-0.0087086	7.76e-05	0.029031	0.038969	0.00012798
72	-0.0027802	9.297e-05	0.022023	0.051212	0.0001299
81	-0.00097308	8.862e-05	0.043183	0.034768	0.00010518
211	0.00048412	8.451e-05	0.043266	0.020415	7.417e-06
324	0.00097866	7.548e-05	1.0884	-0.03665	-0.00038838
486	0.01431	-9.086e-05	0.033267	0.0060243	0.00013515
Consumer	0.15231	0.00019693	-0.1094	1.117	0.00010636

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta_{x,81}^{share\,trend}$	$\beta_{x,54,54}^{substitution}$	$\beta_{x,54,81}^{substitution}$	$\beta_{x,54,52}^{substitution}$	$\beta_{x,81,81}^{substitution}$
11	1.492e-05	-0.0045726	-0.0019813	0.0065539	-0.00021887
21	4.208e-05	-0.102	-0.0086035	0.1106	-0.02094
22	2.06e-05	0.047135	-0.0098445	-0.03729	0.063265
23	6.329e-05	-0.013311	-0.0047888	0.018099	0.0022554
31	8.349e-05	-0.023676	-0.00099797	0.024674	-0.014755
42	3.494e-05	-0.023191	-0.0071319	0.030323	-0.0029557
44	3.525e-05	-0.022952	-0.0070545	0.030006	-0.0029287
48	6.437e-05	0.031884	-0.00020766	-0.031676	0.0055887
51	5.928e-05	0.078571	-0.0063706	-0.072201	0.029568
52	2.209e-05	-0.010395	-0.0040622	0.014457	-0.0013879
53	1.971e-05	-0.013624	-0.0048097	0.018434	-0.0013377
54	4.498e-05	-0.0051975	-0.0031048	0.0083023	-7.945e-05
55	2.208e-05	-0.012017	-0.0046761	0.016694	-0.0016203
56	4.26e-05	-0.0080128	-0.0042673	0.01228	0.00019376
61	4.422e-05	-0.0060196	-0.0033572	0.0093767	-0.00017599
62	4.495e-05	-0.0059383	-0.0034068	0.0093452	-0.0001914
71	4.362e-05	-0.0063428	-0.003429	0.0097718	-8.438e-05
72	3.684e-05	-0.0084761	-0.0031339	0.01161	-0.00020506
81	3.988e-05	-0.002379	-0.0024131	0.0047921	0.00022158
211	7.845e-06	-0.063691	-0.0054632	0.069155	0.017203
324	7.016e-05	-0.096706	0.039866	0.05684	-0.038001
486	6.42e-05	0.032033	-0.00039	-0.031643	0.0057066
Consumer	-0.00037558	-0.12338	0.11731	0.0060624	-0.17067

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta^{substitution}_{x,81,52}$	$\beta^{share\ constant}_{x,52}$	$\beta^{substitution}_{x,52,52}$	$\beta^{share\ trend}_{x,52}$	$\beta^{share\ constant}_{x,11}$
11	0.0022002	0.98632	-0.0087541	-5.468e-05	0.22158
21	0.029544	1.0471	-0.14015	-0.00012578	-0.0078169
22	-0.05342	0.84867	0.090711	-0.00011893	0.0023984
23	0.0025334	0.94498	-0.020633	-0.00029724	-0.039079
31	0.015753	1.0206	-0.040427	-0.00029311	0.96483
42	0.010088	0.9412	-0.04041	-0.00016267	0.0077152
44	0.0099832	0.94268	-0.03999	-0.00016335	0.0061698
48	-0.005381	0.96107	0.037057	-0.00019943	-2.037e-05
51	-0.023197	0.87067	0.095398	-0.0001939	-0.0020161
52	0.0054501	0.98474	-0.019908	-7.399e-05	-0.066298
53	0.0061473	0.97263	-0.024581	-9.578e-05	-0.045896
54	0.0031843	0.9252	-0.011487	-0.00016744	-0.0066825
55	0.0062964	0.9841	-0.02299	-7.326e-05	-0.062916
56	0.0040736	0.96489	-0.016354	-0.00019066	-0.0045602
61	0.0035332	0.92185	-0.01291	-0.00016683	-0.01955
62	0.0035982	0.92411	-0.012943	-0.00016801	-0.017597
71	0.0035134	0.932	-0.013285	-0.0001716	-0.016625
72	0.003339	0.92677	-0.014949	-0.00016674	-0.023466
81	0.0021915	0.92205	-0.0069836	-0.00014506	-0.017474
211	-0.01174	0.93632	-0.057415	-1.526e-05	-0.00094635
324	-0.0018655	-0.051736	-0.054974	0.00031821	-0.0012445
486	-0.0053166	0.96071	0.036959	-0.00019935	-6.839e-05
Consumer	0.053353	-0.0076392	-0.059415	0.00026922	0.15417

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta_{x,11}^{share\,trend}$	$\beta_{x,11,11}^{substitution}$	$\beta_{x,11,31}^{substitution}$	$\beta_{x,31}^{share\,constant}$	$\beta_{x,31,31}^{substitution}$
11	0.0002159	0.17245	-0.17115	0.77096	0.16951
21	5.727e-06	-0.007878	0.0075173	0.96167	0.036012
22	2.111e-06	0.0023916	-0.00034291	0.13057	0.11258
23	3.832e-05	-0.040903	0.039587	1.0256	-0.037192
31	-0.00042343	0.001335	-0.0053263	0.0049677	0.0049166
42	2.544e-05	0.007378	-0.007515	0.95903	0.018302
44	2.638e-05	0.0053543	-0.006584	0.96914	0.020347
48	1.575e-06	-2.385e-05	1.568e-05	0.87211	0.1109
51	4.914e-06	-0.0021326	0.0010893	0.85753	0.10163
52	0.00010142	-0.091648	0.048453	0.95786	0.026525
53	5.446e-05	-0.058262	0.030658	0.94318	0.037963
54	1.495e-05	-0.006827	-0.00067143	0.13429	0.0322
55	0.00010067	-0.091261	0.047818	0.96466	0.027289
56	1.162e-05	-0.0045929	0.0043137	0.98668	0.006094
61	2.061e-05	-0.020051	0.017364	0.91799	0.01484
62	1.962e-05	-0.018256	0.015152	0.93094	0.022518
71	1.934e-05	-0.020425	0.012157	0.9669	0.012056
72	2.725e-05	-0.024113	0.021661	0.95304	-0.010704
81	2.157e-05	-0.026585	0.016419	0.96578	0.008902
211	1.369e-06	-0.00094725	0.00017365	0.19552	0.027897
324	1.702e-06	-0.0012461	0.00034375	0.27621	0.19049
486	1.561e-06	-0.00010294	3.558e-05	0.89203	0.096246
Consumer	-5.555e-05	0.057424	-0.057424	0.84583	0.057424

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta_{x,31}^{share\,trend}$	$\beta_{x,21}^{share\,constant}$	$\beta_{x,n}^{share\,constant}$	$\beta_{x,11,21}^{substitution}$	$\beta_{x,31,21}^{substitution}$
11	-0.00021365	-0.0016344	0.0090906	0.00032188	0.00050704
21	-0.00021767	0.012951	0.033191	0.00010118	-0.014047
22	6.955e-05	0.86203	0.0050016	-0.0020801	-0.11307
23	-4.536e-05	0.00044483	0.013017	1.648e-05	-0.00061089
31	0.00042593	-0.0011156	0.031318	-0.00055802	-0.0001945
42	-2.697e-05	-0.0010086	0.034261	-0.00012534	0.00044156
44	-3.248e-05	-0.00074116	0.025436	-6.308e-05	0.00047654
48	-0.00011944	-0.00088112	0.1288	-1.434e-05	0.00074794
51	-1.164e-05	-0.0021738	0.14666	-7.4e-05	0.0014257
52	-0.00013589	-0.011153	0.11959	-0.0007491	0.010549
53	-5.079e-05	-0.0043855	0.10711	-0.00044935	0.003828
54	0.00041128	0.0031799	0.86921	1.041e-05	-0.00061205
55	-0.00014154	-0.011375	0.10963	-0.00078023	0.010937
56	-4.515e-05	-0.0011448	0.019022	-1.497e-05	0.00079196
61	1.767e-05	0.00010224	0.10146	-2.288e-06	-0.00025488
62	9.487e-06	0.00026157	0.086397	-3.02e-05	-0.00046015
71	-1.133e-05	-0.0015833	0.05131	-3.933e-05	0.0011605
72	-4.734e-06	-0.0016741	0.072096	-6.768e-05	0.0012475
81	-1.018e-05	-0.0015903	0.053287	-0.00013042	0.0012956
211	0.00019873	0.51369	0.29173	0.00048558	-0.1093
324	-4.208e-06	0.70585	0.01918	0.00087844	-0.19501
486	-0.00012874	-0.00078947	0.10883	-5.399e-08	0.00065825
Consumer	5.555e-05	0	0	0	0

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta^{substitution}_{x,21,21}$	$\beta^{substitution}_{x,21,n}$	$\beta^{substitution}_{x,11,n}$	$\beta^{substitution}_{x,31,n}$	$\beta^{substitution}_{x,n,n}$
11	-0.0018194	0.0009905	-0.0016263	0.0011335	-0.00049773
21	0.0064341	0.0075113	0.00025952	-0.029482	0.021712
22	0.1155	-0.00035569	3.142e-05	0.0008262	-0.00050193
23	4.233e-05	0.00055208	0.0012989	-0.001785	-6.602e-05
31	-0.0047541	0.0055066	0.0045493	0.00060422	-0.01066
42	-0.001182	0.00086573	0.00026231	-0.011229	0.010101
44	-0.00075535	0.00034189	0.0012927	-0.014239	0.012605
48	-0.00094115	0.00020756	2.252e-05	-0.11166	0.11143
51	-0.0022512	0.00089952	0.0011174	-0.10415	0.10213
52	-0.01135	0.0015505	0.043944	-0.085527	0.040032
53	-0.004411	0.0010324	0.028053	-0.072449	0.043363
54	0.0030375	-0.0024359	0.007488	-0.030916	0.025864
55	-0.011506	0.0013491	0.044223	-0.086043	0.040471
56	-0.0015346	0.0007576	0.00029413	-0.0112	0.010148
61	7.333e-05	0.00018384	0.0026895	-0.031949	0.029076
62	0.00011633	0.00037402	0.0031349	-0.037209	0.033701
71	-0.0016093	0.00048813	0.008307	-0.025374	0.016579
72	-0.0017942	0.00061436	0.0025194	-0.012205	0.0090709
81	-0.0016	0.00043484	0.010296	-0.026617	0.015886
211	0.24729	-0.13848	0.00028803	0.081232	0.056955
324	0.20763	-0.013494	2.387e-05	0.0041783	0.0092921
486	-0.00084925	0.00019105	6.742e-05	-0.09694	0.096682
Consumer	0	0	0	0	0

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta_{x,21}^{share\,trend}$	$\beta_{x,n}^{share\,trend}$	$\beta_{x,61}^{share\,constant}$	$\beta_{x,62}^{share\,constant}$	$\beta_{x,71}^{share\,constant}$
11	2.051e-06	-4.304e-06	0.95831	-0.062833	0.019195
21	0.00021064	1.299e-06	0.0098597	0.055976	0.11863
22	-7.025e-05	-1.407e-06	0.0082316	0.70553	0.021329
23	1.328e-05	-6.241e-06	0.95606	-0.063614	-0.0019015
31	9.93e-06	-1.243e-05	0.0061013	0.81692	-0.013936
42	6.283e-07	8.95e-07	0.0035377	0.28463	0.019372
44	5.143e-07	5.582e-06	0.0025712	0.29244	0.01239
48	1.298e-06	0.00011656	0.0086339	0.78105	-0.050288
51	1.316e-06	5.413e-06	0.0017612	0.87541	0.0056762
52	1.042e-05	2.405e-05	0.0047866	0.89531	0.010058
53	4.009e-06	-7.673e-06	0.0012024	0.87501	0.0085755
54	-4.039e-07	-0.00042582	0.0030739	0.32602	0.014578
55	1.058e-05	3.028e-05	0.0047984	0.89581	0.010181
56	1.224e-06	3.231e-05	0.00419	0.22848	0.0069495
61	2.673e-07	-3.854e-05	0.0030821	0.32709	0.014628
62	2.155e-07	-2.932e-05	0.0030909	0.32469	0.01404
71	8.576e-07	-8.866e-06	0.0031365	0.31726	0.01222
72	8.389e-07	-2.336e-05	0.0033955	0.30566	0.022371
81	1.037e-06	-1.243e-05	0.0048959	0.26143	0.024654
211	-0.00010679	-9.331e-05	0.0040542	0.79624	-0.022837
324	1.223e-06	1.283e-06	0.00018371	1.0473	0.0031448
486	1.271e-06	0.00012591	0.0083411	0.79878	-0.059907
Consumer	0	0	0.073593	-0.38565	0.24501

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta_{x,61}^{share\,trend}$	$\beta_{x,62}^{share\,trend}$	$\beta_{x,71}^{share\,trend}$	$\beta_{x,61,61}^{substitution}$	$\beta_{x,61,62}^{substitution}$
11	-0.00047686	0.00038201	3.726e-05	0.039004	0.060162
21	1.951e-06	0.00034635	-1.198e-05	0.0080024	-0.00078535
22	2.896e-06	2.661e-05	3.806e-05	0.008142	-0.0067854
23	-0.00047491	0.00040796	4.539e-05	0.024578	0.060775
31	3.857e-06	-4.15e-05	5.234e-05	0.0059518	-0.0064234
42	5.607e-06	0.00024333	3.511e-05	0.0028593	-0.0025818
44	6.099e-06	0.00023938	3.863e-05	0.0019306	-0.0022833
48	2.453e-06	-1.264e-05	7.841e-05	0.0084741	-0.0076994
51	6.542e-06	-5.273e-05	4.216e-05	0.0017052	-0.0028432
52	5.014e-06	-6.172e-05	4.044e-05	0.0045089	-0.0065927
53	6.831e-06	-5.196e-05	4.109e-05	0.0011468	-0.0021806
54	5.888e-06	0.0002245	3.764e-05	0.0022691	-0.0027685
55	5.008e-06	-6.196e-05	4.038e-05	0.0045189	-0.0066081
56	5.236e-06	0.0002726	4.254e-05	0.0039083	-0.0047598
61	5.884e-06	0.00022397	3.761e-05	0.0022695	-0.0027769
62	5.877e-06	0.00022514	3.795e-05	0.002302	-0.0027697
71	5.844e-06	0.00022876	3.899e-05	0.0024108	-0.0027519
72	5.715e-06	0.00023437	3.369e-05	0.0026688	-0.0027936
81	4.955e-06	0.00025712	3.259e-05	0.0044105	-0.0056148
211	5.124e-06	-2.121e-05	5.821e-05	0.0040167	-0.0040575
324	6.391e-06	-0.00016892	4.809e-05	-0.00022594	-0.0014235
486	2.598e-06	-2.164e-05	8.333e-05	0.008181	-0.0076313
Consumer	2.762e-06	0.00051643	-9.28e-05	0.064982	0.028115

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta^{substitution}_{x,61,71}$	$\beta^{substitution}_{x,61,72}$	$\beta^{substitution}_{x,62,62}$	$\beta^{substitution}_{x,62,71}$	$\beta^{substitution}_{x,62,72}$
11	-0.019634	-0.079533	-0.066986	0.00093405	0.0058892
21	-0.0072831	6.603e-05	0.045938	-0.016942	-0.028211
22	-0.00048555	-0.00087111	0.13917	-0.043073	-0.08931
23	-0.00053833	-0.084814	-0.067794	-0.00044851	0.0074672
31	-0.00031991	0.00079147	0.10979	0.00034634	-0.10371
42	-0.0017895	0.0015119	-0.0031	-0.013769	0.019451
44	-0.0008888	0.0012415	-0.00229	-0.014531	0.019104
48	-0.00045079	-0.00032395	0.094041	0.0098382	-0.09618
51	-0.0001231	0.0012611	0.052121	-0.011402	-0.037876
52	-0.00036436	0.0024481	0.057248	-0.015209	-0.035447
53	-0.00017507	0.0012088	0.045729	-0.013974	-0.029574
54	-0.0010091	0.0015085	-0.0048901	-0.016165	0.023824
55	-0.00036445	0.0024536	0.057374	-0.01525	-0.035516
56	-0.00018759	0.0010391	-0.0051166	-0.0097901	0.019667
61	-0.0010046	0.001512	-0.0048986	-0.016155	0.023831
62	-0.0010224	0.0014902	-0.0048508	-0.016042	0.023662
71	-0.0010744	0.0014156	-0.004596	-0.015657	0.023005
72	-0.0014389	0.0015636	-0.0050816	-0.014587	0.022462
81	-0.00085113	0.0020554	-0.0040099	-0.018026	0.027651
211	-1.391e-05	5.469e-05	0.082165	0.005932	-0.084039
324	-0.00094308	0.0025925	-0.069152	-0.012057	0.082632
486	-0.00038419	-0.00016551	0.086269	0.019313	-0.097951
Consumer	-0.01805	-0.075048	-0.55129	0.090745	0.43243

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta_{x,71,71}^{substitution}$	$\beta_{x,71,72}^{substitution}$	$\beta_{x,72}^{share\ constant}$	$\beta_{x,72,72}^{substitution}$	$\beta_{x,72}^{share\ trend}$
11	0.016769	0.001931	0.08533	0.071712	5.759e-05
21	0.014774	0.0094511	0.81553	0.018694	-0.00033632
22	-0.016719	0.060277	0.2649	0.029904	-6.756e-05
23	-0.0046596	0.0056464	0.10946	0.071701	2.156e-05
31	-0.019839	0.019813	0.19091	0.083105	-1.469e-05
42	0.011032	0.0045268	0.69246	-0.02549	-0.00028405
44	0.0098576	0.005562	0.6926	-0.025907	-0.00028411
48	-0.085711	0.076323	0.2606	0.02018	-6.823e-05
51	0.0026021	0.0089229	0.11715	0.027692	4.036e-06
52	0.0075609	0.008012	0.089843	0.024987	1.626e-05
53	0.0053795	0.0087698	0.11521	0.019596	4.034e-06
54	0.011122	0.0060525	0.65633	-0.031385	-0.00026803
55	0.0075968	0.0080179	0.089211	0.025044	1.657e-05
56	-0.0072123	0.01719	0.76038	-0.037896	-0.00032037
61	0.011121	0.0060386	0.6552	-0.031381	-0.00026746
62	0.010631	0.0064332	0.65818	-0.031585	-0.00026897
71	0.0089953	0.0077363	0.66738	-0.032157	-0.0002736
72	0.011108	0.0049178	0.66858	-0.028944	-0.00027378
81	0.013866	0.0050112	0.70902	-0.034717	-0.00029467
211	-0.031514	0.025595	0.22254	0.058389	-4.213e-05
324	-0.030572	0.043571	-0.050632	-0.1288	0.00011444
486	-0.095396	0.076467	0.25279	0.02165	-6.429e-05
Consumer	0.081815	-0.15451	1.0671	-0.20287	-0.00042639

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta_{x,53}^{share\,constant}$	$\beta_{x,53}^{share\,trend}$	$\beta_{x,53,53}^{substitution}$	$\beta_{x,53,mot}^{substitution}$	$\beta_{x,mot}^{share\,constant}$
11	0.51923	-0.0002272	0.029853	-0.050921	0.52419
21	-0.022304	5.677e-05	-0.022831	-0.003459	-0.16423
22	0.57714	-0.00027427	0.082583	-0.13512	0.57818
23	0.077129	-2.268e-05	0.071173	-0.070217	0.91049
31	-0.019212	2.566e-05	-0.019997	0.0009517	-0.020369
42	-0.13164	0.00015291	-0.14897	-0.0013132	-0.010067
44	0.18463	-2.441e-05	0.1501	-0.17298	0.93946
48	-0.027139	3.401e-05	-0.02788	-0.0016173	-0.060557
51	0.29383	-8.509e-05	0.20724	-0.2447	0.8429
52	-0.39444	0.00041079	-0.55005	-0.041448	-0.10534
53	-0.30558	0.00032106	-0.39897	-0.024329	-0.08005
54	0.22787	-2.868e-05	0.17545	-0.2166	0.95814
55	-0.39542	0.0004118	-0.55178	-0.041759	-0.10561
56	0.2219	-6.198e-05	0.17266	-0.20314	0.91548
61	0.22661	-2.817e-05	0.17472	-0.21531	0.95486
62	-0.17259	0.000194	-0.20238	0.00017864	0.00075086
71	0.23687	-4.153e-05	0.18052	-0.22112	0.93511
72	0.22896	-3.379e-05	0.17632	-0.21363	0.93815
81	-0.19876	0.00021969	-0.23827	-0.0044889	-0.022793
211	-0.21091	0.00026979	-0.25539	-0.024552	-0.11643
324	0.0016146	1.249e-05	0.0015516	0.00035821	-0.16366
486	-0.031261	3.628e-05	-0.032402	-0.0020533	-0.071058
Consumer	0.32184	5.44e-05	0.16087	-0.16087	0.67816

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta^{substitution}_{x,mot,mot}$	$\beta^{share\ trend}_{x,mot}$	$\beta^{share\ constant}_{x,23}$	$\beta^{substitution}_{x,23,23}$	$\beta^{substitution}_{x,23,53}$
11	0.026548	0.00017456	-0.043418	-0.045442	0.021068
21	-0.19262	0.00051673	1.1865	-0.22237	0.02629
22	-0.026997	9.589e-06	-0.15533	-0.21465	0.052533
23	0.06851	2.214e-05	0.012379	-0.00075012	-0.00095635
31	-0.030579	0.00048034	1.0396	-0.048673	0.019046
42	-0.018036	0.00036473	1.1417	-0.16963	0.15028
44	0.021894	-0.00010297	-0.12409	-0.17396	0.022882
48	-0.09763	0.00049386	1.0877	-0.12874	0.029498
51	0.040529	-7.853e-05	-0.13673	-0.24163	0.037458
52	-0.11682	0.00021897	1.4998	-0.74976	0.5915
53	-0.093107	0.00026789	1.3856	-0.54074	0.4233
54	0.029977	-0.00016562	-0.186	-0.22778	0.041155
55	-0.11687	0.00021843	1.501	-0.75217	0.59354
56	0.069637	-7.19e-05	-0.13738	-0.16399	0.030484
61	0.029754	-0.00016396	-0.18147	-0.22614	0.040587
62	-0.0036623	0.00030721	1.1718	-0.20569	0.2022
71	0.049204	-0.000138	-0.17198	-0.21251	0.040598
72	0.046931	-0.00014244	-0.1671	-0.20401	0.037314
81	-0.030889	0.00030077	1.2216	-0.27814	0.24276
211	-0.13496	0.00034435	1.3273	-0.43945	0.27994
324	-0.21149	0.00054757	1.162	-0.20922	-0.0019098
486	-0.089541	0.00049943	1.1023	-0.12605	0.034456
Consumer	0.16087	-5.44e-05	0	0	0

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta^{substitution}_{x,23,mot}$	$\beta^{share\ trend}_{x,23}$	$\beta^{share\ constant}_{x,mss}$	$\beta^{share\ constant}_{x,51}$	$\beta^{share\ trend}_{x,mss}$
11	0.024373	5.264e-05	1.0161	0.0075348	-8.263e-05
21	0.19608	-0.00057349	0.0027037	0.80129	0.0004151
22	0.16211	0.00026468	0.19782	0.74802	0.00025636
23	0.0017065	5.43e-07	0.072151	0.95113	0.00029751
31	0.029627	-0.000506	0.15998	0.92425	0.00023831
42	0.01935	-0.00051765	0.071578	0.90222	0.00032217
44	0.15108	0.00012737	0.053842	0.90296	0.00033108
48	0.099247	-0.00052787	0.11255	0.92968	0.00023311
51	0.20417	0.00016362	-0.042058	1.075	0.00020595
52	0.15826	-0.00062976	-0.04055	0.96852	0.0004428
53	0.11744	-0.00058895	-0.017011	0.95491	0.0004128
54	0.18663	0.00019429	-0.0086758	0.94435	0.00035805
55	0.15863	-0.00063023	-0.041903	0.95604	0.00044373
56	0.13351	0.00013388	0.080829	0.93764	0.00030084
61	0.18556	0.00019213	0.016634	0.95489	0.00034481
62	0.0034836	-0.0005012	-0.0063166	0.96329	0.00035604
71	0.17191	0.00017953	0.017757	0.95143	0.00034327
72	0.1667	0.00017623	0.042683	0.91971	0.00033297
81	0.035378	-0.00052046	0.077911	0.85769	0.00032536
211	0.15951	-0.00061413	0.020306	0.95945	0.0004544
324	0.21113	-0.00056006	-0.008862	0.032179	0.00036009
486	0.091594	-0.00053572	0.11247	0.98161	0.00023269
Consumer	0	0	1.0743	-0.0056073	-0.00015337

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta_{x,51}^{share\,trend}$	$\beta_{x,mss,mss}^{substitution}$	$\beta_{x,mss,51}^{substitution}$	$\beta_{x,mss,56}^{substitution}$	$\beta_{x,51,51}^{substitution}$
11	3.104e-05	-0.0303	-0.015135	0.048085	-0.00058388
21	-0.00036624	-0.050782	-0.078368	0.13075	0.027259
22	-0.00030571	0.14744	-0.15455	0.0078246	0.012032
23	-0.00039088	0.066847	-0.069419	0.0025365	0.025472
31	-0.00036574	0.13434	-0.14812	0.014237	0.062779
42	-0.00035746	0.066379	-0.065547	-0.00074873	0.054802
44	-0.00035779	0.050176	-0.05269	0.0025089	0.043604
48	-0.0003653	0.099123	-0.11084	0.011212	-0.01073
51	-0.00025459	-0.044852	0.043545	0.0022138	-0.083509
52	-0.00043685	-0.042196	0.039126	0.0032447	-0.023693
53	-0.00041722	-0.028356	0.010176	0.019344	0.0014802
54	-0.00037471	-0.0098604	0.0019474	0.0081281	-0.021028
55	-0.0004308	-0.043659	0.039963	0.0039362	-0.022146
56	-0.00036834	0.074294	-0.075917	0.0015231	0.049138
61	-0.00038007	0.016281	-0.01725	0.0010237	0.0050926
62	-0.0003837	-0.0075267	-0.00020276	0.0081134	-0.024538
71	-0.00037821	0.016053	-0.022623	0.0070824	-4.308e-05
72	-0.00036359	0.038499	-0.044455	0.0066103	0.040385
81	-0.00033863	0.032923	-0.077478	0.046536	0.076955
211	-0.00046727	0.019728	-0.02151	0.0019032	0.0021193
324	3.386e-05	-0.1758	-0.042903	0.20996	0.019966
486	-0.00039141	0.099821	-0.11045	0.010109	-0.013216
Consumer	0.00010588	-0.086574	0.0046394	0.081935	-0.0065387

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta^{substitution}_{x,51,56}$	$\beta^{share\ constant}_{x,56}$	$\beta^{substitution}_{x,56,56}$	$\beta^{share\ trend}_{x,56}$	$\beta^{share\ constant}_{x,55}$
11	0.016047	-0.025704	-0.065704	4.214e-05	0.0020379
21	0.054423	0.19758	-0.19271	-5.9e-05	-0.0015699
22	0.14362	0.054393	-0.15359	4.312e-05	-0.0002334
23	0.043357	-0.020649	-0.048806	8.867e-05	-0.002628
31	0.088251	-0.086459	-0.10525	0.00012466	0.0022288
42	0.01248	0.026865	-0.015235	2.871e-05	-0.00066714
44	0.010543	0.044206	-0.015732	1.998e-05	-0.0010077
48	0.1192	-0.037636	-0.13304	0.00012519	-0.0045955
51	0.043104	-0.034213	-0.050425	4.659e-05	0.0012218
52	-0.017951	0.076176	0.012831	-1.799e-05	-0.0041489
53	-0.01374	0.067074	-0.010271	-7.06e-06	-0.0049689
54	0.021123	0.064112	-0.03163	1.089e-05	0.00021378
55	-0.020613	0.091519	0.013435	-2.58e-05	-0.0056585
56	0.026866	-0.01723	-0.030872	6.123e-05	-0.0012387
61	0.013614	0.028411	-0.01629	2.947e-05	6.848e-05
62	0.027263	0.043144	-0.038539	2.173e-05	-0.00011593
71	0.024864	0.030952	-0.035315	2.9e-05	-0.00014144
72	0.0046061	0.041048	-0.016436	2.283e-05	-0.0034424
81	0.0025807	0.064158	-0.053669	6.886e-06	0.00024089
211	0.021938	0.021417	-0.029202	4.013e-07	-0.0011767
324	0.054709	-0.0097026	-0.28902	9.695e-05	0.98639
486	0.12122	-0.089025	-0.13476	0.00015147	-0.0050597
Consumer	0.0018993	-0.06874	-0.083834	4.749e-05	0

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta^{substitution}_{x,mss,55}$	$\beta^{substitution}_{x,51,55}$	$\beta^{substitution}_{x,55,55}$	$\beta^{substitution}_{x,55,56}$	$\beta^{share\ trend}_{x,55}$
11	-0.0026507	-0.00032791	0.0014067	0.0015719	9.452e-06
21	-0.0015996	-0.0033138	-0.0026284	0.0075418	1.014e-05
22	-0.00071427	-0.001095	-0.00034342	0.0021527	6.235e-06
23	3.535e-05	0.00058964	-0.0035381	0.0029131	4.697e-06
31	-0.00045925	-0.0029087	0.00060765	0.0027603	2.775e-06
42	-8.242e-05	-0.0017342	-0.0016871	0.0035037	6.582e-06
44	5.838e-06	-0.0014569	-0.0012288	0.0026799	6.725e-06
48	0.00050719	0.00237	-0.0055041	0.0026269	6.995e-06
51	-0.00090664	-0.0031389	-0.0010624	0.0051079	2.043e-06
52	-0.00017432	0.0025177	-0.0042188	0.0018754	1.204e-05
53	-0.001163	0.0020845	-0.005589	0.0046675	1.149e-05
54	-0.00021514	-0.0020429	-0.00012048	0.0023785	5.768e-06
55	-0.00024097	0.002796	-0.0057972	0.0032421	1.288e-05
56	9.95e-05	-8.709e-05	-0.0024958	0.0024834	6.264e-06
61	-5.385e-05	-0.001456	-0.00014215	0.001652	5.79e-06
62	-0.00038391	-0.002522	-0.0002567	0.0031626	5.922e-06
71	-0.00051206	-0.0021982	-0.0006581	0.0033684	5.939e-06
72	-0.00065368	-0.00053604	-0.0040295	0.0052192	7.781e-06
81	-0.0019812	-0.0020576	-0.00051378	0.0045525	6.387e-06
211	-0.00012127	-0.0025472	-0.0026927	0.0053612	1.247e-05
324	0.0087414	-0.031772	-0.0013219	0.024352	-0.00049089
486	0.00052202	0.0024445	-0.0063971	0.0034306	7.257e-06
Consumer	0	0	0	0	0

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta_{x,mm}^{share\,constant}$	$\beta_{x,mp}^{share\,constant}$	$\beta_{x,ms}^{share\,constant}$	$\beta_{x,mm}^{share\,trend}$	$\beta_{x,mp}^{share\,trend}$
11	0.77427	0.024819	0.093248	-1.334e-05	-4.226e-06
21	0.17688	0.066603	0.31481	0.00023318	-1.462e-05
22	0.61141	0.057116	0.10939	-2.795e-05	-7.455e-07
23	0.76637	0.071424	0.11363	-7.366e-05	1.567e-06
31	0.4342	0.043375	0.099858	0.00016521	-3.924e-06
42	0.057623	0.064129	0.28381	0.00012281	4.817e-05
44	0.056409	0.062559	0.29148	0.00012348	4.887e-05
48	-0.0045794	0.9376	-0.0067208	0.00010542	-0.00042272
51	1.1222	0.10772	-0.0036803	-0.00042726	8.065e-06
52	0.025056	0.74121	-0.10281	2.417e-05	-0.00031723
53	0.57319	0.091124	0.19127	-0.0002201	2.48e-05
54	0.11607	1.0179	-0.16856	6.434e-05	-0.00042737
55	0.10799	0.19734	-0.13776	-1.77e-05	-4.073e-05
56	0.107	1.0296	-0.28984	6.761e-05	-0.0004503
61	0.11858	1.018	-0.1641	6.309e-05	-0.00042682
62	0.11671	1.0159	-0.16765	6.375e-05	-0.00042626
71	0.73411	0.078412	0.15033	-0.00024531	5.172e-05
72	0.64072	0.072125	0.15199	-0.0001916	5.38e-05
81	0.75141	0.075778	0.15191	-0.00025921	5.083e-05
211	-0.011785	0.11044	0.20604	0.00021837	-3.725e-05
324	0.036211	0.081683	0.2929	0.00021511	-1.703e-05
486	-0.0047148	0.9397	-0.0058667	0.00010547	-0.00042396
Consumer	0.73709	0.17229	-0.15926	-0.00026839	1.379e-05

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta^{share\ trend}_{x,ms}$	$\beta^{substitution}_{x,mm,mm}$	$\beta^{substitution}_{x,mm,mp}$	$\beta^{substitution}_{x,mm,ms}$	$\beta^{substitution}_{x,mm,mo}$
11	2.93e-06	0.16744	-0.01935	-0.073406	-0.074688
21	-8.787e-05	0.12634	-0.027706	-0.055684	-0.042949
22	1.152e-05	0.22511	-0.036027	-0.066886	-0.1222
23	-7.777e-06	-0.063882	-0.055583	-0.087188	0.20665
31	-2.216e-05	0.15591	-0.050633	-0.043579	-0.061695
42	3.371e-05	0.052421	-0.0037396	-0.01917	-0.029511
44	2.977e-05	0.053194	-0.0035289	-0.016777	-0.032888
48	0.00012391	-0.0070792	0.004282	-0.00069355	0.0034907
51	0.00024299	-0.16591	-0.12455	0.0016022	0.28886
52	0.00037747	0.0066601	-0.019599	-0.047725	0.060664
53	0.00017115	-0.027664	-0.062695	-0.10964	0.19999
54	0.00029702	-0.019083	-0.11877	-0.016686	0.15454
55	0.00039408	0.0013561	-0.021433	-0.066562	0.086639
56	0.00034195	-0.040338	-0.1106	-0.01522	0.16616
61	0.00029438	-0.023757	-0.12211	-0.016536	0.16241
62	0.00029541	-0.026475	-0.12069	-0.017877	0.16505
71	0.0001211	-0.019567	-0.066281	-0.11182	0.19767
72	0.00011834	-0.0064181	-0.058728	-0.10308	0.16822
81	0.00013361	0.0047459	-0.063981	-0.11425	0.17348
211	9.367e-05	-0.012469	0.0012094	0.0024282	0.0088312
324	-9.405e-05	0.026615	-0.0089314	-0.011	-0.0066834
486	0.0001231	-0.0058778	0.0043626	-0.00053225	0.0020474
Consumer	0.00021089	0.02568	-0.14186	0.086498	0.029678

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta^{substitution}_{x,mp,mp}$	$\beta^{substitution}_{x,mp,ms}$	$\beta^{substitution}_{x,mp,mo}$	$\beta^{substitution}_{x,ms,ms}$	$\beta^{substitution}_{x,ms,mo}$
11	0.023259	-0.0025554	-0.0013534	0.084292	-0.0083304
21	0.048996	-0.020968	-0.00032238	0.21571	-0.13905
22	0.053731	-0.0062482	-0.011455	0.097185	-0.024051
23	0.065803	-0.0081163	-0.0021037	0.099554	-0.0042499
31	0.028674	-0.0053031	0.027262	0.085006	-0.036124
42	0.059699	-0.019259	-0.0367	0.19391	-0.15548
44	0.058645	-0.018302	-0.036814	0.19371	-0.15863
48	0.055453	0.0055544	-0.06529	-0.0071243	0.0022634
51	0.095295	5.781e-05	0.029196	-0.19574	0.19408
52	0.19175	0.073279	-0.24543	-0.26051	0.23495
53	0.082354	-0.018182	-0.001477	0.13981	-0.011996
54	-0.022014	0.1697	-0.02892	-0.20855	0.05553
55	0.1584	0.027053	-0.16401	-0.23024	0.26975
56	-0.031184	0.29829	-0.1565	-0.38958	0.10652
61	-0.024468	0.16643	-0.019847	-0.20132	0.051432
62	-0.023476	0.16965	-0.025477	-0.20657	0.054801
71	0.071909	-0.011865	0.006237	0.11805	0.0056359
72	0.065804	-0.011814	0.0047384	0.12104	-0.0061473
81	0.06975	-0.011803	0.006034	0.11652	0.0095343
211	0.096993	-0.022768	-0.075435	0.1628	-0.14246
324	0.070613	-0.024299	-0.037383	0.20605	-0.17075
486	0.056029	0.0054436	-0.065836	-0.0061301	0.0012188
Consumer	0.12872	0.0076836	0.0054525	-0.24259	0.14841

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta_{x,mo}^{share\,constant}$	$\beta_{x,mo,mo}^{substitution}$	$\beta_{x,mo}^{share\,trend}$	$\beta_{x,22}^{share\,constant}$	$\beta_{x,324}^{share\,constant}$
11	0.10767	0.084371	1.464e-05	0.48331	0.47477
21	0.4417	0.18233	-0.00013068	-0.053692	-0.30917
22	0.22207	0.1577	1.718e-05	-0.0035159	0.055926
23	0.048581	-0.2003	7.987e-05	0.12274	0.79758
31	0.42257	0.070557	-0.00013912	0.18655	0.731
42	0.59444	0.22169	-0.00020469	0.30983	0.67363
44	0.58956	0.22834	-0.00020211	0.32068	0.66339
48	0.073704	0.059535	0.00019338	0.092689	0.87722
51	-0.22621	-0.51213	0.0001762	0.28085	0.69504
52	0.33654	-0.050189	-8.442e-05	0.10269	0.76848
53	0.14441	-0.18652	2.414e-05	0.23212	0.7135
54	0.03457	-0.18115	6.601e-05	0.17361	0.87147
55	0.83243	-0.19237	-0.00033564	0.10136	0.76749
56	0.15321	-0.11618	4.073e-05	0.2	0.77942
61	0.027511	-0.19399	6.935e-05	0.22322	0.75388
62	0.034999	-0.19437	6.71e-05	0.248	0.73462
71	0.037146	-0.20954	7.249e-05	0.27463	0.70726
72	0.13516	-0.16681	1.946e-05	0.2248	0.75694
81	0.020898	-0.18905	7.476e-05	0.24075	0.74264
211	0.6953	0.20907	-0.00027478	1.065	0.33386
324	0.58921	0.21482	-0.00010402	0.04149	0.92108
486	0.070885	0.06257	0.00019539	0.092516	0.87707
Consumer	0.24989	-0.18354	4.371e-05	0.55046	0.43755

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta_{x,22}^{share\,trend}$	$\beta_{x,324}^{share\,trend}$	$\beta_{x,22,22}^{substitution}$	$\beta_{x,22,324}^{substitution}$	$\beta_{x,22,486}^{substitution}$
11	-7.869e-05	9.661e-05	0.23669	-0.23047	-0.0045812
21	0.0002066	0.00027161	-0.056896	-0.017178	0.0010366
22	0.00022783	1.759e-05	-0.011624	3.988e-05	0.011659
23	-2.454e-06	3.593e-05	0.10741	-0.098921	-0.0080751
31	0.0002553	-0.00024631	0.14921	-0.13799	0.00018297
42	0.00017321	-0.00016707	0.21265	-0.21002	-0.0017581
44	0.00016698	-0.0001611	0.21635	-0.21403	-0.0013424
48	1.159e-05	-7.257e-06	0.084071	-0.081323	-0.0029091
51	0.00019406	-0.00018737	0.19726	-0.19621	0.00046521
52	0.00036054	-0.00030219	0.091994	-0.079006	-0.012766
53	0.00021671	-0.00019492	0.17794	-0.1681	-0.0094995
54	0.00023554	-0.00027057	0.14344	-0.15145	-0.0010003
55	0.00036185	-0.00030229	0.090619	-0.07789	-0.012492
56	7.759e-05	-7.444e-05	0.1599	-0.15598	-0.0040683
61	0.00021363	-0.00020588	0.17177	-0.16985	-0.00094215
62	0.0001893	-0.00018457	0.1852	-0.18284	-0.0013845
71	0.00014582	-0.00014143	0.19842	-0.19513	-0.0025034
72	0.00021594	-0.00021023	0.17392	-0.17106	-0.0021991
81	0.00020912	-0.00020473	0.18215	-0.17899	-0.0022657
211	-0.000445	-7.488e-05	-0.069248	-0.35557	-0.0013688
324	4.326e-05	-0.00036143	0.039659	-0.038334	-5.216e-05
486	1.142e-05	-6.942e-06	0.083922	-0.081159	-0.0029186
Consumer	2.046e-05	-1.626e-05	0.23731	-0.24182	0.0045073

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta^{substitution}_{x,324,324}$	$\beta^{substitution}_{x,324,486}$	$\beta^{share\ constant}_{x,486}$	$\beta^{substitution}_{x,486,486}$	$\beta^{share\ trend}_{x,486}$
11	0.24909	-0.017925	0.040511	0.021493	-1.726e-05
21	-0.40637	0.0029488	0.0023689	-0.00078854	8.007e-07
22	0.01441	-0.015184	0.96072	-0.009118	-0.00048249
23	0.11275	-0.012414	0.078369	0.019741	-3.271e-05
31	0.19483	-0.012297	0.021526	0.013385	-4.644e-06
42	0.21554	-0.0044552	0.014947	0.0054545	-5.392e-06
44	0.21988	-0.0048435	0.014413	0.0054008	-5.187e-06
48	0.10605	-0.026336	0.031959	0.028844	-6.394e-06
51	0.20976	-0.012127	0.022068	0.010546	-5.703e-06
52	0.0747	0.0049137	0.12817	0.0075168	-5.798e-05
53	0.17166	-0.0025048	0.053088	0.011277	-2.118e-05
54	0.11054	-0.0043715	0.0068772	0.0050117	2.487e-07
55	0.073875	0.0046222	0.13048	0.0075292	-5.919e-05
56	0.17114	-0.015927	0.02165	0.01978	-4.316e-06
61	0.17675	-0.0052945	0.020952	0.0053572	-6.824e-06
62	0.19006	-0.0058348	0.015586	0.0063876	-3.932e-06
71	0.2036	-0.0074158	0.016625	0.0091653	-3.859e-06
72	0.17623	-0.0037647	0.016541	0.005268	-4.894e-06
81	0.18508	-0.0045516	0.014698	0.0059668	-3.48e-06
211	0.22074	0.0012325	0.0012871	-0.00037885	6.628e-08
324	0.067657	-0.0010712	0.0067589	0.0013306	-3.086e-06
486	0.10599	-0.026364	0.032193	0.02885	-6.499e-06
Consumer	0.24503	-0.0032123	0.011992	-0.001295	-4.202e-06

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta_{x,211}^{share\ constant}$	$\beta_{x,211,211}^{substitution}$	$\beta_{x,211,22}^{substitution}$	$\beta_{x,211,324}^{substitution}$	$\beta_{x,211,486}^{substitution}$
11	0.0014064	0.0013228	-0.0016404	-0.0006963	0.0010138
21	1.3605	-0.49044	0.073037	0.4206	-0.0031968
22	-0.013129	-0.013302	-7.481e-05	0.00073398	0.012642
23	0.0013117	0.0010716	-0.00040918	-0.0014111	0.00074869
31	0.060921	0.057209	-0.011394	-0.044544	-0.0012706
42	0.001591	0.0011909	-0.00087771	-0.001072	0.00075885
44	0.0015226	0.0012069	-0.00098187	-0.0010102	0.00078514
48	-0.0018655	-0.0021703	0.00016156	0.0016074	0.00040134
51	0.0020469	0.0018169	-0.0015099	-0.0014227	0.0011156
52	0.00066144	0.00049522	-0.00022247	-0.00060843	0.00033568
53	0.0012909	0.00067332	-0.00034598	-0.0010549	0.00072758
54	-0.051959	-0.054659	0.0090182	0.04528	0.00036017
55	0.00066628	0.00050213	-0.00023631	-0.0006068	0.00034098
56	-0.0010664	-0.0011194	0.00014276	0.0007611	0.00021554
61	0.0019482	0.0017149	-0.00098353	-0.0016108	0.00087939
62	0.0017933	0.0015279	-0.00097245	-0.001387	0.00083161
71	0.0014751	0.0010861	-0.00078246	-0.0010575	0.00075383
72	0.0017196	0.0013732	-0.00066263	-0.0014064	0.00069585
81	0.0019076	0.0015959	-0.00090176	-0.0015446	0.00085047
211	-0.40017	-0.5603	0.42619	0.1336	0.00051512
324	0.030672	0.029731	-0.0012726	-0.028251	-0.00020731
486	-0.0017814	-0.0021236	0.00015491	0.0015364	0.00043233
Consumer	0	0	0	0	0

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta_{x,211}^{share\,trend}$	$\beta_{x,e}^{share\,constant}$	$\beta_{x,e}^{share\,trend}$	$\beta_{x,e,e}^{substitution}$	$\beta_{x,e,m}^{substitution}$
11	-6.622e-07	0.026328	6.863e-06	0.025425	-0.015069
21	-0.00047901	0.18002	-2.421e-05	0.067009	0.045069
22	0.00023706	0.03137	0.00011916	0.0098083	-0.0035847
23	-7.63e-07	0.019007	4.104e-06	0.014097	-0.0024311
31	-4.34e-06	0.12168	-4.695e-05	0.015887	-0.018831
42	-7.427e-07	0.87475	-0.00042092	0.024038	-0.01074
44	-6.965e-07	0.19134	-7.721e-05	0.020546	-0.021868
48	2.065e-06	0.099446	1.289e-05	0.088476	-0.030852
51	-9.902e-07	0.0050235	4.074e-06	0.0045631	0.0014248
52	-3.724e-07	0.017492	6.643e-07	0.016572	-0.013351
53	-5.994e-07	0.0095535	5.065e-06	0.0084495	0.0016399
54	3.478e-05	0.14849	-5.888e-05	0.025356	0.0037426
55	-3.742e-07	0.0087306	3.469e-06	0.0082925	-0.00035325
56	1.169e-06	0.0035707	1.533e-05	0.0034316	0.0022471
61	-9.182e-07	-0.00030339	9.85e-06	-0.00031151	3.626e-05
62	-7.907e-07	0.13515	-5.267e-05	0.023252	0.003128
71	-5.288e-07	0.02943	9.559e-07	0.022242	-0.019385
72	-8.197e-07	-6.591e-05	1.088e-05	-0.00055171	0.00059855
81	-9.16e-07	-0.00041446	9.12e-06	-0.0016749	0.0022362
211	0.00051982	1.063	-0.00043706	-0.052353	0.1736
324	0.00032125	0.057257	0.00028118	0.051749	-0.027202
486	2.017e-06	0.067398	2.126e-05	0.062569	0.017097
Consumer	0	0.19712	-7.57e-05	0.026555	-0.026555

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta_{x,m}^{share\,constant}$	$\beta_{x,m,m}^{substitution}$	$\beta_{x,m}^{share\,trend}$	$\beta_{x,k}^{share\,constant}$	$\beta_{x,l}^{share\,constant}$
11	0.61055	0.1401	-3.269e-05	0.13904	0.22408
21	0.69245	-0.14777	-0.00018373	0.058724	0.068808
22	0.86943	0.085668	-0.00031827	0.13457	-0.035366
23	0.8861	-0.061879	-0.00017515	0.045613	0.049284
31	0.91866	-0.020267	-0.00017613	-0.026616	-0.01373
42	0.20198	-0.24071	6.748e-05	-0.0092202	-0.067513
44	0.87567	-0.18942	-0.00027414	-0.01343	-0.053574
48	0.32162	-0.19681	3.706e-05	0.11775	0.46119
51	0.019037	-0.021031	0.00019472	-0.0041921	0.98013
52	0.82415	-0.10729	-0.00026583	0.070932	0.087423
53	-0.024488	-0.044139	0.00017607	0.97049	0.044445
54	0.65756	0.12309	-0.00014432	0.022114	0.17184
55	0.11511	-0.010553	9.412e-05	0.75558	0.12058
56	-0.22465	-0.48978	0.00029131	1.0987	0.12241
61	-0.086593	-0.095469	0.00022782	1.0341	0.05283
62	0.67116	0.12545	-0.00015084	0.021424	0.17228
71	0.89686	0.084455	-0.00027157	0.037229	0.036479
72	-0.017003	-0.10173	0.00018858	0.99113	0.025943
81	-0.11315	-0.14702	0.00023686	1.0451	0.06848
211	-0.066789	-0.19245	0.00024083	-0.10878	0.11256
324	0.54907	0.024669	-0.00014813	0.056728	0.33695
486	-0.24931	-0.31471	0.00033246	0.11209	1.0698
Consumer	0.80288	0.026555	7.57e-05	0	0

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta^{substitution}_{x,k,k}$	$\beta^{substitution}_{x,k,l}$	$\beta^{substitution}_{x,k,e}$	$\beta^{substitution}_{x,k,m}$	$\beta^{substitution}_{x,l,l}$
11	0.11959	-0.031508	-0.0037532	-0.084329	0.078815
21	0.05521	-0.004229	-0.010728	-0.040253	-0.037373
22	0.11642	0.0047593	-0.0047205	-0.11646	-0.037633
23	0.043356	-0.0025945	-0.0014534	-0.039308	-0.090811
31	-0.027328	-0.00037648	0.0028798	0.024825	-0.013962
42	-0.025513	-0.00077916	-0.0089937	0.035286	-0.21108
44	-0.013616	-0.00073598	0.0018622	0.01249	-0.19752
48	0.1021	-0.054419	-0.011751	-0.035934	-0.1633
51	-0.0042146	0.0037726	1.48e-05	0.0004272	-0.016948
52	0.021513	-0.067271	-0.001327	0.047085	-0.0043935
53	0.013905	-0.044173	-0.00932	0.039588	0.042031
54	0.021225	-0.0038008	-0.003581	-0.013843	0.14231
55	0.18433	-0.09114	-0.0068612	-0.086333	-0.0050219
56	-0.1123	-0.15247	-0.004022	0.26879	-0.064618
61	-0.036485	-0.054631	0.00025928	0.090857	0.050039
62	0.020045	-0.0038331	-0.0030692	-0.013143	0.14257
71	0.035501	-0.0013615	-0.0017759	-0.032364	0.035148
72	-0.025796	-0.040455	3.366e-05	0.066217	0.0056211
81	-0.064622	-0.071697	-0.00056943	0.13689	0.063789
211	0.027724	-0.0025168	-0.029844	0.0046367	0.079705
324	0.052918	-0.019203	-0.0038641	-0.029851	0.0075
486	0.099052	-0.1206	-0.0075574	0.029105	-0.075802
Consumer	0	0	0	0	0

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta^{substitution}_{x,l,e}$	$\beta^{substitution}_{x,l,m}$	$\beta^{share\,trend}_{x,k}$	$\beta^{share\,trend}_{x,l}$	$\beta^{cost\,trend}_{KLEM,x}$
11	-0.0066023	-0.040705	4.21e-05	-1.627e-05	-0.014002
21	-0.10135	0.14295	0.00012936	7.858e-05	0.00027895
22	-0.0015032	0.034377	9.631e-05	0.00010281	0.0086446
23	-0.010212	0.10362	1.296e-06	0.00016975	0.0091044
31	6.471e-05	0.014273	7.599e-05	0.00014709	-0.0067229
42	-0.0043041	0.21616	7.545e-05	0.00027799	-0.009068
44	-0.00054062	0.1988	7.984e-05	0.00027151	-0.0066816
48	-0.045873	0.2636	7.343e-06	-5.729e-05	-0.0075694
51	-0.0060027	0.019179	0.00011767	-0.00031647	-0.0054345
52	-0.0018938	0.073558	0.00019108	7.408e-05	-0.0082512
53	-0.00076942	0.0029117	-0.00031802	0.00013688	-0.0031074
54	-0.025517	-0.11299	4.741e-05	0.00015579	0.0048193
55	-0.001078	0.09724	-0.00015463	5.704e-05	-0.0027728
56	-0.0016568	0.21874	-0.00048767	0.00018103	0.00097876
61	1.597e-05	0.004576	-0.00046212	0.00022445	0.0060527
62	-0.023311	-0.11543	4.675e-05	0.00015677	0.0050091
71	-0.0010804	-0.032706	3.996e-05	0.00023065	0.0025875
72	-8.049e-05	0.034914	-0.00043778	0.00023832	0.00090496
81	8.054e-06	0.0078995	-0.00044597	0.00019999	0.003928
211	-0.0914	0.014212	0.00019405	2.189e-06	0.025391
324	-0.020682	0.032385	7.874e-06	-0.00014092	-0.0015724
486	-0.072109	0.26851	7.858e-06	-0.00036157	-0.0084042
Consumer	0	0	0	0	0

Table D.1: Cost and Expenditure Function Parameters for the Energy Model

Industry x	$\beta_{KLEM,x}^{cost\ constant}$
11	27.71
21	-0.73033
22	-17.208
23	-18.07
31	13.284
42	17.963
44	13.253
48	15.052
51	10.836
52	16.387
53	6.1916
54	-9.5529
55	5.5504
56	-1.9235
61	-11.986
62	-9.9237
71	-5.1155
72	-1.7813
81	-7.7779
211	-50.621
324	2.9008
486	16.69
Consumer	0

Appendix E

Cost and Expenditure Function Parameters for the GRT Model

This section lists the parameters estimated for the firm cost and consumer expenditure functions in the GRT model. These parameters are from the baseline regression specification that uses iterated three-stage least squares with one period lagged prices as instruments.

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta_{x,48}^{share\, constant}$	$\beta_{x,42}^{share\, constant}$	$\beta_{x,48}^{share\, trend}$	$\beta_{x,42}^{share\, trend}$	$\beta_{x,48,48}^{substitution}$
11	0.97766	0.0022902	-0.00033345	0.00024629	0.003662
22	0.98043	-6.683e-05	-0.00016969	0.0001292	0.0024437
23	0.93993	0.0088988	-0.00037038	0.00028337	0.016934
31	0.97612	0.0091424	-0.00034034	0.00024845	0.015971
42	-0.066486	1.0656	0.0001465	-0.00025514	-0.071647
44	-0.065334	1.0648	0.00014589	-0.00025469	-0.069623
48	0.28062	0.49485	0.00026911	-0.00018217	0.20156
51	-0.013699	0.59479	0.00016056	-4.705e-05	-0.014252
52	-0.02797	1.0253	0.00025504	-0.00032601	-0.030394
53	-0.045838	1.0377	0.00024433	-0.00031832	-0.048424
54	-0.025918	0.62689	0.00015346	-5.37e-05	-0.029039
55	-0.023224	1.0228	0.00025374	-0.00032553	-0.024894
56	0.98978	-0.010033	-0.00021349	0.00016278	-0.0066444
61	-0.024834	0.62603	0.0001523	-5.281e-05	-0.027752
62	-0.022939	0.62753	0.00016143	-6.087e-05	-0.024057
71	1.0075	-0.028204	-0.00032937	0.00024925	-0.035448
72	-0.084152	1.0547	0.00017361	-0.00026221	-0.092904
81	-0.090852	1.0545	0.0001899	-0.00027126	-0.10072
211	0.99941	-0.0014418	-0.00030896	0.00022307	-0.00032773
212	0.99401	-0.0014625	-0.0002606	0.00019012	-0.0013589
213	0.99968	-0.0026271	-0.00030007	0.00021714	-0.0025858
Consumer	0.81924354	-0.080867	-0.000338	0.0001524	0.11679

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta^{substitution}_{x,48,42}$	$\beta^{substitution}_{x,48,44}$	$\beta^{substitution}_{x,42,42}$	$\beta^{substitution}_{x,42,44}$	$\beta^{share\ constant}_{x,44}$
11	-0.0032574	-0.00040461	0.0020841	0.0011733	0.020048
22	-0.0015421	-0.00090168	-0.00043236	0.0019744	0.019634
23	-0.012277	-0.0046572	0.0082809	0.0039963	0.051174
31	-0.011628	-0.0043436	0.008062	0.0035658	0.014733
42	0.070185	0.0014616	-0.070983	0.00079736	0.00084922
44	0.069449	0.00017392	-0.070214	0.00076473	0.00049936
48	-0.14523	-0.056331	0.10441	0.040823	0.22454
51	0.006783	0.0074691	-0.0093731	0.0025901	0.41891
52	0.02678	0.0036137	-0.028132	0.0013516	0.0026931
53	0.046557	0.0018674	-0.047621	0.001064	0.0081324
54	0.014795	0.014245	-0.016015	0.0012207	0.39903
55	0.023093	0.0018006	-0.025557	0.0024643	0.00043192
56	0.0069615	-0.00031705	-0.010945	0.0039832	0.020248
61	0.01384	0.013913	-0.015325	0.0014849	0.39881
62	0.010972	0.013085	-0.013289	0.0023169	0.39541
71	0.027981	0.0074671	-0.029323	0.0013418	0.020712
72	0.086268	0.0066359	-0.0836	-0.0026688	0.029461
81	0.090669	0.010046	-0.087356	-0.0033129	0.036355
211	0.0011633	-0.00083559	-0.0020143	0.00085101	0.0020329
212	0.0013561	2.82e-06	-0.0015365	0.00018044	0.0074543
213	0.002434	0.00015183	-0.0028632	0.00042916	0.002947
Consumer	0.062011	-0.17881	-0.094906	0.032895	0.26162

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta_{x,44,44}^{substitution}$	$\beta_{x,44}^{share\,trend}$	$\beta_{x,54}^{share\,constant}$	$\beta_{x,81}^{share\,constant}$	$\beta_{x,54}^{share\,trend}$
11	-0.00076872	8.716e-05	-0.0039254	0.017602	3.976e-05
22	-0.0010728	4.049e-05	0.079809	0.071525	9.833e-05
23	0.00066088	8.701e-05	-0.0086736	0.063695	0.00023395
31	0.00077781	9.189e-05	-0.02358	0.072733	0.00020662
42	-0.0022589	0.00010863	0.0099605	0.048835	0.00012772
44	-0.00093865	0.00010879	0.0091167	0.0482	0.0001281
48	0.015508	-8.694e-05	0.033169	0.0056353	0.00013513
51	-0.010059	-0.00011351	0.092041	0.037291	0.00013462
52	-0.0049653	7.097e-05	0.00071496	0.014541	5.19e-05
53	-0.0029314	7.4e-05	-0.0070082	0.034377	7.607e-05
54	-0.015465	-9.977e-05	0.038954	0.035845	0.00012246
55	-0.0042648	7.179e-05	0.0015531	0.014347	5.118e-05
56	-0.0036662	5.071e-05	-0.0073346	0.042446	0.00014806
61	-0.015398	-9.949e-05	0.040207	0.037939	0.00012261
62	-0.015402	-0.00010056	0.039375	0.036519	0.00012306
71	-0.0088089	8.013e-05	0.029031	0.038969	0.00012798
72	-0.0039671	8.861e-05	0.022023	0.051212	0.0001299
81	-0.006733	8.137e-05	0.043183	0.034768	0.00010518
211	-1.542e-05	8.59e-05	0.043266	0.020415	7.417e-06
212	-0.00018326	7.049e-05	-0.0040695	0.013475	0.00012123
213	-0.000581	8.293e-05	-0.053008	0.083932	5.736e-05
Consumer	0.14591	0.0001856	-0.1094	1.117	0.00010636

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta_{x,81}^{share\ trend}$	$\beta_{x,54,54}^{substitution}$	$\beta_{x,54,81}^{substitution}$	$\beta_{x,54,52}^{substitution}$	$\beta_{x,81,81}^{substitution}$
11	1.492e-05	-0.0045726	-0.0019813	0.0065539	-0.00021887
22	2.06e-05	0.047135	-0.0098445	-0.03729	0.063265
23	6.329e-05	-0.013311	-0.0047888	0.018099	0.0022554
31	4.534e-05	-0.055636	-0.04139	0.097026	0.0082274
42	3.494e-05	-0.023191	-0.0071319	0.030323	-0.0029557
44	3.525e-05	-0.022952	-0.0070545	0.030006	-0.0029287
48	6.436e-05	0.031931	-0.00019983	-0.031731	0.0056022
51	5.928e-05	0.078571	-0.0063706	-0.072201	0.029568
52	2.209e-05	-0.010395	-0.0040622	0.014457	-0.0013879
53	1.971e-05	-0.013624	-0.0048097	0.018434	-0.0013377
54	4.498e-05	-0.0051975	-0.0031048	0.0083023	-7.945e-05
55	2.208e-05	-0.012017	-0.0046761	0.016694	-0.0016203
56	4.26e-05	-0.0080128	-0.0042673	0.01228	0.00019376
61	4.422e-05	-0.0060196	-0.0033572	0.0093767	-0.00017599
62	4.495e-05	-0.0059383	-0.0034068	0.0093452	-0.0001914
71	4.362e-05	-0.0063428	-0.003429	0.0097718	-8.438e-05
72	3.684e-05	-0.0084761	-0.0031339	0.01161	-0.00020506
81	3.988e-05	-0.002379	-0.0024131	0.0047921	0.00022158
211	7.845e-06	-0.063691	-0.0054632	0.069155	0.017203
212	4.724e-05	-0.012441	-0.0045499	0.01699	-0.00026495
213	-2.343e-05	-0.079091	-0.00065189	0.079743	0.011735
Consumer	-0.00037558	-0.12338	0.11731	0.0060624	-0.17067

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta^{substitution}_{x,81,52}$	$\beta^{share\ constant}_{x,52}$	$\beta^{substitution}_{x,52,52}$	$\beta^{share\ trend}_{x,52}$	$\beta^{share\ constant}_{x,11}$
11	0.0022002	0.98632	-0.0087541	-5.468e-05	0.30899
22	-0.05342	0.84867	0.090711	-0.00011893	0.0038957
23	0.0025334	0.94498	-0.020633	-0.00029724	-0.032856
31	0.033163	0.95085	-0.13019	-0.00025197	1.0143
42	0.010088	0.9412	-0.04041	-0.00016267	0.0018083
44	0.0099832	0.94268	-0.03999	-0.00016335	0.00022015
48	-0.0054023	0.9612	0.037133	-0.00019949	0.0009863
51	-0.023197	0.87067	0.095398	-0.0001939	0.0011228
52	0.0054501	0.98474	-0.019908	-7.399e-05	-0.065544
53	0.0061473	0.97263	-0.024581	-9.578e-05	-0.038972
54	0.0031843	0.9252	-0.011487	-0.00016744	-0.015848
55	0.0062964	0.9841	-0.02299	-7.326e-05	-0.066525
56	0.0040736	0.96489	-0.016354	-0.00019066	-0.0060059
61	0.0035332	0.92185	-0.01291	-0.00016683	-0.014381
62	0.0035982	0.92411	-0.012943	-0.00016801	-0.014064
71	0.0035134	0.932	-0.013285	-0.0001716	-0.014931
72	0.003339	0.92677	-0.014949	-0.00016674	-0.011384
81	0.0021915	0.92205	-0.0069836	-0.00014506	-0.020697
211	-0.01174	0.93632	-0.057415	-1.526e-05	-0.0036648
212	0.0048148	0.99059	-0.021805	-0.00016847	-0.0069212
213	-0.011084	0.96908	-0.06866	-3.392e-05	-0.0052114
Consumer	0.053353	-0.0076392	-0.059415	0.00026922	0.11728

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta_{x,11}^{share\ trend}$	$\beta_{x,11,11}^{substitution}$	$\beta_{x,11,31}^{substitution}$	$\beta_{x,31}^{share\ constant}$	$\beta_{x,31,31}^{substitution}$
11	0.00015379	0.20954	-0.20861	0.65297	0.20728
22	1.362e-06	0.0038544	-0.00099837	0.25216	0.18809
23	3.537e-05	-0.03395	0.032853	1.0054	-0.024047
31	-0.00045022	-0.015964	0.011213	-0.011056	-0.011178
42	2.611e-05	0.0016814	-0.0018615	0.96158	0.013378
44	2.703e-05	-0.00040081	-0.00030087	0.97798	0.014789
48	3.354e-07	0.00089448	-0.00053233	0.53467	0.24712
51	3.17e-06	0.00089885	-0.00096954	0.86291	0.11535
52	9.582e-05	-0.097308	0.067953	1.0368	-0.039746
53	4.848e-05	-0.059219	0.038321	0.98794	0.010098
54	1.9e-05	-0.020349	0.012749	0.96275	0.029215
55	9.706e-05	-0.097485	0.068616	1.0376	-0.043177
56	1.084e-05	-0.0061142	0.0059853	0.99658	0.00027706
61	1.803e-05	-0.02058	0.013658	0.95462	0.024752
62	1.779e-05	-0.019664	0.012165	0.96622	0.030234
71	1.775e-05	-0.017758	0.012896	0.98267	0.0043643
72	2.082e-05	-0.014374	0.0099435	0.96484	0.027148
81	2.271e-05	-0.025855	0.018922	0.95804	0.026139
211	2.722e-06	-0.0036782	0.0036614	0.9991	-0.0010556
212	5.425e-06	-0.0069842	0.0066301	0.958	0.040239
213	3.774e-06	-0.0052498	0.0052852	1.0147	-0.017543
Consumer	-3.979e-05	0.032415	-0.032415	0.88272	0.032415

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta^{share\ trend}_{x,31}$	$\beta^{share\ constant}_{x,212}$	$\beta^{share\ constant}_{x,n}$	$\beta^{substitution}_{x,11,212}$	$\beta^{substitution}_{x,31,212}$
11	-0.00013608	-0.0016262	0.039664	0.00045562	0.00066328
22	9.703e-05	0.73348	0.010457	-0.003126	-0.18586
23	-3.53e-05	0.0060558	0.021367	0.00019881	-0.0065342
31	0.00043633	0.00062575	-0.0039181	-0.00073419	5.216e-06
42	-2.442e-05	-0.00046512	0.037078	-6.006e-05	-2.995e-05
44	-3.304e-05	-0.00026672	0.022064	-3.848e-05	0.00018036
48	0.0001226	0.0012382	0.4631	-1.852e-06	-0.0010353
51	-1.059e-05	-0.0011047	0.13707	-2.16e-05	0.0009498
52	-0.00015775	-0.011658	0.040389	-0.00079184	0.012087
53	-6.363e-05	-0.0043233	0.055358	-0.00021848	0.0041864
54	-4.378e-06	0.0002078	0.052893	-1.491e-05	-0.00050539
55	-0.00015974	-0.011884	0.040836	-0.00086772	0.012326
56	-4.07e-05	-0.002002	0.011427	-4.207e-05	0.0019944
61	7.007e-07	0.00016932	0.059593	-1.692e-05	-0.00034604
62	-6.334e-06	0.00021501	0.047627	-1.732e-05	-0.00047097
71	-1.642e-05	-0.0011392	0.033404	-2.434e-05	0.00083343
72	-1.076e-05	0.0002856	0.04626	-9.668e-06	-0.00034689
81	-5.989e-06	0.00021344	0.062448	-0.00014695	-0.00030572
211	-5.855e-05	-0.0064741	0.011041	-2.665e-05	0.0059976
212	-0.00018094	0.038018	0.010907	0.0002631	-0.036421
213	-0.00010355	-0.034242	0.024715	-0.00018199	0.034743
Consumer	3.979e-05	0	0	0	0

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta^{substitution}_{x,212,212}$	$\beta^{substitution}_{x,212,n}$	$\beta^{substitution}_{x,11,n}$	$\beta^{substitution}_{x,31,n}$	$\beta^{substitution}_{x,n,n}$
11	-0.0016936	0.00057474	-0.0013866	0.00066525	0.00014657
22	0.18891	7.946e-05	0.00027	-0.0012242	0.00087475
23	0.0057515	0.00058385	0.00089799	-0.0022721	0.0007903
31	-0.0039714	0.0047004	0.0054848	-4.001e-05	-0.010145
42	-0.00078075	0.00087076	0.00024019	-0.011487	0.010376
44	-0.00027414	0.00013227	0.00074016	-0.014668	0.013796
48	0.0010164	2.078e-05	-0.00036029	-0.24555	0.24589
51	-0.0016431	0.00071492	9.229e-05	-0.11533	0.11452
52	-0.011794	0.00049869	0.030147	-0.040294	0.0096487
53	-0.0043482	0.00038037	0.021116	-0.052605	0.031109
54	0.0001903	0.00033	0.0076149	-0.041458	0.033513
55	-0.012025	0.00056707	0.029736	-0.037765	0.0074612
56	-0.0020208	6.843e-05	0.00017094	-0.0082568	0.0080174
61	0.00014321	0.00021975	0.0069391	-0.038064	0.030905
62	0.00018164	0.00030665	0.0075168	-0.041928	0.034104
71	-0.0012336	0.00042454	0.0048871	-0.018093	0.012782
72	0.0002843	7.225e-05	0.00444	-0.036745	0.032233
81	0.00020313	0.00024954	0.0070796	-0.044756	0.037427
211	-0.0070978	0.0011269	4.343e-05	-0.0086034	0.007433
212	0.036568	-0.0004102	9.093e-05	-0.010449	0.010768
213	-0.035535	0.00097386	0.00014654	-0.022485	0.021364
Consumer	0	0	0	0	0

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta_{x,212}^{share\ trend}$	$\beta_{x,n}^{share\ trend}$	$\beta_{x,61}^{share\ constant}$	$\beta_{x,62}^{share\ constant}$	$\beta_{x,71}^{share\ constant}$
11	2.025e-06	-1.973e-05	0.95831	-0.062833	0.019195
22	-9.423e-05	-4.161e-06	0.0082316	0.70553	0.021329
23	1.041e-05	-1.049e-05	0.95606	-0.063614	-0.0019015
31	8.524e-06	5.357e-06	-0.00080372	0.94744	-0.0078003
42	4.275e-07	-2.113e-06	0.0035377	0.28463	0.019372
44	3.285e-07	5.678e-06	0.0025712	0.29244	0.01239
48	-6.292e-08	-0.00012287	0.0086315	0.7813	-0.050402
51	9.282e-07	6.492e-06	0.0017612	0.87541	0.0056762
52	1.054e-05	5.14e-05	0.0047866	0.89531	0.010058
53	3.889e-06	1.126e-05	0.0012024	0.87501	0.0085755
54	2.297e-07	-1.486e-05	0.0030739	0.32602	0.014578
55	1.074e-05	5.194e-05	0.0047984	0.89581	0.010181
56	1.415e-06	2.845e-05	0.00419	0.22848	0.0069495
61	2.095e-07	-1.894e-05	0.0030821	0.32709	0.014628
62	1.983e-07	-1.165e-05	0.0030909	0.32469	0.01404
71	7.184e-07	-2.044e-06	0.0031365	0.31726	0.01222
72	1.495e-07	-1.02e-05	0.0033955	0.30566	0.022371
81	3.935e-07	-1.712e-05	0.0048959	0.26143	0.024654
211	3.692e-06	5.213e-05	0.0040542	0.79624	-0.022837
212	0.00017611	-5.91e-07	0.0012745	-0.032358	0.18094
213	5.526e-05	4.452e-05	0.0048216	0.39065	-0.00073738
Consumer	0	0	0.073593	-0.38565	0.24501

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta_{x,61}^{share\,trend}$	$\beta_{x,62}^{share\,trend}$	$\beta_{x,71}^{share\,trend}$	$\beta_{x,61,61}^{substitution}$	$\beta_{x,61,62}^{substitution}$
11	-0.00047686	0.00038201	3.726e-05	0.039004	0.060162
22	2.896e-06	2.661e-05	3.806e-05	0.008142	-0.0067854
23	-0.00047491	0.00040796	4.539e-05	0.024578	0.060775
31	7.362e-06	-0.00010792	4.939e-05	-0.00082928	0.00012563
42	5.607e-06	0.00024333	3.511e-05	0.0028593	-0.0025818
44	6.099e-06	0.00023938	3.863e-05	0.0019306	-0.0022833
48	2.454e-06	-1.276e-05	7.847e-05	0.0084717	-0.0076998
51	6.542e-06	-5.273e-05	4.216e-05	0.0017052	-0.0028432
52	5.014e-06	-6.172e-05	4.044e-05	0.0045089	-0.0065927
53	6.831e-06	-5.196e-05	4.109e-05	0.0011468	-0.0021806
54	5.888e-06	0.0002245	3.764e-05	0.0022691	-0.0027685
55	5.008e-06	-6.196e-05	4.038e-05	0.0045189	-0.0066081
56	5.236e-06	0.0002726	4.254e-05	0.0039083	-0.0047598
61	5.884e-06	0.00022397	3.761e-05	0.0022695	-0.0027769
62	5.877e-06	0.00022514	3.795e-05	0.002302	-0.0027697
71	5.844e-06	0.00022876	3.899e-05	0.0024108	-0.0027519
72	5.715e-06	0.00023437	3.369e-05	0.0026688	-0.0027936
81	4.955e-06	0.00025712	3.259e-05	0.0044105	-0.0056148
211	5.124e-06	-2.121e-05	5.821e-05	0.0040167	-0.0040575
212	6.264e-06	0.00038946	-4.311e-05	0.00089019	4.121e-05
213	4.707e-06	0.00018265	4.721e-05	0.0046884	-0.0038072
Consumer	2.762e-06	0.00051643	-9.28e-05	0.064982	0.028115

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta^{substitution}_{x,61,71}$	$\beta^{substitution}_{x,61,72}$	$\beta^{substitution}_{x,62,62}$	$\beta^{substitution}_{x,62,71}$	$\beta^{substitution}_{x,62,72}$
11	-0.019634	-0.079533	-0.066986	0.00093405	0.0058892
22	-0.00048555	-0.00087111	0.13917	-0.043073	-0.08931
23	-0.00053833	-0.084814	-0.067794	-0.00044851	0.0074672
31	-0.00021852	0.00092217	0.018074	-0.0035719	-0.014628
42	-0.0017895	0.0015119	-0.0031	-0.013769	0.019451
44	-0.0008888	0.0012415	-0.00229	-0.014531	0.019104
48	-0.0004499	-0.00032192	0.093955	0.0099536	-0.096209
51	-0.0001231	0.0012611	0.052121	-0.011402	-0.037876
52	-0.00036436	0.0024481	0.057248	-0.015209	-0.035447
53	-0.00017507	0.0012088	0.045729	-0.013974	-0.029574
54	-0.0010091	0.0015085	-0.0048901	-0.016165	0.023824
55	-0.00036445	0.0024536	0.057374	-0.01525	-0.035516
56	-0.00018759	0.0010391	-0.0051166	-0.0097901	0.019667
61	-0.0010046	0.001512	-0.0048986	-0.016155	0.023831
62	-0.0010224	0.0014902	-0.0048508	-0.016042	0.023662
71	-0.0010744	0.0014156	-0.004596	-0.015657	0.023005
72	-0.0014389	0.0015636	-0.0050816	-0.014587	0.022462
81	-0.00085113	0.0020554	-0.0040099	-0.018026	0.027651
211	-1.391e-05	5.469e-05	0.082165	0.005932	-0.084039
212	-0.002006	0.0010746	-0.033407	0.0053275	0.028039
213	-0.00040061	-0.00048057	0.07423	-0.018132	-0.052291
Consumer	-0.01805	-0.075048	-0.55129	0.090745	0.43243

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta^{substitution}_{x,71,71}$	$\beta^{substitution}_{x,71,72}$	$\beta^{share\ constant}_{x,72}$	$\beta^{substitution}_{x,72,72}$	$\beta^{share\ trend}_{x,72}$
11	0.016769	0.001931	0.08533	0.071712	5.759e-05
22	-0.016719	0.060277	0.2649	0.029904	-6.756e-05
23	-0.0046596	0.0056464	0.10946	0.071701	2.156e-05
31	-0.014619	0.018409	0.061159	-0.0047037	5.116e-05
42	0.011032	0.0045268	0.69246	-0.02549	-0.00028405
44	0.0098576	0.005562	0.6926	-0.025907	-0.00028411
48	-0.085833	0.076329	0.26047	0.020202	-6.816e-05
51	0.0026021	0.0089229	0.11715	0.027692	4.036e-06
52	0.0075609	0.008012	0.089843	0.024987	1.626e-05
53	0.0053795	0.0087698	0.11521	0.019596	4.034e-06
54	0.011122	0.0060525	0.65633	-0.031385	-0.00026803
55	0.0075968	0.0080179	0.089211	0.025044	1.657e-05
56	-0.0072123	0.01719	0.76038	-0.037896	-0.00032037
61	0.011121	0.0060386	0.6552	-0.031381	-0.00026746
62	0.010631	0.0064332	0.65818	-0.031585	-0.00026897
71	0.0089953	0.0077363	0.66738	-0.032157	-0.0002736
72	0.011108	0.0049178	0.66858	-0.028944	-0.00027378
81	0.013866	0.0050112	0.70902	-0.034717	-0.00029467
211	-0.031514	0.025595	0.22254	0.058389	-4.213e-05
212	0.016806	-0.020128	0.85014	-0.0089852	-0.00035262
213	-0.0051774	0.02371	0.60527	0.029062	-0.00023457
Consumer	0.081815	-0.15451	1.0671	-0.20287	-0.00042639

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta_{x,53}^{share\ constant}$	$\beta_{x,53}^{share\ trend}$	$\beta_{x,53,53}^{substitution}$	$\beta_{x,53,mot}^{substitution}$	$\beta_{x,mot}^{share\ constant}$
11	0.13589	-3.472e-05	0.037636	-0.038889	0.89043
22	0.5734	-0.00027251	0.081345	-0.13382	0.56969
23	-0.0029017	2.163e-05	-0.0029233	0.00012383	0.03812
31	-0.015434	2.332e-05	-0.015679	0.00030987	-0.0088677
42	0.1848	-2.466e-05	0.1496	-0.17275	0.94054
44	0.18169	-2.308e-05	0.14811	-0.17212	0.9569
48	-0.028611	3.463e-05	-0.030086	-0.0010772	-0.060958
51	-0.17065	0.00017345	-0.19977	-0.0051879	-0.030716
52	-0.39355	0.00040967	-0.54864	-0.041648	-0.10635
53	-0.30486	0.00032006	-0.3978	-0.024816	-0.081725
54	0.22673	-2.845e-05	0.17528	-0.2161	0.95498
55	-0.39456	0.0004107	-0.55057	-0.041676	-0.10646
56	0.22032	-6.17e-05	0.17173	-0.20137	0.91528
61	0.22601	-2.82e-05	0.17453	-0.21483	0.95304
62	0.22771	-3.113e-05	0.17581	-0.21624	0.95172
71	0.23587	-4.145e-05	0.18002	-0.22027	0.93588
72	0.22953	-3.437e-05	0.17557	-0.21295	0.93419
81	0.25275	-3.424e-05	0.18886	-0.24419	0.96616
211	0.50664	-0.00012335	0.24705	-0.39194	0.78632
212	0.094654	-2.991e-05	0.083146	-0.067444	0.742
213	-0.18486	0.00024021	-0.21904	-0.021604	-0.11687
Consumer	0.31325	5.867e-05	0.16011	-0.16011	0.68675

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta^{substitution}_{x,mot,mot}$	$\beta^{share\ trend}_{x,mot}$	$\beta^{share\ constant}_{x,23}$	$\beta^{substitution}_{x,23,23}$	$\beta^{substitution}_{x,23,53}$
11	0.012954	-1.042e-05	-0.026319	-0.027188	0.001253
22	-0.025438	1.534e-05	-0.14309	-0.21173	0.052475
23	0.021255	0.00045809	0.96478	0.018579	0.0027995
31	-0.039075	0.00047448	1.0243	-0.054134	0.015369
42	0.022273	-0.0001033	-0.12534	-0.17364	0.023158
44	0.021334	-0.00011135	-0.1386	-0.1748	0.024011
48	-0.092556	0.0004946	1.0896	-0.1248	0.031163
51	-0.037274	0.00034759	1.2014	-0.24742	0.20496
52	-0.11786	0.0002205	1.4999	-0.7498	0.59029
53	-0.093029	0.00026982	1.3866	-0.54046	0.42262
54	0.030018	-0.00016339	-0.18171	-0.2269	0.040821
55	-0.11812	0.00021986	1.501	-0.75204	0.59224
56	0.069098	-7.082e-05	-0.1356	-0.16192	0.029645
61	0.029761	-0.00016242	-0.17904	-0.22537	0.040302
62	0.03504	-0.0001577	-0.17943	-0.22163	0.04043
71	0.049178	-0.00013761	-0.17176	-0.21135	0.040254
72	0.046896	-0.00013988	-0.16372	-0.20344	0.037384
81	0.017447	-0.00018185	-0.21891	-0.28207	0.055329
211	0.14694	-8.764e-05	-0.29296	-0.38988	0.14489
212	-0.1011	9.377e-05	0.16335	-0.15284	-0.015703
213	-0.13231	0.00036485	1.3017	-0.39456	0.24064
Consumer	0.16011	-5.867e-05	0	0	0

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta^{substitution}_{x,23,mot}$	$\beta^{share\ trend}_{x,23}$	$\beta^{share\ constant}_{x,mss}$	$\beta^{share\ constant}_{x,51}$	$\beta^{share\ trend}_{x,mss}$
11	0.025935	4.515e-05	1.0161	0.0075348	-8.263e-05
22	0.15926	0.00025717	0.19782	0.74802	0.00025636
23	-0.021379	-0.00047971	0.072151	0.95113	0.00029751
31	0.038765	-0.0004978	0.15721	0.88235	0.00024123
42	0.15048	0.00012795	0.071578	0.90222	0.00032217
44	0.15079	0.00013442	0.053842	0.90296	0.00033108
48	0.093633	-0.00052923	0.11837	0.95001	0.00023012
51	0.042462	-0.00052104	-0.042058	1.075	0.00020595
52	0.15951	-0.00063017	-0.04055	0.96852	0.0004428
53	0.11784	-0.00058988	-0.017011	0.95491	0.0004128
54	0.18608	0.00019184	-0.0086758	0.94435	0.00035805
55	0.1598	-0.00063056	-0.041903	0.95604	0.00044373
56	0.13228	0.00013252	0.080829	0.93764	0.00030084
61	0.18507	0.00019062	0.016634	0.95489	0.00034481
62	0.1812	0.00018882	-0.0063166	0.96329	0.00035604
71	0.1711	0.00017906	0.017757	0.95143	0.00034327
72	0.16605	0.00017425	0.042683	0.91971	0.00033297
81	0.22674	0.00021609	0.077911	0.85769	0.00032536
211	0.245	0.00021099	0.020306	0.95945	0.0004544
212	0.16854	-6.386e-05	-0.032748	0.032831	0.00038096
213	0.15391	-0.00060506	0.020827	0.9402	0.00045164
Consumer	0	0	1.0743	-0.0056073	-0.00015337

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta^{share\ trend}_{x,51}$	$\beta^{substitution}_{x,mss,mss}$	$\beta^{substitution}_{x,mss,51}$	$\beta^{substitution}_{x,mss,56}$	$\beta^{substitution}_{x,51,51}$
11	3.104e-05	-0.0303	-0.015135	0.048085	-0.00058388
22	-0.00030571	0.14744	-0.15455	0.0078246	0.012032
23	-0.00039088	0.066847	-0.069419	0.0025365	0.025472
31	-0.0003472	0.13244	-0.13972	0.0076668	0.058758
42	-0.00035746	0.066379	-0.065547	-0.00074873	0.054802
44	-0.00035779	0.050176	-0.05269	0.0025089	0.043604
48	-0.00037545	0.10436	-0.11248	0.0077322	-0.01276
51	-0.00025459	-0.044852	0.043545	0.0022138	-0.083509
52	-0.00043685	-0.042196	0.039126	0.0032447	-0.023693
53	-0.00041722	-0.028356	0.010176	0.019344	0.0014802
54	-0.00037471	-0.0098604	0.0019474	0.0081281	-0.021028
55	-0.0004308	-0.043659	0.039963	0.0039362	-0.022146
56	-0.00036834	0.074294	-0.075917	0.0015231	0.049138
61	-0.00038007	0.016281	-0.01725	0.0010237	0.0050926
62	-0.0003837	-0.0075267	-0.00020276	0.0081134	-0.024538
71	-0.00037821	0.016053	-0.022623	0.0070824	-4.308e-05
72	-0.00036359	0.038499	-0.044455	0.0066103	0.040385
81	-0.00033863	0.032923	-0.077478	0.046536	0.076955
211	-0.00046727	0.019728	-0.02151	0.0019032	0.0021193
212	4.069e-05	-0.033842	0.00049856	0.00045855	0.002348
213	-0.00045653	0.020206	-0.021856	0.0017676	-0.0012734
Consumer	0.00010588	-0.086574	0.0046394	0.081935	-0.0065387

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta^{substitution}_{x,51,56}$	$\beta^{share\ constant}_{x,56}$	$\beta^{substitution}_{x,56,56}$	$\beta^{share\ trend}_{x,56}$	$\beta^{share\ constant}_{x,55}$
11	0.016047	-0.025704	-0.065704	4.214e-05	0.0020379
22	0.14362	0.054393	-0.15359	4.312e-05	-0.0002334
23	0.043357	-0.020649	-0.048806	8.867e-05	-0.002628
31	0.083732	-0.041993	-0.092931	0.00010326	0.0024354
42	0.01248	0.026865	-0.015235	2.871e-05	-0.00066714
44	0.010543	0.044206	-0.015732	1.998e-05	-0.0010077
48	0.12287	-0.065082	-0.13117	0.00013909	-0.0032962
51	0.043104	-0.034213	-0.050425	4.659e-05	0.0012218
52	-0.017951	0.076176	0.012831	-1.799e-05	-0.0041489
53	-0.01374	0.067074	-0.010271	-7.06e-06	-0.0049689
54	0.021123	0.064112	-0.03163	1.089e-05	0.00021378
55	-0.020613	0.091519	0.013435	-2.58e-05	-0.0056585
56	0.026866	-0.01723	-0.030872	6.123e-05	-0.0012387
61	0.013614	0.028411	-0.01629	2.947e-05	6.848e-05
62	0.027263	0.043144	-0.038539	2.173e-05	-0.00011593
71	0.024864	0.030952	-0.035315	2.9e-05	-0.00014144
72	0.0046061	0.041048	-0.016436	2.283e-05	-0.0034424
81	0.0025807	0.064158	-0.053669	6.886e-06	0.00024089
211	0.021938	0.021417	-0.029202	4.013e-07	-0.0011767
212	0.035666	-0.0045084	-0.055232	7.714e-05	1.0044
213	0.025438	0.040134	-0.031492	-7.405e-06	-0.0011609
Consumer	0.0018993	-0.06874	-0.083834	4.749e-05	0

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta^{substitution}_{x,mss,55}$	$\beta^{substitution}_{x,51,55}$	$\beta^{substitution}_{x,55,55}$	$\beta^{substitution}_{x,55,56}$	$\beta^{share\ trend}_{x,55}$
11	-0.0026507	-0.00032791	0.0014067	0.0015719	9.452e-06
22	-0.00071427	-0.001095	-0.00034342	0.0021527	6.235e-06
23	3.535e-05	0.00058964	-0.0035381	0.0029131	4.697e-06
31	-0.00038643	-0.0027697	0.0016242	0.0015319	2.711e-06
42	-8.242e-05	-0.0017342	-0.0016871	0.0035037	6.582e-06
44	5.838e-06	-0.0014569	-0.0012288	0.0026799	6.725e-06
48	0.00039008	0.0023766	-0.0033384	0.00057174	6.246e-06
51	-0.00090664	-0.0031389	-0.0010624	0.0051079	2.043e-06
52	-0.00017432	0.0025177	-0.0042188	0.0018754	1.204e-05
53	-0.001163	0.0020845	-0.005589	0.0046675	1.149e-05
54	-0.00021514	-0.0020429	-0.00012048	0.0023785	5.768e-06
55	-0.00024097	0.002796	-0.0057972	0.0032421	1.288e-05
56	9.95e-05	-8.709e-05	-0.0024958	0.0024834	6.264e-06
61	-5.385e-05	-0.001456	-0.00014215	0.001652	5.79e-06
62	-0.00038391	-0.002522	-0.0002567	0.0031626	5.922e-06
71	-0.00051206	-0.0021982	-0.0006581	0.0033684	5.939e-06
72	-0.00065368	-0.00053604	-0.0040295	0.0052192	7.781e-06
81	-0.0019812	-0.0020576	-0.00051378	0.0045525	6.387e-06
211	-0.00012127	-0.0025472	-0.0026927	0.0053612	1.247e-05
212	0.032885	-0.038513	-0.013479	0.019107	-0.0004988
213	-0.00011752	-0.0023092	-0.0018591	0.0042859	1.229e-05
Consumer	0	0	0	0	0

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta_{x,mm}^{share\,constant}$	$\beta_{x,mp}^{share\,constant}$	$\beta_{x,ms}^{share\,constant}$	$\beta_{x,mm}^{share\,trend}$	$\beta_{x,mp}^{share\,trend}$
11	0.5913	0.024425	0.096191	8.378e-05	-4.386e-06
22	0.84478	0.080724	0.18004	-0.00016394	-1.508e-05
23	0.19618	0.096828	0.15033	0.00022305	-1.443e-05
31	0.8452	0.04089	0.076838	-4.384e-05	-3.662e-06
42	0.069373	0.064485	0.2983	0.00012719	4.594e-05
44	0.068911	0.064752	0.29644	0.00012752	4.573e-05
48	0.096103	0.091727	0.18225	0.00011973	-5.05e-06
51	0.22714	0.27532	-0.22892	3.296e-05	-7.938e-05
52	0.034238	0.76522	-0.047549	2.318e-05	-0.00032895
53	0.043048	0.8664	-0.22343	5.169e-05	-0.00037623
54	0.70119	0.07436	0.14072	-0.00022203	5.214e-05
55	0.016688	0.71906	-0.2151	2.935e-05	-0.00030966
56	0.62576	0.11505	0.22971	-0.0001715	1.698e-05
61	0.70967	0.075768	0.14337	-0.00022616	5.181e-05
62	0.69049	0.076288	0.1444	-0.0002161	5.089e-05
71	0.66026	0.082877	0.16742	-0.00019955	4.557e-05
72	0.57099	0.074198	0.17114	-0.00014956	4.943e-05
81	0.74038	0.074781	0.15742	-0.00024782	4.809e-05
211	-0.016923	0.082791	0.19379	0.00017176	-2.017e-05
212	0.26614	0.048271	0.20606	0.00022062	-6.545e-06
213	0.019539	0.082261	0.15599	0.00017739	-2.068e-05
Consumer	1.0122	0.033243	-0.040646	-0.00041683	0.00011191

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta_{x,ms}^{share\,trend}$	$\beta_{x,mm,mm}^{substitution}$	$\beta_{x,mm,mp}^{substitution}$	$\beta_{x,mm,ms}^{substitution}$	$\beta_{x,mm,mo}^{substitution}$
11	-4.959e-07	0.16789	-0.016451	-0.061979	-0.089459
22	-3.265e-05	0.13086	-0.068363	-0.15223	0.089729
23	-2.751e-05	0.051309	-0.069952	-0.029508	0.048151
31	-1.185e-05	0.092601	-0.044293	-0.066687	0.018379
42	2.109e-05	0.064472	-0.0045548	-0.021167	-0.03875
44	2.199e-05	0.064163	-0.0044622	-0.020433	-0.039268
48	1.067e-06	0.085556	-0.0088388	-0.018482	-0.058235
51	0.00036022	0.039708	-0.066304	0.048263	-0.021666
52	0.0003445	0.001047	-0.03033	-0.076839	0.10612
53	0.00039456	0.035085	-0.037526	0.00029355	0.0021478
54	0.00012408	0.0076842	-0.065469	-0.099063	0.15685
55	0.00043478	0.015431	-0.012901	0.0034557	-0.0059863
56	4.579e-05	-0.05452	-0.079846	-0.15796	0.29232
61	0.00012251	0.0070657	-0.064107	-0.10174	0.15878
62	0.00012069	0.0058671	-0.065802	-0.10136	0.16129
71	0.00010471	-0.0017818	-0.067558	-0.11138	0.18072
72	0.00010232	0.0076946	-0.06156	-0.098228	0.15209
81	0.00012481	0.0043136	-0.068734	-0.11655	0.18097
211	0.00013253	-0.020936	0.001253	0.0032795	0.016404
212	-6.425e-05	0.09034	-0.029205	-0.05693	-0.0042047
213	0.00013183	0.013222	-0.0020109	-0.0030483	-0.0081631
Consumer	0.00013327	-0.019339	-0.037352	0.029569	0.027123

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta^{substitution}_{x,mp,mp}$	$\beta^{substitution}_{x,mp,ms}$	$\beta^{substitution}_{x,mp,mo}$	$\beta^{substitution}_{x,ms,ms}$	$\beta^{substitution}_{x,ms,mo}$
11	0.023664	-0.0026735	-0.0045401	0.085266	-0.020613
22	0.074103	-0.014617	0.0088769	0.14553	0.021314
23	0.062569	-0.014579	0.021962	0.12773	-0.083646
31	0.029506	-0.0041124	0.018899	0.067979	0.002821
42	0.060206	-0.020056	-0.035594	0.20091	-0.15969
44	0.059662	-0.01963	-0.035571	0.20007	-0.16001
48	0.083117	-0.016823	-0.057455	0.14812	-0.11282
51	0.11571	0.062793	-0.1122	-0.28349	0.17244
52	0.17803	0.026202	-0.1739	-0.24241	0.29304
53	0.10857	0.1928	-0.26384	-0.28761	0.094513
54	0.06795	-0.010553	0.0080721	0.11538	-0.0057674
55	0.19584	0.15453	-0.33747	-0.26138	0.1034
56	0.1016	-0.026816	0.005061	0.17555	0.009225
61	0.069363	-0.011503	0.0062462	0.11125	0.001994
62	0.069639	-0.01112	0.007283	0.11749	-0.0050159
71	0.075252	-0.0142	0.0065055	0.12804	-0.0024592
72	0.06714	-0.01274	0.0071591	0.13303	-0.022062
81	0.068235	-0.011989	0.012488	0.1105	0.01804
211	0.075779	-0.016134	-0.060897	0.15618	-0.14333
212	0.04339	-0.010433	-0.0037522	0.11823	-0.050864
213	0.074819	-0.01323	-0.059579	0.13141	-0.11513
Consumer	0.028815	-0.010568	0.019105	-0.08705	0.068049

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta^{share\ constant}_{x,mo}$	$\beta^{substitution}_{x,mo,mo}$	$\beta^{share\ trend}_{x,mo}$	$\beta^{share\ constant}_{x,211}$	$\beta^{share\ constant}_{x,22}$
11	0.28808	0.11461	-7.89e-05	0.00036768	0.95685
22	-0.10554	-0.11992	0.00021167	-0.031895	1.0167
23	0.55666	0.013533	-0.00018111	-0.00018488	0.012334
31	0.03707	-0.040098	5.935e-05	-0.022139	0.0028288
42	0.56785	0.23404	-0.00019422	0.0019125	0.97573
44	0.5699	0.23484	-0.00019524	0.001913	0.97572
48	0.62992	0.22851	-0.00011575	0.95825	0.03893
51	0.72647	-0.038571	-0.0003138	0.0030786	0.97447
52	0.24809	-0.22527	-3.874e-05	0.00091153	0.97246
53	0.31398	0.16718	-7.001e-05	0.0021002	0.97578
54	0.083724	-0.15915	4.581e-05	0.97133	0.029485
55	0.47935	0.24006	-0.00015447	0.0032657	0.97708
56	0.029471	-0.30661	0.00010873	0.12084	0.87717
61	0.071193	-0.16703	5.184e-05	0.0024124	0.97448
62	0.088824	-0.16356	4.451e-05	0.0029019	0.97464
71	0.089441	-0.18476	4.927e-05	0.0020589	0.97738
72	0.18367	-0.13719	-2.19e-06	0.001741	0.97505
81	0.027412	-0.2115	7.492e-05	0.00087926	0.97385
211	0.74034	0.18782	-0.00028412	1.1332	-0.1519
212	0.47954	0.058821	-0.00014983	0.00010194	0.93963
213	0.74221	0.18287	-0.00028855	1.141	-0.16378
Consumer	-0.0047984	-0.11428	0.00017165	0	1

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta_{x,213}^{share\ constant}$	$\beta_{x,211,211}^{substitution}$	$\beta_{x,211,22}^{substitution}$	$\beta_{x,211,213}^{substitution}$	$\beta_{x,22,22}^{substitution}$
11	0.042783	0.00033611	0.00028681	-0.00062292	-0.0012509
22	0.015186	-0.044585	0.044807	-0.00022198	-0.053647
23	0.98785	-0.00018802	0.00026427	-7.625e-05	-0.031511
31	1.0193	-0.02263	6.312e-05	0.022566	0.0020596
42	0.022356	0.00064011	1.635e-05	-0.00065646	0.00042695
44	0.022365	0.00063968	1.671e-05	-0.00065639	0.00042734
48	0.0028222	0.016971	-0.014266	-0.0027052	0.014293
51	0.022451	0.00099077	-0.00010514	-0.00088563	-2.63e-05
52	0.026624	0.00057558	0.0003527	-0.00092827	8.5e-05
53	0.022121	0.0015266	-0.00031432	-0.0012123	0.00050405
54	-0.00081132	0.011661	-0.011962	0.00030069	0.011182
55	0.019655	0.000623	0.00031325	-0.00093625	-8.021e-05
56	0.0019828	0.0033174	-0.0030112	-0.00030623	0.0031154
61	0.023108	0.00078138	-8.664e-05	-0.00069474	0.00030988
62	0.022456	0.00096121	-0.00024831	-0.0007129	0.00059815
71	0.020561	0.0016548	-0.0006648	-0.00099003	0.001213
72	0.023208	0.00072292	-5.567e-05	-0.00066725	0.00035023
81	0.025276	0.00073803	-4.581e-05	-0.00069221	0.00029622
211	0.0187	-0.1602	0.19333	-0.033122	-0.23146
212	0.060272	9.097e-05	0.00027411	-0.00036508	0.025433
213	0.022767	-0.17192	0.20521	-0.033287	-0.24593
Consumer	0	0	0	0	0

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta^{substitution}_{x,213,22}$	$\beta^{substitution}_{x,213,213}$	$\beta^{share\,trend}_{x,211}$	$\beta^{share\,trend}_{x,22}$	$\beta^{share\,trend}_{x,213}$
11	0.00096412	-0.00034119	-2.498e-07	2.141e-05	-2.116e-05
22	0.0088408	-0.0086188	0.00023913	-0.0002748	3.567e-05
23	0.031247	-0.03117	7.901e-08	0.00048787	-0.00048795
31	-0.0021227	-0.020444	0.00024492	0.00022459	-0.00046951
42	-0.0004433	0.0010998	-8.655e-07	1.199e-05	-1.112e-05
44	-0.00044405	0.0011004	-8.658e-07	1.199e-05	-1.113e-05
48	-2.742e-05	0.0027326	-0.00047085	0.00047041	4.375e-07
51	0.00013144	0.00075419	-1.498e-06	1.273e-05	-1.123e-05
52	-0.0004377	0.001366	-5.446e-07	1.369e-05	-1.315e-05
53	-0.00018973	0.001402	-7.624e-07	1.17e-05	-1.093e-05
54	0.00078021	-0.0010809	-0.00047061	0.0004673	3.319e-06
55	-0.00023303	0.0011693	-1.724e-06	1.141e-05	-9.681e-06
56	-0.00010422	0.00041045	-5.843e-05	5.898e-05	-5.488e-07
61	-0.00022324	0.00091798	-1.09e-06	1.263e-05	-1.154e-05
62	-0.00034985	0.0010627	-1.237e-06	1.24e-05	-1.117e-05
71	-0.00054816	0.0015382	-5.099e-07	1.063e-05	-1.012e-05
72	-0.00029456	0.00096181	-7.591e-07	1.234e-05	-1.158e-05
81	-0.00025041	0.00094262	-3.382e-07	1.295e-05	-1.261e-05
211	0.038129	-0.005007	-0.00023906	0.00018829	5.077e-05
212	-0.025707	0.026072	-1.045e-07	-3.478e-06	3.583e-06
213	0.040721	-0.007434	-0.00024921	0.00020138	4.783e-05
Consumer	0	0	0	0	0

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta_{x,e}^{share\ constant}$	$\beta_{x,e}^{share\ trend}$	$\beta_{x,e,e}^{substitution}$	$\beta_{x,e,m}^{substitution}$	$\beta_{x,m}^{share\ constant}$
11	0.010363	1.849e-06	0.010246	-0.0043692	0.51586
22	-0.0040739	0.00013168	-0.027058	0.028894	0.88738
23	0.0063019	-1.348e-06	0.0022105	-0.00030965	1.0531
31	0.037632	1.467e-05	0.034824	-0.0067603	0.24449
42	0.018815	4.478e-06	0.018331	0.0014625	-0.00018766
44	0.84715	-0.00041493	0.011198	-0.028638	0.27103
48	0.011802	4.659e-07	0.011036	0.0050669	-0.27461
51	0.0048259	2.457e-06	0.0046655	0.0011133	-0.0064951
52	0.01762	-1.237e-06	0.014042	-0.0099992	0.84602
53	0.02318	-3.72e-06	0.011639	0.010117	0.039743
54	0.92118	-0.00045391	0.021599	-0.0096303	0.068316
55	0.0067542	2.907e-06	0.0060455	-0.0004574	0.21209
56	0.0029099	5.38e-06	0.0024748	0.00034235	0.037551
61	-0.00056103	6.954e-06	-0.0011582	0.00080498	-0.08982
62	-0.0011453	7.067e-06	-0.0021038	0.001029	-0.027199
71	0.085592	-3.381e-05	0.014397	0.0032901	0.72736
72	-0.00033804	7.798e-06	-0.0011088	0.0026752	0.062539
81	0.0012861	6.007e-06	0.00022175	0.0011799	-0.090385
211	0.57168	-0.00019234	-0.045123	0.2052	0.14997
212	0.16979	-6.075e-05	0.012422	0.0028327	0.87463
213	1.0461	-0.00043952	-0.077757	0.17927	-0.14262
Consumer	0.46514	-0.00021874	0.013106	-0.013106	0.53486

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta^{substitution}_{x,m,m}$	$\beta^{share\,trend}_{x,m}$	$\beta^{share\,constant}_{x,k}$	$\beta^{share\,constant}_{x,l}$	$\beta^{substitution}_{x,k,k}$
11	0.14117	2.807e-05	0.1668	0.30698	0.13897
22	0.071786	-0.00032356	0.12807	-0.011381	0.11166
23	-0.075092	-0.00025151	0.0435	-0.10291	0.041412
31	0.037579	0.00016325	-0.029308	0.74718	-0.030166
42	-0.083337	0.00017705	-0.022253	1.0036	-0.023643
44	-0.21043	3.293e-05	-0.013116	-0.10507	-0.020143
48	-0.36688	0.00037715	0.094484	1.1683	0.085535
51	-0.018442	0.00020897	-0.0043229	1.006	-0.0043416
52	-0.11967	-0.00027521	0.12228	0.01408	-0.0034837
53	-0.059992	0.00014687	0.89709	0.039988	0.011127
54	0.0074625	0.00015132	0.012316	-0.001812	0.011996
55	-0.000471	4.621e-05	0.65408	0.12707	0.1872
56	-0.098253	0.00017325	0.91369	0.045846	-0.015243
61	-0.10358	0.00023166	1.033	0.057361	-0.037684
62	-0.10318	0.0002005	0.96863	0.059711	-0.038317
71	0.13096	-0.00017446	0.025067	0.16198	0.024384
72	-0.14361	0.00015012	0.92693	0.010869	-0.027951
81	-0.10432	0.00022719	1.0335	0.055607	-0.039311
211	-0.16442	8.203e-05	0.061172	0.21718	0.057429
212	-0.071776	-0.00023697	0.10155	-0.14597	0.090232
213	-0.19361	0.00023006	0.017658	0.078866	0.017346
Consumer	0.013106	0.00021874	0	0	0

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta_{x,k,l}^{substitution}$	$\beta_{x,k,e}^{substitution}$	$\beta_{x,k,m}^{substitution}$	$\beta_{x,l,l}^{substitution}$	$\beta_{x,l,e}^{substitution}$
11	-0.051628	-0.0017314	-0.085613	0.10696	-0.0041457
22	0.0014574	0.00031053	-0.11343	-0.012061	-0.0021467
23	0.0032492	-0.00047143	-0.04419	-0.12141	-0.0014294
31	0.021898	0.0011024	0.007166	0.045252	-0.029166
42	0.017333	0.0002273	0.0060834	-0.073103	-0.020021
44	-0.0018962	-0.0047283	0.026767	-0.23257	0.022168
48	-0.11078	-0.0011721	0.026419	-0.20968	-0.014931
51	0.0043324	1.959e-05	-1.04e-05	-0.015873	-0.0057984
52	-0.055131	-0.0031595	0.061774	-0.011876	-0.0008838
53	-0.038766	-0.020826	0.048465	0.038286	-0.00093024
54	-0.00011557	-0.012138	0.0002583	-0.001964	0.00017001
55	-0.086104	-0.0047076	-0.096386	-0.01033	-0.00088051
56	-0.060044	-0.0026587	0.077945	0.040236	-0.00015843
61	-0.059677	0.00057486	0.096786	0.053911	-0.00022167
62	-0.060476	0.0010135	0.09778	0.056044	6.125e-05
71	-0.0040781	-0.0024228	-0.017884	0.13571	-0.015264
72	-0.051546	-0.00086107	0.080358	-0.0083274	-0.00070538
81	-0.057469	-0.00133	0.098109	0.052514	-7.17e-05
211	-0.013285	-0.035335	-0.0088091	0.16998	-0.12474
212	0.013971	-0.017525	-0.086678	-0.17186	0.00227
213	-0.0013926	-0.018472	0.0025184	0.072623	-0.083046
Consumer	0	0	0	0	0

Table E.1: Cost and Expenditure Function Parameters for the GRT Model

Industry	$\beta_{x,l,m}^{substitution}$	$\beta_{x,k}^{share\ trend}$	$\beta_{x,l}^{share\ trend}$	$\beta_{x}^{cost\ trend}$	$\beta_{x}^{cost\ constant}$
11	-0.051191	3.026e-05	-6.018e-05	-0.013847	27.41
22	0.01275	0.00010339	8.848e-05	0.0090018	-17.924
23	0.11959	2.161e-06	0.00025069	0.0096268	-19.095
31	-0.037984	7.677e-05	-0.0002547	-0.007582	14.97
42	0.075792	8.367e-05	-0.0002652	-0.0088258	17.498
44	0.2123	7.875e-05	0.00030325	-0.0054095	10.748
48	0.3354	2.034e-05	-0.00039796	-0.0042505	8.435
51	0.017339	0.00011765	-0.00032908	-0.0052071	10.402
52	0.067891	0.0001649	0.00011155	-0.00866	17.186
53	0.0014106	-0.00028223	0.00013908	-0.0025146	5.021
54	0.0019095	5.1e-05	0.00025158	0.0032568	-6.4542
55	0.097314	-0.00010325	5.414e-05	-0.0021853	4.3844
56	0.019966	-0.00039586	0.00021723	0.00095443	-1.8781
61	0.0059878	-0.00046072	0.0002221	0.0060428	-11.964
62	0.0043706	-0.00042787	0.00022031	0.0048083	-9.5327
71	-0.11637	4.604e-05	0.00016223	0.0048331	-9.5683
72	0.060579	-0.00040468	0.00024677	0.0011281	-2.2191
81	0.0050262	-0.0004403	0.0002071	0.003627	-7.1744
211	-0.031963	0.00018373	-7.342e-05	0.025933	-51.699
212	0.15562	6.868e-05	0.00022904	-0.0050388	9.7253
213	0.011815	0.00019585	1.361e-05	0.014004	-28.101
Consumer	0	0	0	0	0

Appendix F

Full Regression Summary Statistics

This section lists the full summary statistics for the baseline regressions used to parametrize the energy model. These summary statistics are for the baseline regression specification that uses iterated three-stage least squares with one period lagged prices as instruments.

Table F.1: Full Regression Summary Statistics

Industry	Monotonic (%) MOT	Monotonic (%) MSS	Monotonic (%) MM
11	86.3	100	97.8
21	70.6	84.3	26.1
22	82.4	98	97.8
23	82.4	70.6	82.6
31	80.4	76.5	93.5
42	78.4	82.4	97.8
44	66.7	84.3	95.7
48	0	72.5	100
51	64.7	82.4	65.2
52	78.4	80.4	97.8
53	86.3	98	78.3
54	47.1	76.5	0
55	56.9	92.2	82.6
56	84.3	84.3	97.8
61	72.5	78.4	23.9
62	78.4	92.2	21.7
71	74.5	80.4	95.7
72	72.5	74.5	97.8
81	76.5	86.3	73.9
211	94.1	94.1	0
324	76.5	66.7	87
486	0	66.7	97.8
Consumer	0	78.4	0

Table F.1: Full Regression Summary Statistics

Industry	Monotonic (%) MP	Monotonic (%) MO	Monotonic (%) MS
11	0	98	98
21	100	68.6	94.1
22	100	0	86.3
23	0	0	94.1
31	96.1	94.1	98
42	98	58.8	92.2
44	96.1	21.6	96.1
48	98	90.2	88.2
51	96.1	0	84.3
52	90.2	60.8	96.1
53	96.1	56.9	94.1
54	98	15.7	98
55	96.1	62.7	82.4
56	94.1	0	98
61	100	15.7	96.1
62	92.2	74.5	98
71	94.1	0	90.2
72	100	1.96	88.2
81	90.2	72.5	94.1
211	92.2	58.8	100
324	90.2	94.1	13.7
486	100	90.2	100
Consumer	0	90.2	80.4

Table F.1: Full Regression Summary Statistics

Industry	Monotonic (%) M	Monotonic (%) E	Monotonic (%) KLEM
11	32.6	0	63
21	0	62.7	78.3
22	80.4	86.3	95.7
23	43.5	0	84.8
31	0	0	93.5
42	0	0	80.4
44	0	0	100
48	89.1	58.8	17.4
51	41.3	0	93.5
52	0	0	10.9
53	0	0	95.7
54	60.9	96.1	10.9
55	0	0	95.7
56	0	54.9	65.2
61	78.3	0	91.3
62	87	0	15.2
71	76.1	0	32.6
72	78.3	0	84.8
81	78.3	0	84.8
211	0	0	67.4
324	0	41.2	93.5
486	91.3	64.7	26.1
Consumer	0	9.8	86.3

Table F.1: Full Regression Summary Statistics

Industry	Cost Share R^2 11	Cost Share R^2 21	Cost Share R^2 22
11	0.0986	0.272	0.597
21	0.516	0.00553	0.0497
22	0.0332	0.00021	0.00722
23	0.0559	0.296	0.603
31	0.71	0.439	0.326
42	0.0372	0.074	0.683
44	0.0332	0.00417	0.683
48	0.852	0.108	0.776
51	0.415	0.019	0.633
52	0.677	0.375	0.718
53	0.739	0.23	0.671
54	0.718	0.585	0.604
55	0.674	0.391	0.719
56	0.495	0.000169	0.8
61	0.613	0.787	0.548
62	0.656	0.784	0.59
71	0.751	0.0603	0.682
72	0.287	0.0404	0.585
81	0.771	0.0807	0.562
211	0.471	0.673	0.722
324	0.219	0.232	0.0115
486	0.818	0.101	0.775
Consumer	0.396	na	0.982

Table F.1: Full Regression Summary Statistics

Industry	Cost Share R^2 23	Cost Share R^2 31	Cost Share R^2 42
11	0.0795	0.0962	0.802
21	0.806	0.0542	0.288
22	0.478	7.99e-07	0.862
23	0.0125	0.175	0.348
31	0.907	0.633	0.836
42	0.612	0.249	0.16
44	0.809	0.252	0.161
48	0.822	0.729	0.164
51	0.746	0.586	0.108
52	0.64	0.52	0.866
53	0.647	0.661	0.223
54	0.732	0.654	0.0657
55	0.64	0.516	0.867
56	0.708	0.711	0.657
61	0.729	0.669	0.0648
62	0.4	0.669	0.126
71	0.717	0.685	0.426
72	0.73	0.497	0.0655
81	0.535	0.703	0.0316
211	0.618	0.727	0.782
324	0.773	0.259	0.324
486	0.822	0.731	0.168
Consumer	na	0.394	0.523

Table F.1: Full Regression Summary Statistics

Industry	Cost Share R^2 44	Cost Share R^2 48	Cost Share R^2 51
11	0.802	0.802	0.804
21	0.267	0.283	0.369
22	0.489	0.792	0.646
23	0.279	0.327	0.534
31	0.834	0.835	0.753
42	0.0382	0.0946	0.489
44	0.036	0.0959	0.497
48	0.197	0.173	0.0812
51	0.15	0.189	0.319
52	0.946	0.793	0.387
53	0.831	0.0249	0.594
54	0.0175	0.0359	0.781
55	0.946	0.795	0.372
56	0.431	0.629	0.51
61	0.0168	0.0353	0.718
62	0.00999	0.101	0.654
71	0.203	0.373	0.72
72	0.105	0.0204	0.618
81	0.202	0.00273	0.613
211	0.742	0.773	0.0131
324	0.317	0.322	0.191
486	0.201	0.177	0.0856
Consumer	0.758	0.0324	0.351

Table F.1: Full Regression Summary Statistics

Industry	Cost Share R^2 52	Cost Share R^2 53	Cost Share R^2 54
11	0.515	0.868	0.539
21	0.563	0.442	0.602
22	0.621	0.949	0.36
23	0.372	0.922	0.294
31	0.409	0.0922	0.319
42	0.241	0.222	0.249
44	0.248	0.943	0.255
48	0.878	0.343	0.881
51	0.763	0.964	0.783
52	0.677	0.335	0.683
53	0.428	0.318	0.418
54	0.104	0.942	0.101
55	0.703	0.336	0.707
56	0.211	0.953	0.237
61	0.0976	0.941	0.0955
62	0.102	0.2	0.101
71	0.12	0.95	0.119
72	0.144	0.947	0.142
81	0.165	0.237	0.161
211	0.254	0.181	0.476
324	0.0107	0.292	0.018
486	0.879	0.339	0.881
Consumer	0.00126	0.461	0.806

Table F.1: Full Regression Summary Statistics

Industry	Cost Share R^2 55	Cost Share R^2 56	Cost Share R^2 61
11	0.839	0.325	0.395
21	0.585	0.65	0.703
22	0.414	0.875	0.641
23	0.0101	0.8	0.422
31	0.458	0.594	0.339
42	0.433	0.106	0.187
44	0.424	0.115	0.317
48	0.0524	0.797	0.466
51	0.0961	0.419	0.143
52	0.262	0.659	0.0513
53	0.135	0.395	0.207
54	0.173	0.0529	0.114
55	0.18	0.659	0.0523
56	0.249	0.573	0.377
61	0.173	0.0459	0.111
62	0.178	0.0374	0.129
71	0.191	0.00183	0.194
72	0.435	0.00848	0.124
81	0.112	0.00132	0.0202
211	0.0346	4.55e-05	0.718
324	0.394	0.368	0.822
486	0.0272	0.793	0.44
Consumer	na	0.0999	0.78

Table F.1: Full Regression Summary Statistics

Industry	Cost Share R^2 62	Cost Share R^2 71	Cost Share R^2 72
11	0.845	0.129	0.837
21	0.883	0.54	0.936
22	0.94	0.989	0.803
23	0.904	0.156	0.916
31	0.828	0.903	0.789
42	0.88	0.0165	0.875
44	0.88	0.0436	0.873
48	0.967	0.956	0.825
51	0.917	0.502	0.937
52	0.833	0.0685	0.904
53	0.824	0.238	0.879
54	0.811	0.00012	0.811
55	0.833	0.0729	0.904
56	0.91	0.881	0.818
61	0.81	8.17e-05	0.811
62	0.817	0.0246	0.811
71	0.835	0.311	0.811
72	0.844	0.0174	0.846
81	0.81	0.0192	0.804
211	0.885	0.935	0.857
324	0.764	0.625	0.654
486	0.968	0.952	0.825
Consumer	0.114	0.33	0.701

Table F.1: Full Regression Summary Statistics

Industry	Cost Share R^2 81	Cost Share R^2 211	Cost Share R^2 324
11	0.434	0.00937	0.638
21	0.416	0.742	0.741
22	0.833	0.0392	0.281
23	0.522	0.00923	0.668
31	0.449	0.0106	0.131
42	0.22	0.219	0.688
44	0.226	0.242	0.688
48	0.862	0.129	0.803
51	0.688	0.136	0.652
52	0.661	0.0118	0.693
53	0.453	0.16	0.649
54	0.113	0.383	0.567
55	0.69	0.00354	0.693
56	0.0985	0.0676	0.795
61	0.103	0.0148	0.555
62	0.107	0.121	0.596
71	0.123	0.374	0.687
72	0.154	0.015	0.592
81	0.178	0.024	0.567
211	0.393	0.532	0.196
324	0.253	0.276	0.00206
486	0.861	0.124	0.803
Consumer	0.209	na	0.982

Table F.1: Full Regression Summary Statistics

Industry	Cost Share R^2 486	Cost Share R^2 MOT	Cost Share R^2 MSS
11	0.904	0.0221	0.522
21	0.0246	0.000186	0.599
22	0.247	0.227	0.907
23	0.91	0.871	0.728
31	0.772	0.57	0.745
42	0.909	0.0131	0.514
44	0.908	0.108	0.522
48	0.862	0.629	0.6
51	0.888	0.104	0.283
52	0.439	0.275	0.114
53	0.831	0.182	0.534
54	0.809	0.0652	0.797
55	0.455	0.276	0.104
56	0.893	0.177	0.682
61	0.834	0.0628	0.754
62	0.871	0.00197	0.791
71	0.901	0.0823	0.751
72	0.821	0.11	0.671
81	0.822	0.0714	0.665
211	0.0858	0.00961	0.00342
324	0.662	0.554	0.591
486	0.862	0.633	0.598
Consumer	0.514	0.461	0.0299

Table F.1: Full Regression Summary Statistics

Industry	Cost Share R^2 MM	Cost Share R^2 MP	Cost Share R^2 MO
11	0.932	0.973	0.624
21	0.42	0.953	0.321
22	0.82	0.821	0.062
23	0.689	0.958	0.405
31	0.869	0.957	0.34
42	0.333	0.633	0.901
44	0.331	0.63	0.898
48	0.421	0.886	0.871
51	0.612	0.952	0.556
52	0.603	0.932	0.931
53	0.731	0.957	0.849
54	0.866	0.905	0.89
55	0.558	0.968	0.913
56	0.829	0.868	0.948
61	0.864	0.902	0.884
62	0.86	0.903	0.888
71	0.84	0.899	0.885
72	0.845	0.873	0.883
81	0.865	0.896	0.884
211	0.754	0.915	0.0465
324	0.205	0.862	0.526
486	0.422	0.887	0.871
Consumer	0.766	0.444	0.0685

Table F.1: Full Regression Summary Statistics

Industry	Cost Share R^2 MS	Cost Share R^2 M	Cost Share R^2 E
11	0.933	0.765	0.874
21	0.685	0.522	0.389
22	0.487	0.681	0.136
23	0.904	0.303	0.821
31	0.929	0.348	0.248
42	0.844	0.538	0.665
44	0.839	0.64	0.679
48	0.919	0.115	0.855
51	0.458	0.161	0.379
52	0.793	0.75	0.839
53	0.642	0.264	0.739
54	0.947	0.449	0.46
55	0.755	0.853	0.657
56	0.936	0.29	0.103
61	0.949	0.402	0.702
62	0.952	0.459	0.446
71	0.828	0.641	0.126
72	0.857	0.428	0.625
81	0.799	0.282	0.39
211	0.724	0.407	0.31
324	0.787	0.14	0.296
486	0.922	0.151	0.672
Consumer	0.201	0.939	0.939

Table F.1: Full Regression Summary Statistics

Industry	Cost Share R^2 K	Cost Share R^2 L	Cost Share R^2 N
11	0.941	0.509	0.000207
21	0.168	0.769	0.591
22	0.0756	0.415	0.847
23	0.621	0.652	0.165
31	0.0021	0.184	0.392
42	0.294	0.876	0.36
44	0.321	0.878	0.369
48	0.606	0.462	0.73
51	0.0313	0.752	0.599
52	0.468	0.415	0.245
53	0.622	0.402	0.44
54	0.522	0.554	0.586
55	0.685	0.436	0.243
56	0.309	0.593	0.642
61	0.189	0.629	0.557
62	0.513	0.557	0.57
71	0.567	0.642	0.568
72	0.0313	0.562	0.493
81	0.351	0.616	0.549
211	0.4	0.51	0.526
324	0.713	0.456	0.657
486	0.584	0.61	0.733
Consumer	na	na	na

Table F.1: Full Regression Summary Statistics

Industry	Cost R^2 KLEM	Under ID P-Value (%) MOT	Under ID P-Value (%) MSS
11	0.983	1.34	0.00139
21	0.972	1.34	0.00139
22	0.987	1.34	0.00139
23	0.998	1.34	0.00139
31	0.995	1.34	0.00139
42	0.989	1.34	0.00139
44	0.998	1.34	0.00139
48	0.993	1.34	0.00139
51	0.991	1.34	0.00139
52	0.998	1.34	0.00139
53	0.999	1.34	0.00139
54	0.998	1.34	0.00139
55	0.996	1.34	0.00139
56	0.998	1.34	0.00139
61	0.998	1.34	0.00139
62	0.998	1.34	0.00139
71	0.998	1.34	0.00139
72	0.998	1.34	0.00139
81	0.999	1.34	0.00139
211	0.971	1.34	0.00139
324	0.985	1.34	0.00139
486	0.995	1.34	0.00139
Consumer	na	17.5	4.54

Table F.1: Full Regression Summary Statistics

Industry	Under ID P-Value (%) MM	Under ID P-Value (%) MP	Under ID P-Value (%) MO
11	0.0128	0.0121	0.000146
21	0.018	0.0121	0.000921
22	0.459	0.0121	0.0107
23	0.00836	0.0121	5.88e-05
31	0.0298	0.0121	0.000113
42	0.0308	0.0121	6.97e-05
44	0.0309	0.0121	6.96e-05
48	0.0575	0.0121	0.0426
51	0.0168	0.0121	0.000142
52	0.0264	0.0121	0.0012
53	0.0175	0.0121	0.000692
54	0.0117	0.0121	0.000106
55	0.0266	0.0121	0.00123
56	0.017	0.0121	0.00367
61	0.0117	0.0121	0.000104
62	0.0113	0.0121	0.000124
71	0.00992	0.0121	0.000214
72	0.0124	0.0121	9.33e-05
81	0.0122	0.0121	0.000119
211	0.00621	0.0121	0.00032
324	0.0631	0.0121	0.000789
486	0.0577	0.0121	0.0426
Consumer	72	36.3	1.34

Table F.1: Full Regression Summary Statistics

Industry	Under ID P-Value (%) MS	Under ID P-Value (%) M	Under ID P-Value (%) E
11	0.116	3.59	0.00806
21	0.116	0.00297	0.00806
22	0.117	0.000468	0.00806
23	0.119	0.00899	0.00806
31	0.118	0.0174	0.00806
42	0.117	0.00231	0.00806
44	0.117	0.00149	0.00806
48	0.117	0.000521	0.00806
51	0.118	0.00452	0.00806
52	0.116	0.000213	0.00806
53	0.116	0.00024	0.00806
54	0.117	0.00018	0.00806
55	0.116	0.000213	0.00806
56	0.117	0.000421	0.00806
61	0.117	0.000192	0.00806
62	0.117	0.000265	0.00806
71	0.117	0.000188	0.00806
72	0.117	0.00021	0.00806
81	0.117	0.000206	0.00806
211	0.116	0.00172	0.00806
324	0.117	0.00794	0.00806
486	0.117	0.000538	0.00806
Consumer	21.2	76.5	79.7

Table F.1: Full Regression Summary Statistics

Industry	Under ID P-Value (%) KLEM	Weak Stat MOT	Weak Stat MSS
11	0.108	2.1	9.64
21	0.0436	2.1	9.64
22	0.00202	2.1	9.64
23	7.14e-05	2.1	9.64
31	0.0211	2.1	9.64
42	17.7	2.1	9.64
44	17.8	2.1	9.64
48	0.293	2.1	9.64
51	5.78e-05	2.1	9.64
52	0.299	2.1	9.64
53	0.961	2.1	9.64
54	30.8	2.1	9.64
55	0.308	2.1	9.64
56	18.2	2.1	9.64
61	21.8	2.1	9.64
62	25	2.1	9.64
71	29.4	2.1	9.64
72	32.1	2.1	9.64
81	22.9	2.1	9.64
211	1.98	2.1	9.64
324	4.53	2.1	9.64
486	0.297	2.1	9.64
Consumer	27	0.455	1.2

Table F.1: Full Regression Summary Statistics

Industry	Weak Stat MM	Weak Stat MP	Weak Stat MO
11	4.71	4.77	14.2
21	4.42	4.77	10.4
22	2.12	4.77	6.68
23	5.11	4.77	16.6
31	4	4.77	14.8
42	3.97	4.77	16.1
44	3.97	4.77	16.1
48	3.49	4.77	5.08
51	4.48	4.77	14.3
52	4.1	4.77	9.9
53	4.44	4.77	10.9
54	4.8	4.77	15
55	4.09	4.77	9.85
56	4.47	4.77	8.12
61	4.8	4.77	15
62	4.83	4.77	14.6
71	4.95	4.77	13.3
72	4.74	4.77	15.3
81	4.76	4.77	14.7
211	5.4	4.77	12.4
324	3.42	4.77	10.6
486	3.49	4.77	5.08
Consumer	0.0464	0.125	3.87

Table F.1: Full Regression Summary Statistics

Industry	Weak Stat MS	Weak Stat M	Weak Stat E
11	2.99	1.06	5.15
21	2.99	6.17	5.15
22	2.98	8.5	5.15
23	2.97	5.04	5.15
31	2.97	4.45	5.15
42	2.98	6.45	5.15
44	2.98	6.96	5.15
48	2.98	8.35	5.15
51	2.97	5.72	5.15
52	2.99	9.73	5.15
53	2.99	9.53	5.15
54	2.98	10	5.15
55	2.99	9.73	5.15
56	2.98	8.66	5.15
61	2.98	9.9	5.15
62	2.98	9.37	5.15
71	2.98	9.94	5.15
72	2.98	9.75	5.15
81	2.98	9.78	5.15
211	2.99	6.8	5.15
324	2.98	5.16	5.15
486	2.98	8.3	5.15
Consumer	0.375	0.0128	0.0143

Table F.1: Full Regression Summary Statistics

Industry	Weak Stat KLEM	Nonnegative (%) 48	Nonnegative (%) 42
11	3.04	100	100
21	3.7	100	100
22	6.6	100	100
23	11.7	100	100
31	4.28	100	100
42	0.412	100	100
44	0.41	100	100
48	2.39	100	100
51	12.2	100	100
52	2.37	100	100
53	1.71	100	100
54	0.231	100	100
55	2.36	100	100
56	0.401	100	100
61	0.341	100	100
62	0.296	100	100
71	0.245	100	100
72	0.218	100	100
81	0.324	100	100
211	1.34	100	100
324	0.953	100	100
486	2.38	100	100
Consumer	0.477	100	100

Table F.1: Full Regression Summary Statistics

Industry	Nonnegative (%) 44	Nonnegative (%) 54	Nonnegative (%) 81
11	100	100	100
21	100	100	100
22	100	100	100
23	100	100	100
31	100	100	100
42	100	100	100
44	100	100	100
48	100	100	100
51	100	100	100
52	100	100	100
53	100	100	100
54	100	100	100
55	100	100	100
56	100	100	100
61	100	100	100
62	100	100	100
71	100	100	100
72	100	100	100
81	100	100	100
211	100	100	100
324	100	100	100
486	100	100	100
Consumer	100	100	100

Table F.1: Full Regression Summary Statistics

Industry	Nonnegative (%) 52	Nonnegative (%) 11	Nonnegative (%) 31
11	100	100	100
21	100	100	100
22	100	100	100
23	100	100	100
31	100	100	100
42	100	100	100
44	100	100	100
48	100	100	100
51	100	100	100
52	100	100	100
53	100	100	100
54	100	100	100
55	100	100	100
56	100	100	100
61	100	100	100
62	100	100	100
71	100	100	100
72	100	100	100
81	100	100	100
211	100	100	100
324	100	100	100
486	100	100	100
Consumer	100	100	100

Table F.1: Full Regression Summary Statistics

Industry	Nonnegative (%) 21	Nonnegative (%) N	Nonnegative (%) 61
11	100	99.8	100
21	100	100	100
22	100	100	100
23	100	100	100
31	100	100	100
42	100	100	100
44	100	100	100
48	100	100	100
51	100	100	100
52	100	100	100
53	100	100	100
54	100	100	100
55	100	100	100
56	100	100	100
61	100	100	100
62	100	100	100
71	100	100	100
72	99	100	100
81	100	100	100
211	100	100	100
324	100	100	100
486	100	100	100
Consumer	100	100	100

Table F.1: Full Regression Summary Statistics

Industry	Nonnegative (%) 62	Nonnegative (%) 71	Nonnegative (%) 72
11	100	100	100
21	100	100	100
22	100	100	100
23	100	100	100
31	100	100	100
42	100	100	100
44	100	100	100
48	100	100	100
51	100	100	100
52	100	100	100
53	100	100	100
54	100	100	100
55	100	100	100
56	100	100	100
61	100	100	100
62	100	100	100
71	100	100	100
72	100	100	100
81	100	100	100
211	100	100	100
324	100	100	100
486	100	100	100
Consumer	100	100	100

Table F.1: Full Regression Summary Statistics

Industry	Nonnegative (%) 23	Nonnegative (%) 53	Nonnegative (%) MOT
11	100	100	100
21	98.1	100	100
22	100	100	100
23	100	100	100
31	100	100	100
42	100	100	100
44	100	100	100
48	98.8	100	100
51	100	100	100
52	100	100	100
53	100	100	100
54	100	100	100
55	100	100	100
56	100	100	100
61	100	100	100
62	100	100	100
71	100	100	100
72	100	100	100
81	100	100	100
211	100	100	100
324	97.9	100	100
486	99	100	100
Consumer	100	100	100

Table F.1: Full Regression Summary Statistics

Industry	Nonnegative (%) MSS	Nonnegative (%) 51	Nonnegative (%) 55
11	100	100	100
21	100	100	100
22	100	100	100
23	100	100	100
31	100	100	100
42	100	100	100
44	100	100	100
48	100	100	100
51	100	100	100
52	100	100	100
53	100	100	100
54	100	100	100
55	100	100	100
56	100	100	100
61	100	100	100
62	100	100	100
71	100	100	100
72	100	100	100
81	100	100	100
211	100	100	100
324	100	100	100
486	100	100	100
Consumer	100	100	100

Table F.1: Full Regression Summary Statistics

Industry	Nonnegative (%) 56	Nonnegative (%) MM	Nonnegative (%) MP
11	100	100	100
21	100	100	100
22	100	100	100
23	100	100	100
31	100	100	100
42	100	100	100
44	100	100	100
48	100	100	100
51	100	100	100
52	100	100	100
53	100	100	100
54	100	100	100
55	100	100	100
56	100	100	100
61	100	100	100
62	100	100	100
71	100	100	100
72	100	100	100
81	100	100	100
211	100	100	100
324	100	100	100
486	100	100	100
Consumer	100	100	100

Table F.1: Full Regression Summary Statistics

Industry	Nonnegative (%) MS	Nonnegative (%) MO	Nonnegative (%) 211
11	100	100	95.8
21	100	100	100
22	100	100	100
23	100	100	96.2
31	100	100	100
42	100	100	99.7
44	100	100	99.7
48	100	100	100
51	100	100	96.9
52	100	100	95.8
53	100	100	99.8
54	100	100	99.7
55	100	100	95.3
56	100	100	100
61	100	100	99.3
62	100	100	100
71	100	100	100
72	100	100	99.5
81	100	100	99.1
211	100	100	100
324	100	100	100
486	100	100	100
Consumer	100	100	100

Table F.1: Full Regression Summary Statistics

Industry	Nonnegative (%) 22	Nonnegative (%) 324	Nonnegative (%) 486
11	100	100	99.8
21	100	100	100
22	100	100	97
23	100	100	100
31	100	100	100
42	100	100	100
44	100	100	100
48	100	100	100
51	100	100	100
52	100	100	100
53	100	100	100
54	100	100	100
55	100	100	100
56	100	100	100
61	100	100	100
62	100	100	100
71	100	100	100
72	100	100	100
81	100	100	100
211	100	97.2	100
324	100	100	99.8
486	100	100	100
Consumer	100	100	100

Table F.1: Full Regression Summary Statistics

Industry	Nonnegative (%) K	Nonnegative (%) L	Nonnegative (%) E
11	100	100	100
21	100	100	100
22	100	100	100
23	100	100	100
31	100	100	100
42	100	100	100
44	100	100	100
48	100	100	100
51	100	100	100
52	100	100	100
53	100	100	100
54	100	100	100
55	100	100	100
56	100	100	100
61	100	100	100
62	100	100	100
71	100	100	100
72	100	100	100
81	100	100	100
211	100	100	100
324	100	100	100
486	100	100	100
Consumer	100	100	100