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THE IMPORTANCE OF POLICY NEUTRALITY FOR LOWERING GREENHOUSE GAS EMISSIONS

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SUMMARY

The drive by Canadian governments, at the provincial and federal level, to lower greenhouse gas emissions has resulted in a hodgepodge of different policy approaches. Some governments have opted for energy taxes, others for regulated limits on total emissions or emission intensity. Unfortunately, not all policy solutions are created equal; some are more effective than others in lowering total emissions and, worse still, may exact a heavy price on the economy. Policy-makers require a better understanding of how various policies affect the health of an economy and of how to mitigate the most pernicious costs.

Key to gaining this improved understanding is to recognize one simple fact: some firms are more productive than others. As a consequence, it matters how workers, machines, energy, and other inputs are distributed between these firms. More productive firms should be larger — it is that simple. Some policies, however, increase input costs differently across firms and create costly distortions. Energy intensity targets are a clear example of a policy that disproportionately burdens lower productivity firms, changing firm sizes for the worse and even leading some to shut down altogether.

Using a detailed model of production and energy use that matches the Canadian economy, we explore the consequences of the several forms that energy intensity regulations can take. We find the best approach to lowering greenhouse gas emissions is one that is neutral across firms — one that affects the cost of energy for smaller firms no more, or less, than larger ones. The only policy that fulfils this criterion is a flat energy tax. However, a flat tax on energy could well be politically unsellable in Canada, leaving governments to resort to politically palatable but economically risky intensity targets instead. Recognizing this, we explore a number of ways to improve the performance of intensity targets. First, governments should allow firms the option to pay a fine if an intensity standard is violated. Second, we propose a compensation scheme to firms covered by the regulation to prevent bankruptcy. These modifications can bring the cost of intensity standards closer to flat energy taxes.

In short, policy-makers seeking an approach to lower greenhouse gas emissions, with minimal impact on economic efficiency and productivity, should look no further than the flat tax on energy. If this is off-limits politically, a combination of intensity standards, fines and compensation comes very close to having the same effect and may well be the policy approach they can persuade the public, and industry, to accept.

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INTRODUCTION

Environmental policy evaluation is deeply concerned with the most efficient method of achieving emission reductions. Despite common goals, governments vary in their choice of policies, with some opting for energy taxes and others for regulations directly governing emissions and energy intensity.[1] The effectiveness of market-based versus command-and-control policies has been long debated in the academic literature.[2] The theoretical literature acknowledges that heterogeneity across firms requires a neutral policy that equates the cost of additional units of pollution across firms for minimizing the cost of pollution reduction.[3] Nevertheless, few studies evaluate environmental policy in the presence of rich productivity dispersion across firms.[4] In response, we recently developed a model of energy use that features firm productivity dispersion and maps cleanly into industry-level data on production and input use.[5] Using this model we can evaluate a wide variety of policy instruments to determine the most efficient means of achieving energy conservation and greenhouse gas emission reductions.[6] We find a flat tax is almost always better than an intensity standard under a wide range of scenarios.

Recognizing that political realities may prohibit governments from enacting broad and uniform energy taxes, we examine various means of reducing the adverse consequences of intensity regulations. First, we consider fines as an enforcement mechanism. We show that the loss in GDP from intensity standards is dramatically reduced if firms can opt to pay a fine proportional to energy use, for failing to meet the target. Second, we allow for compensatory mechanisms to ensure the heavily-burdened firms remain in operation. We also find this substantially lowers the costs of intensity standards. Overall, standards coupled with fines and compensation are almost as good as uniform energy taxes at achieving energy reductions and reducing greenhouse gas (GHG) emissions. We outline the details and the intuition behind the results in what follows.

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[1] Examples of recent intensity targets in environmental regulations include Argentina's (1999) goal of adopting an intensity target under the Kyoto Protocol, the U.K. Climate Change Levy Agreement (2002), the U.S. targets under the George W. Bush administration (2002) and subsequent National Commission on Energy Policy (2004) recommendations, and Canada's recent Regulatory Framework for Industrial Greenhouse Gas Emissions (2007).

[2] See, for example, Cropper and Oates (1992) for a survey, or, more recently, Svante Mandell, "Optimal mix of emissions taxes and cap-and-trade," *Journal of Environmental Economics and Management* 56, 2 (2008): 131–140.

[3] See Don Fullerton, Andrew Leicester and Stephen Smith, "Environmental Taxes," in *Dimensions of Tax Design: the Mirrlees Review,* ed. J. Mirrlees et al. (Oxford: Oxford University Press, 2010); Richard G. Newell and Robert N. Stavins, "Cost Heterogeneity and the Potential Savings form Market-Based Policies," *Journal of Regulatory Economics* 23, 1 (2003): 43–59; and Robert N. Stavins, "Experience with Market-Based Environmental Policy Instruments," *Handbook of Environmental Economics*, Volume 1, ed. K.-G. Mäler and J. R. Vincent (Amsterdam: North Holland Elsevier, 2003).

[4] Helfand (1991) considers the three-firm case where firms differ in optimal scale, while Katsoulacos and Xepapadeas (1995) consider an oligopolous market structure. Recently, theoretical work by Li and Shi (2012) finds intensity standards dominate if productivity dispersion is sufficiently low and market power sufficiently high. That market power leads quantity regulations to dominate corrective taxes was first demonstrated by Buchanan (1969). He shows when a monopoly produces a good with a negative externality, a corrective tax lowers total welfare. This is in stark contrast to the case of a perfectly competitive market.

[5] Trevor Tombe and Jennifer Winter, "Taxes vs Standards (Again): Misallocation and Productivity Consequences of Energy and Emissions Intensity Targets," Working paper, University of Calgary, 2013.

[6] Other recent work that uses Canadian data to evaluate environmental policy questions includes Wigle (2001); Dissou et al. (2002); Jaccard et al. (2003); Bataille et al (2006); Murphy et al. (2007); Rivers and Jaccard (2010), and Li and Sun (2011) among many others.

Productivity dispersion is important to consider because environmental policy regulations can burden firms differently. For example, limits on energy intensity are easier for high-productivity firms to achieve than for low-productivity firms, as the high-productivity firms are more efficient in their use of energy, and hence use less per unit of output produced. This is important for two reasons. First, many of these low-productivity firms will shut down, leading to losses from reduced product variety. Second, policies with differential burdens create differences in the value of inputs across firms, even for the firms that continue to operate. These differences create scope to reallocate inputs from firms with a low value to firms with a high value. So long as such reallocation is impeded by policy, aggregate productivity is not as high as it could be. This applies even if all firms face identical intensity improvement targets relative to their own baseline, as differences in production technologies across industries means achieving the target is more costly for some firms than for others. There is also a reallocation of inputs and production from high-productivity industries, which tend to be energy intensive, to low-productivity industries. Our results stress the importance of burdens being equal across producers; that is, environmental policies aimed at lowering energy use should be *policy neutral*.

The economic model we use to demonstrate these results is straightforward. The aggregate productivity cost from misallocations across firms and industries has been the subject of a large and growing body of literature in recent years; we incorporate a number of insights from this research.[7] Briefly put, we develop a tractable, though highly parametric, multi-sector model that accurately reflects the industrial structure and energy-use patterns of Canada. Within each industry, there is a continuum of firms producing horizontally differentiated varieties.[8] Production requires energy and labour, so that all varieties are "dirty," but vary in their "dirtiness" according to energy use. While emissions from energy use are only a subset of emissions, they are a key determinant of greenhouse gas emissions.[9] This contrasts with existing approaches that consider emissions as a by-product of production. The structure allows us to evaluate various emission reduction policies and quantify their relative efficiency in addressing the desired reductions. A firm's optimal input choice between labour and energy also builds in a simple abatement mechanism: adopt a less energy-intensive input bundle. This choice will respond cleanly to changes in input prices and provides a simple and natural alternative to modeling a specific abatement technology.

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7 See, for example, Douglas Gollin, Stephen L. Parente and Richard Rogerson, "Farm Work, Home Work, and International Productivity Differences," *Review of Economic Dynamics* 7,4 (2004): 827–850; Douglas Gollin, Stephen L. Parente and Richard Rogerson, "The food problem and the evolution of international income levels," *Journal of Monetary Economics* 54,4 (2007): 1230–1255; Diego Restuccia, Dennis Tao Yang and Xiaodong Zhu, "Agriculture and aggregate productivity: A quantitative cross-country analysis," *Journal of Monetary Economics* 55, 2 (2008): 234–250; Diego Restuccia and Richard Rogerson, "Policy Distortions and Aggregate Productivity with Heterogeneous Plants," *Review of Economic Dynamics* 11, 4 (2008): 707–720; Chang-Tai Hsieh and Peter J. Klenow, "Misallocation and Manufacturing TFP in China and India," *The Quarterly Journal of Economics* 124, 4 (2009): 1403–1448; Zheng Song, Kjetil Storesletten and Fabrizio Zilibotti, "Growing Like China," *The American Economic Review* 101, 1 (2011): 196–233; or Loren Brandt, Trevor Tombe and Xiaodong Zhu, "Factor Market Distortions Across Time, Space and Sectors in China," *Review of Economic Dynamics* 16 , 1 (2013): 39-58, among many others.

8 An example of horizontally differentiated products is different varieties of bread.

9 The U.S. Energy Information Administration estimates 87 per cent of U.S. GHGs are related to energy consumption (Energy in Brief, 21 June 2012). Statistics Canada infers GHG emissions from energy use data in the Materials and Energy Flow Accounts. Specifically, emissions per quantity of various forms of energy is calculated and combined with data on energy use by industry. The data on energy use, which we use to calibrate the model, includes ten energy commodities: coal, natural gas, liquid petroleum gases, electricity, coke, motor gasoline, diesel fuel, aviation fuel, light fuel oil and heavy fuel oil.

With this model, calibrated to Canadian data, we compare a flat tax on energy use to various types of emission-intensity standards. Specifically, we consider three energy-intensity targets that encapsulate many forms of emission regulations: firm-specific, sector-specific, and threshold-based. The firm-specific targets require firms lower their own energy intensity by a given amount relative to their own baseline. Sector-specific policies require firms meet or exceed a common target based on the sector's overall average. Threshold-based policies will require improvements only for large emitters. For all policies, we find a flat tax on energy is the superior policy. We find sector specific targets are extremely inefficient, resulting in little reduction in energy use and large economic costs. For example, requiring firms to not exceed an energy intensity 10 per cent lower than their sector's baseline average will lower total energy use by about eight per cent, cause more than 11 per cent of firms to exit, and lower aggregate GDP by nearly 1.5 per cent. A tax that achieves the same total energy reduction will lower GDP by an order of magnitude less.[10]

While standards on their own are significantly more damaging than taxes, there are two simple policy changes that can make intensity standards more neutral and, therefore, more efficient. First, we investigate to what extent fines for non-compliance improve the economic efficiency of regulatory standards. We find that the heavy burden that standards place on low-productivity firms can be alleviated if firms can opt to pay a fine instead. If the fine is not too large or too small, which we will make more precise later in the paper, then paying a fine will still result in energy conservation. Given the fee's uniformity across firms there is little misallocation cost.

The intuition behind this result is simple. Ideally, size differences between firms should be determined by differences in underlying productivity. Regulations that are not neutral across firms create differences in the costs for these firms to acquire more inputs. If one firm faces artificially high costs for using an additional terajoule of energy relative to other firms, then it grows smaller than its productivity warrants. The gain to this firm from using an additional terajoule of energy is, therefore, larger than the gain for other firms. Removing the policy distortion will allow this firm to grow and will increase aggregate productivity as a result. The option to pay a fine provides such a mechanism to remove the policy distortion, as the fine payment is common to all firms and what matters for misallocation and productivity are differences in input costs across firms. Policies should not discriminate across producers and should strive, wherever possible, to have identical cost burdens across all firms.

The second policy change to mitigate the economic costs of standards is to reduce the number of firms that are induced to exit. If lump-sum compensation is provided to firms with the lowest productivity, for example, then they will be less likely to declare bankruptcy and exit the industry. Preventing exit lowers the costs of standards relative to taxes. While taxes are always superior in our framework, the gap between the two policy choices becomes negligible when intensity standards are combined with fines and also ensure firms do not shut down.

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[10] These results depend on the degree of substitutability between varieties and the extent of productivity dispersion, but the tax dominates the standard for all parameters within what evidence suggests is a reasonable range. For estimates of the elasticity of substitution between goods within industries, for various degrees of aggregation, see Christian Broda and David E. Weinstein, "Globalization and the Gains from Variety," *The Quarterly Journal of Economics* 121, 6 (2006): 541–585, and others that follow. For the inverse relationship between within-industry substitutability and productivity dispersion, see Chad Syverson, "Product Substitutability and Productivity Dispersion," *The Review of Economics and Statistics* 86, 2 (2004): 534–550.

In the following section we proceed to review the forms that energy conservation and emission-reduction policies take in Canada. We then explore the importance of considering productivity differentials when evaluating policy changes. With the model, we perform a number of quantitative evaluations of various forms of energy-intensity targets, comparing their economic costs to simple (flat) energy taxes. We then provide policy recommendations and conclude.

SUMMARY OF ENVIRONMENTAL POLICIES IN CANADA

Both the federal and provincial governments are taking steps to reduce energy use and greenhouse gas emissions, though there is considerable variation in the policies developed. The federal government has chosen to take a sector-by-sector regulatory approach, as have Manitoba and New Brunswick. Saskatchewan and Alberta have chosen to regulate emitters at the facility level above an emissions threshold. Nova Scotia and Ontario have chosen to focus on the electricity sector. The governments of P.E.I. and Newfoundland and Labrador have focused on programs to increase energy efficiency. British Columbia has imposed a tax on fossil fuels; it is also part of a regional cap-and-trade system, along with Manitoba, Ontario and Quebec. The majority of policies are still being developed, but where details are available, they are elaborated upon below.

The Canadian federal government published the Regulatory Framework for Air Emissions in 2007. The report outlines the architecture of the federal government's regulatory framework for managing air emissions, including short-term industrial emission-reducing targets, which are part of the Clean Air Regulatory Agenda. The final framework, the Regulatory Framework for Industrial Greenhouse Gas Emissions, was published in March 2008, and defined reduction targets for several industrial sectors. The affected industries are electricity generation produced by combustion, oil and gas (including oil sands, upstream oil and gas, petroleum refining, and natural gas pipelines), pulp and paper, iron and steel, iron ore pelletizing, smelting and refining, cement, lime, potash, and chemical and fertilizer production.

The covered industrial sectors have a target of reducing their emissions intensity from 2006 levels by 18 per cent by 2010, with a two-per-cent continuous improvement every year after.[11] New facilities — those whose first year of operation is 2004 or later — are granted a three-year grace period, with two-per-cent reductions per year required following the grace period. The federal government has chosen to apply the targets in three different ways, facility-specific, sector-wide and corporate-specific, depending on the sector. In addition, minimum thresholds are in place for some of the sectors with facility-specific regulations. The Framework also lists several compliance mechanisms as alternatives to abatement. One of these is contributing to a technology fund, which is essentially a fine for failing to abate.

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[11] "Regulatory Framework for Industrial Greenhouse Gas Emissions," 2008, Government of Canada.

Several provinces joined the Western Climate Initiative (WCI; signatories are British Columbia, Manitoba, Ontario, Quebec, and California) as part of a regional cap-and-trade system. The Western Climate Initiative system is designed to cover emissions from electricity generation and imports, industrial fuel combustion, industrial processes, transportation fuel use, and residential and commercial fuel use.[12] The initial allowance is set by each jurisdiction and is based on expected 2012 emissions in the covered sectors. The goal is to reduce GHG emissions to 15 per cent below 2005 levels by 2020.[13] The program start date is January 2013, with planned full implementation by 2015.

In 2008, the B.C. government released its Climate Action Plan, which included the passing of legislation on GHG emission targets. The government also implemented a revenue-neutral carbon tax in 2008 at $10 per tonne of CO_2-equivalent, with $5 annual increments. The tax applies to fossil fuel combustion as well as tires and peat, with a tax rate specific to the emission intensity of each fossil fuel. According to the B.C. government, the carbon tax covers 70 per cent of B.C.'s GHG emissions.[14]

In Alberta, the *Specified Gas Emitters Regulation* outlines required reductions in greenhouse gas emissions. For facilities that emitted 100,000 tonnes or more of CO_2-equivalent units in 2003 or any year since, a 12-per-cent intensity reduction will be applied to the average of that facility's 2003 to 2005 baseline emissions intensity, for facilities in operation before January 1, 2000. For facilities operational after that date — or with less than eight years of commercial operations — baseline intensities will be established from their third year of operation. These facilities are required to reduce emissions by two per cent starting with the fourth year of commercial operation, and by two per cent every year after, until the 12-per-cent reduction target has been achieved. If the intensity target is not met through improved operations, facilities may: pay $15 per tonne of CO_2-equivalent into Alberta's Climate Change and Emissions Management Fund; purchase emission offsets generated from facilities not subject to the *Regulation*; and purchase Emission Performance Credits from a different Alberta facility.

In Saskatchewan, environmental regulations are currently under development, but the government has outlined facility-based targets to help meet Saskatchewan's GHG-reduction goal, reducing emissions 20 per cent below 2006 levels by 2020. The emissions threshold is 50,000 tonnes of CO_2-equivalent per year. Regulated emitters are required to reduce emissions by two per cent per year over the baseline emission level from 2010 to 2019 in order to achieve a net reduction of 20 per cent over 2006 levels by 2020. The draft Saskatchewan Environmental Code states that emitters that do not meet their reduction targets will be required to pay carbon-compliance payments.

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[12] Western Climate Initiative, "The WCI Cap & Trade Program," http://www.westernclimateinitiative.org/the-wci-cap-and-trade-program

[13] Western Climate Initiative, "Design Summary for the WCI Regional Program," http://www.westernclimateinitiative.org/component/remository/general/program-design/Design-Summary/

[14] B.C. Government, "Making Progress on BC's Climate Action Plan," http://www.env.gov.bc.ca/cas/pdfs/2012-Progress-to-Targets.pdf

In Manitoba, the *Climate Change and Emissions Reduction Act* that came into effect June 12, 2008 states that the province's initial emissions reduction target is to have emissions at least six per cent less than total 1990 emissions by the end of 2012. Following the Act, Manitoba has engaged in reduction programs tailored to individual sectors in addition to joining WCI. In Ontario, the phasing-out of coal-based electricity generation and the development of "green" electricity generation through the Green Energy Act, make up the major efforts to reduce emissions.

In Quebec, emitters in the "industrial and electricity sectors" whose annual GHG emissions are 25,000 tonnes or more of CO_2-equivalent will be subject to the cap-and-trade system designed by WCI. In 2015, firms that distribute or import fossil fuels in Quebec will also be covered by the cap-and-trade system.[15]

The government of Newfoundland and Labrador is supporting energy efficiency initiatives at the household and small-business level, including tax credits for retrofits and legislating energy efficiency requirements into the building code. A plan for reducing emissions in large industries — electricity generation, mining, newsprint, offshore oil, and oil refining — including a GHG-reduction target, was scheduled to be released in 2012[16] but is not yet available. The government of New Brunswick has chosen to engage in sector-specific policies aimed at reducing sectoral emission levels, such as encouraging energy-efficient renovations in the residential sector. The government of Nova Scotia has chosen to regulate only electricity-generating facilities emitting greater than 10,000 tonnes of CO_2-equivalent. The sector is assigned an annual emissions cap, and facilities are assigned a target based on this cap.

The variation in emission-reduction policies across Canada points to a lack of consensus on the best method for reducing greenhouse gases. We enter the debate by evaluating the cost of these policies using a stylized model of the Canadian economy. As many of the policies are in their infancy, or have yet to be formally implemented, evaluating their relative merit is difficult. The model allows evaluation of the different policy regimes through simulation. The policies described above can be classified in the following way: sector-specific targets (federal government); facility-specific targets (federal government); threshold-based targets (federal government, Alberta, Saskatchewan); target plus fine (federal government, Alberta, Saskatchewan); and emission taxes (B.C.). In addition to pure abatement targets, we also simulate abatement plus a fine as a compliance mechanism. In all cases, the targets are applied to the entire Canadian economy, which provides a "worst-case scenario" of the various suggested policies. We abstain from evaluating a cap-and-trade system as the academic literature shows taxes and cap-and-trade systems are generally equivalent.[17]

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[15] Government of Quebec, "2013-2020 Climate Change Action Plan."

[16] Government of Newfoundland and Labrador, "Charting Our Course: Climate Change Action Plan 2011."

[17] L. Goulder, comments during "Designing a U.S. Carbon Tax" Panel Discussion at the 2013 American Economic Association Annual Meeting, San Diego, CA.

THE KEY FACTS AND INTUITION

A common feature of these policies is that they increase the cost of energy differently for different industries and firms. Before proceeding to our main quantitative evaluation of the policies, it is valuable to highlight the key mechanisms at work, and the important facts related to energy intensity and productivity across industries.

We start with a highly stylized example to illustrate the underlying intuition behind how input-cost differences can affect an economy's aggregate productivity. Consider two hypothetical firms — two barber shops — that produce roughly the same output, using only a single type of input (labour). Further presume that the owner of each shop allocates an additional hour of labour to tasks of decreasing importance. The most valuable task may be cutting hair. Following that, workers may be directed to operate the cash register, sweep the floor, wash the windows, arrange the magazines in the waiting room, greet customers as they enter, stand on the sidewalk with a sign, and other, even less valuable tasks. Depending on how costly it is to hire an additional hour of labour, the owner may or may not opt to use worker time to greet customers as they enter or perform other low-value tasks. In general, if it costs $10 to hire an additional hour of labour, then all tasks that are worth *no less than $10* will be completed. The owner will continue to hire workers until there are no tasks remaining with value in excess of the labour cost he or she faces. The potential for misallocation of workers across firms, which lowers productivity, is evident from this underlying intuition if firms face *different costs* when hiring additional workers.

If the two shops in question face different costs when they hire additional labour, then the two owners will make different decisions. If, for some reason, one shop must pay $5 to hire an additional hour of a worker's time, while the other shop must pay $15, then the low-wage shop will be completing tasks worth as little as $5 to the owner, while the high-wage shop will stop hiring at the point where all remaining tasks are worth less than $15. From the point of view of the total combined value of output of both shops, there would be gains from moving a worker doing a $5-valued task in one shop to help with a $15-valued task in the other. All else being equal, it would be *efficient* to move a greeter in one shop to help sweep the floor in the other shop. If the different wage costs between the shops are induced by government policy, and beyond the control of the store owners, then the total economic output of society will be lower than what could potentially be produced. In the context of energy and emissions policy, it is not wage costs that will differ across firms, but energy costs. It is the magnitude and effect of energy-cost differences across firms and industries that we are interested in evaluating.

How does policy create differences in energy costs between different firms? Consider emission-intensity regulations, which set a limit on the ratio of greenhouse gas emissions to total output. If a firm emits 1,000 tonnes of GHGs, for example, and produces $1 million in output, then this firm has an emissions intensity of one tonne per thousand dollars. For a higher-productivity firm, output is higher with the same quantity of inputs. If productivity doubles, then the emissions intensity of the firm will decline to half-a-tonne per thousand dollars. Therefore, if regulators impose an identical emissions intensity target across firms with different productivity levels, the costs to comply will be higher for low-productivity firms. This effectively imposes a higher cost of energy, which is the source of emissions, on lower-productivity firms than on firms with higher productivity. This difference will create a misallocation of energy across firms, just as it did in the barber shop example above, and lower aggregate productivity.

Until recently, the lack of appropriately detailed data limited knowledge of whether productivity differs significantly between firms within an industry. Research in this area has found indisputable evidence for within-industry productivity dispersion. Syverson,[18] for example, finds enormous and persistent variation in productivity between firms, even between those that operate in very similar industries. Specifically, he finds that within four-digit SIC industries of the United States, a firm with productivity equal to the 90th percentile of productivity across firms is nearly twice as productive as a firm at the 10th percentile. For China and India, the differences are even starker. Hsieh and Klenow,[19] for example, find a within-industry 90-to-10 ratio of approximately five. Over time, there is also strong evidence that these differences persist. Syverson[20] reviews this large and important recent literature, and we rely on this literature to discipline the calibration of our model economy.

There is also recent evidence that high-productivity firms have lower energy intensity. This negative relationship should exist almost by definition. Productivity *means* a greater quantity of output for the same quantity of inputs. That implies the use of inputs per unit of output is, in general, decreasing with firm productivity, and this should hold for energy inputs as well. In recent work, Martin[21] finds a clear inverse relationship between productivity and energy intensity using firm-level data from India. With different data, Sahu and Narayanan[22] confirm productivity and energy intensity are inversely related in a cross-section of Indian manufacturers. Recent data from the United Kingdom also reveals that the 90-to-10 ratio for output per kWh of electricity use across U.K. manufacturing is 23, and this dispersion remains even within highly disaggregated classifications.[23] Case studies also reveal this pattern. Gray and Shadbegian[24] and Shadbegian and Gray[25] find a negative relationship between productivity and abatement costs. It is easier for high-productivity firms to lower emissions than low-productivity firms.

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18 Chad Syverson, "Product Substitutability and Productivity Dispersion," *The Review of Economics and Statistics* 86, 2 (2004): 534–550.

19 Chang-Tai and Peter J. Klenow, "Misallocation and Manufacturing TFP in China and India," *The Quarterly Journal of Economics*, 2009, 124 (4), 1403–1448.

20 Chad Syverson, "What Determines Productivity?" *Journal of Economic Literature* 49, 2 (2011): 326–365.

21 Leslie Martin, "Energy efficiency gains from trade: greenhouse gas emissions and India's manufacturing sector," Working paper, University of California, Berkeley, 2012.

22 Santosh Sahu and Krishnan Narayanan, "Total factor productivity and energy intensity in Indian manufacturing: a cross-sectional study," *International Journal of Energy Economics and Policy* 1, 2 (2011): 47-58.

23 Ralf Martin, "Energy efficiency and productivity of UK businesses: Evidence from a new matched database," DTI (Department of Trade and Industry) Occasional Paper No. 5, April 2006.

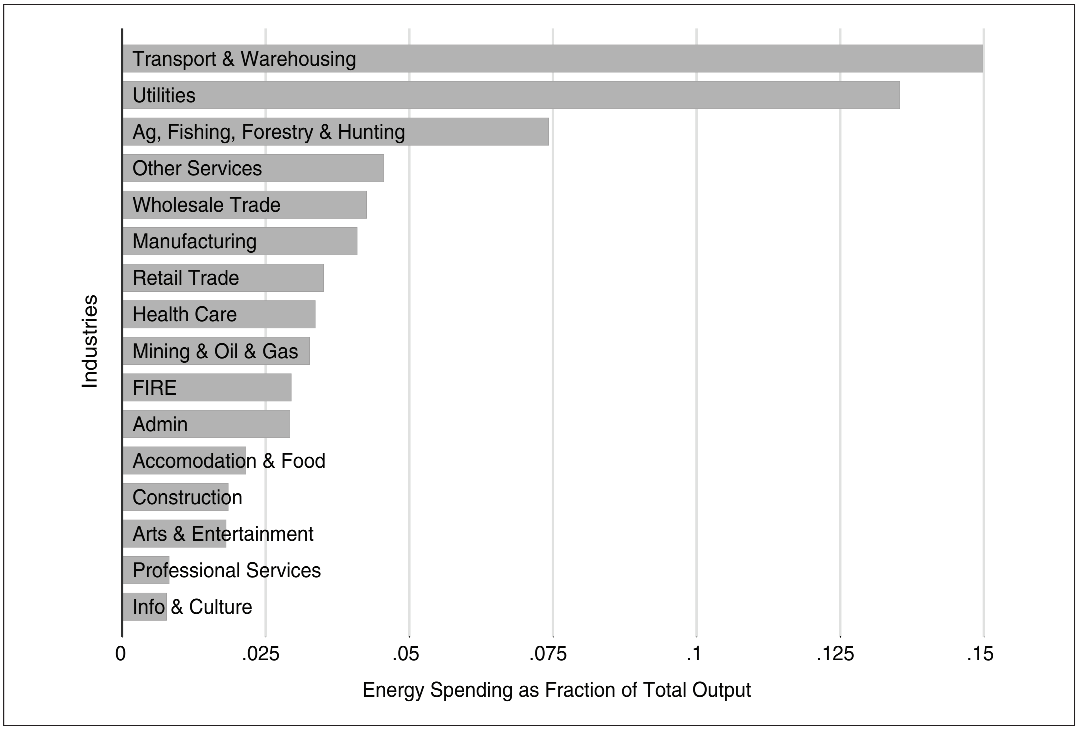
24 Wayne B. Gray and Ronald J. Shadbegian, "Pollution Abatement Costs, Regulation, and Plant-Level Productivity," NBER Working Papers 4994, National Bureau of Economic Research, 1995.

25 Ronald J Shadbegian and Wayne B. Gray, "What Determines Environmental Performance at Paper Mills? The Roles of Abatement Spending, Regulation, and Efficiency," *The B.E. Journal of Economic Analysis & Policy* 3, 1 (2003); and Ronald J. Shadbegian and Wayne B. Gray, "Pollution abatement expenditures and plant-level productivity: A production function approach," *Ecological Economics* 54. 2-3 (2005): 196–208.

Independent of differences between firms within industries, policies can create differences in energy costs between firms even if they do not impose identical intensity targets. Facility-specific intensity targets impose a common *improvement in emissions intensity* but not a common intensity *level* across firms. That is, if firms must all improve their emissions intensity by 18 per cent, differences in intensity levels can persist under this type of policy, and lower-productivity firms are no longer differentially burdened. Instead, energy-cost differences can result from these policies if the importance of energy in the production process differs across firms in different industries. For example, if energy inputs account for 25 per cent of output in one industry and account for five per cent in another industry, then complying with an 18-per-cent intensity improvement target will be more costly for firms in the energy-intensive industry. We will demonstrate this claim formally in the next section, but for the moment, consider the following intuition: the share of output accounted for by energy will also be related to the effect that a change in the amount of energy inputs has on a firm's total output. If energy's share of output is 25 per cent, then a 10-per-cent reduction in energy use will, all else being equal, lower output by 2.5 per cent, compared to only 0.5 per cent when energy's share of output is five per cent. As an intensity target is the ratio of emissions (energy) to output, improving the ratio will require a more dramatic reduction in energy use when energy's share is large.

What is the evidence that energy's share of output differs substantially between industries? To answer this question, we gather data on the amount of energy inputs used and total output produced for a number of Canadian industries. Specifically, Statistics Canada's Productivity Accounts records energy inputs and gross output — both as a value and as a quantity index — and the System of Environmental and Resource Accounts records energy use and greenhouse gas emissions by industry. With this data, we examine sixteen Canadian industries at the two-digit System of National Accounts aggregation level, equivalent to two-digit NAICS. For some industries, such as Transportation and Warehousing or Utilities, the value of energy inputs is nearly 15 per cent of total output. In other industries, such as Arts and Entertainment or Professional Services, this value is on the order of one to two per cent. We demonstrate energy's share of output for all industries in Figure 1. Based on these, we will show in the next section that an 18-per-cent intensity improvement for firms in an industry with an energy share of 15 per cent will raise energy costs by over 21 per cent. For firms in an industry with a one-per-cent energy share, however, the same 18-per-cent improvement target will raise energy costs by just over 18 per cent. These differences in energy costs from the policy will lower aggregate productivity more than a flat tax on energy. In the next section, we quantify precisely what the effect of the various policies is.

FIGURE 1: ENERGY SHARE OF INDUSTRY OUTPUT IN CANADA



Note: Data from Statistics Canada CANSIM Table 323-0022 for year 2008. Energy's share of an industry's output is the ratio of total spending on intermediate energy use to total output.

FIRE: Finance, Insurance and Real Estate.

QUANTITATIVE POLICY EVALUATION

In this section, we simulate the effects of different energy-reduction policies on Canadian productivity and total output, using the model detailed in Appendix A. We also use the model to estimate an implied cost of carbon, which provides a useful means of comparing the economic costs of lowering emissions through different policies. Through our quantitative simulations, to which we now turn, we can calculate precisely the effect on productivity, and GDP, of various energy standards and taxes. The model is calibrated to match data on 16 Canadian industries that correspond to broad categories used by the System of National Accounts.[26] We list these industries, along with their share of Canada's GDP and their energy intensity, in Table 1.

[26] Data extracted from Statistics Canada CANSIM Table 383-0022.

TABLE 1: INDUSTRY-LEVEL SUMMARY STATISTICS

Industry	SNA Code	Industry's Share of Economy	Energy's Share of Industry Output
Agriculture	11	0.027	0.161
Mining and Oil and Gas Extraction	21	0.129	0.042
Utilities	22	0.033	0.162
Construction	23	0.09	0.043
Manufacturing	3A	0.16	0.129
Wholesale Trade	41	0.067	0.069
Retail Trade	4A	0.07	0.052
Transportation and Warehousing	4B	0.066	0.242
Information and Culture	51	0.04	0.014
Professional, Scientific, and Technical	54	0.059	0.013
Administrative/Support, Waste Management	56	0.031	0.042
FIRE and Rental and Leasing	5A	0.138	0.049
Health and Social Services	62	0.032	0.045
Arts, Entertainment, and Recreation	71	0.009	0.035
Accomodation and Food Services	72	0.027	0.041
Other	81	0.022	0.066

Note: Data extracted from Statistics Canada CANSIM Table 383-0022 for year 2008. Output measured as gross output less spending on intermediate materials and services. See text for details regarding construction of each measure.

There are a variety of types of standards imposed and we cover each of them separately in the subsections below. Our focus is on comparing these various types of policies to a flat energy tax. The policies also allow firms to pay a fine if they fail to meet their target. We analyze this policy option separately to highlight the importance of giving firms the option of paying an appropriately determined fine. We also investigate the effect of these policies when the number of firms is held constant, which can loosely be thought of as the government providing compensatory mechanisms to ensure that compliance costs do not bankrupt existing producers.

Facility-Specific Targets

These are emission-intensity targets that are plant-specific. The federal regulatory guidelines propose to apply this type of standard to facilities producing chemicals or fertilizers, or those involved in upstream oil and gas or metal smelting, among others. Under these regulations, plants are required to lower their emissions intensity by 18 per cent relative to each facility's own base-year intensity.

Using the expression for energy intensity derived in Appendix A, the tax required to meet this target is $\tau(j) \propto 1.18^{1/\alpha_i}$, where the constant of proportionality is common to all firms in all industries and α_i is labour's share in production in industry-*i.* This type of energy-intensity standard will result in identical effective energy tax rates across firms within the same industry, so there is no within-industry distortion. Between industries, however, tax rates will differ. For example, consider two industries: one with a labour share (α_i) equal to 75 per cent and the other equal to 95 per cent. The energy tax rate will differ between firms in one industry and firms in the other by nearly 5 per cent. Firm exit will also be higher in energy-intensive industries, leading to lower TFP in those industries.

We simulate this type of standard and report the results in the first column of Table 2. Requiring firms to reach a given energy intensity will effectively increase the cost of energy. In this scenario, the economy-wide average increase in the cost of energy inputs (total energy spending relative to the total units of energy inputs used) increases by nearly 18.5 per cent. In response, total energy use declines by nearly 16 per cent under the standard. The increased cost of energy leads approximately 0.64 per cent of firms to shut down and GDP to decline by 0.61 per cent. The reduction in GDP occurs because of firms shutting down, and the household moving spending away from goods produced by energy-intensive industries. Industries that are energy-intensive face the largest effective energy tax, and also experience a greater increase in production costs. If energy accounts for 25 per cent of output, then a 20 per cent increase in the cost of energy will increase production costs in this industry by five per cent. For an industry where energy is only five per cent of output, the increase in costs will only be one per cent. As consumption spending responds to prices, differences in price increases across industries due to this policy will lead spending patterns to change, lowering GDP (and welfare).

TABLE 2: COMPARING THE COSTS OF TAXES AND STANDARDS

	Facility-Specific		Sector-Specific		Threshold-Based	
	Standard	Tax	Standard	Tax	Standard	Tax
Baseline Results						
GDP	-0.61%	-0.61%	-1.67%	-0.33%	-0.29%	-0.26%
Number of Firms	-0.64%	-0.63%	-12.17%	-0.34%	-0.01%	-0.27%
Total Energy Use	-15.92%	-15.92%	-9.44%	-9.44%	-7.61%	-7.61%
Uniform Energy Tax Rate		20.92%		11.50%		9.09%

Note: *Displays results of various simulations of regulatory energy- and emissions-intensity standards. The "standard"' corresponds to: (1) Facility-Specific, an 18-per-cent reduction in energy intensity; (2) Sector-Specific, an energy-intensity target for all firms to meet or exceed that corresponds to 18 per cent less than the sector's prior average; and (3) Threshold-Based, an 18-per-cent energy-intensity reduction target that is firm specific for the largest firms (cumulatively accounts for 50 per cent of total energy use). The results are contrasted to a flat, economy-wide energy tax that achieves equivalent energy conservation.*

As there are no within-industry distortions, the effect on productivity of a facility-specific target is very similar to a flat tax on energy. To examine this quantitatively, we simulate the model with a flat energy tax which is common to all firms and all industries. We select the tax rate to match the total reduction in energy use from the 18 per cent facility-specific target. The required energy tax rate is 21 per cent and causes energy input costs to rise by 18 per cent. This is lower than the standard, since the price charged by the energy producer declines slightly. Under the tax, aggregate GDP declines by 0.61 per cent. While this is similar to the effect of the facility-specific target, it is actually marginally smaller — in the third decimal place. The number of firms is slightly higher than with the standard, but still over 0.63 per cent of firms shut down. Overall, facility-specific intensity targets are approximately as efficient at lowering energy use, and subsequently emissions, as a flat tax would be.

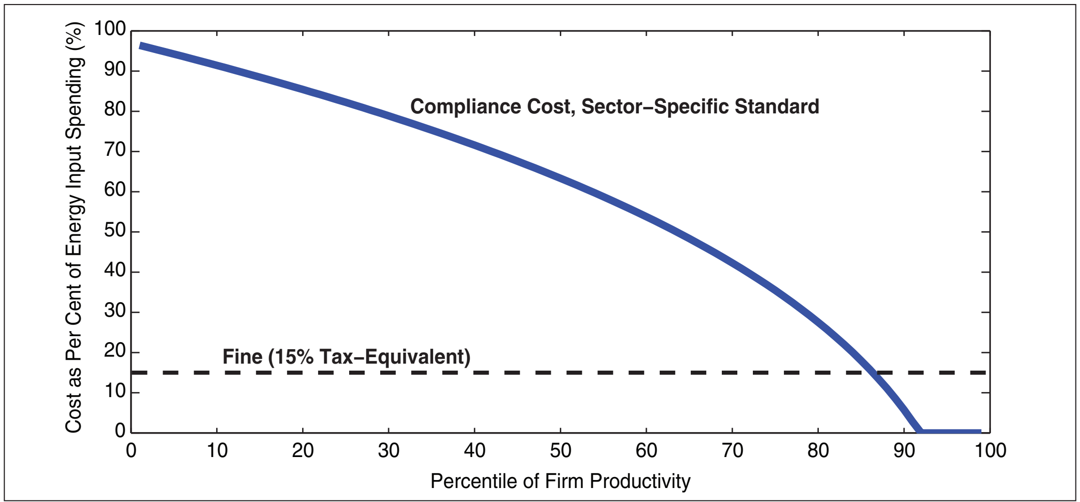
Why not simply end here and declare that intensity targets are an effective alternative to taxes? There are other elements to consider beyond the effects on productivity and aggregate GDP when evaluating these policies. While it goes beyond the scope of this paper, policy-makers must also consider the administrative burden of each type of regulatory standard or tax. If it is not feasible to monitor emissions levels or the energy intensity of all operating plants, then facility-specific targets cannot be implemented. The baseline energy intensity of each firm must be measured prior to the enactment of the regulations in order for a target to be formulated. An alternative type of energy-intensity target, which we investigate next, avoids this issue as all firms within the same industry have the same target.

Sector-Specific Targets

The same federal regulatory framework that places facility-specific targets in some sectors uses sector-specific targets in others. In the cement industry, among others, the target emissions intensity imposed on all producers is equal to 18 per cent less than the sector's average emissions intensity in the base period. While enforcement is still firm-by-firm, the common baseline makes administration and enforcement of this target easier. Unlike facility-specific targets, which require knowledge of each firm's prior and current emission intensity, sector-specific targets require only knowledge of the current intensity. Random audits with high penalties may be sufficient to enforce this standard. The productivity consequences of this type of standard, however, are very different. As noted earlier, energy intensity is negatively related to firm productivity, and so this regulatory approach will introduce a clear distortion across firms, even within industries.

The model implies effective energy tax rates decline with firm productivity if firms face identical intensity targets (from equation (6) in Appendix A). A firm with twice the productivity of another within the same industry will face an effective energy tax rate $2^{-1/\alpha_i}$ times lower. For an industry such as manufacturing, with a 13 per cent energy share of value-added, this more productive firm would face a tax rate roughly 45 per cent ($2^{-1/(1-0.13)}$) the size of its less-productive peer. To illustrate this point further, we plot the implied energy tax for manufacturing in Figure 2 across the productivity distribution of firms. Notice that productive firms with energy intensities less than their sector's target will not be taxed at all while low-productivity firms have a very large effective energy tax.

FIGURE 2: COST OF ACHIEVING SECTOR-SPECIFIC INTENSITY TARGET (18% REDUCTION)



Note: *Displays the costs of achieving a sector-specific intensity target (with an 18-per-cent reduction from baseline) for various firm productivities. This figure will vary by industry, we display here the pattern in the manufacturing sector. The compliance costs are calculated as the energy tax rate necessary to induce firms to meet their intensity target. See text for details in calculating this rate. Note that the burden of complying with a sector-specific target falls largely on low-productivity firms. The fine is depicted as a black dashed line, effectively equivalent to an energy tax of 15 per cent. This fine is common to all firms. Eighty-five per cent of firms would rather pay the fine. Between about the 85th and 92nd percentiles, firms will comply with the intensity target. The highest-productivity firms comply with the target already and no further effort is required.*

With this standard, we simulate the model and report the results in the third and fourth columns of Table 2. This is by far the most costly policy in terms of GDP and firm exit. We also report the effect on each industry's TFP from this sector-specific target in Table 3. The policy has a strong negative effect on the energy-intensive industries, such as manufacturing (-2.17 per cent). Aggregate GDP declines by 1.67 per cent under the standard, but only 0.33 per cent under the uniform tax that achieves an identical reduction in energy use. To help us understand the source of this dramatic difference between sector-specific standards and the flat tax, we decompose the effect in two ways. First, we examine the effect of reductions in each industry's productivity on aggregate GDP, comparing the sector-specific standard to the tax. Second, we determine the effect of firm exit on aggregate GDP, again comparing the standard to the tax.

TABLE 3: THE EFFECT OF SECTOR-SPECIFIC INTENSITY STANDARDS ON INDUSTRY TFP

Industry	% Change in TFP		% Change in TFP		Energy Intensity
	Standard, Without Fine	Tax	Standard, With Fine	Tax	
Agriculture	-2.72%	-0.01%	-0.39%	0.00%	0.161
Mining and Oil and Gas Extraction	-0.78%	-0.03%	-0.13%	-0.02%	0.042
Utilities	-2.75%	-0.01%	-0.40%	0.00%	0.162
Construction	-0.78%	-0.03%	-0.13%	-0.02%	0.043
Manufacturing	-2.17%	-0.02%	-0.32%	-0.01%	0.129
Wholesale Trade	-1.17%	-0.03%	-0.19%	-0.01%	0.069
Retail Trade	-0.93%	-0.03%	-0.15%	-0.02%	0.052
Transportation and Warehousing	-4.28%	0.00%	-0.59%	0.00%	0.242
Information and Culture	-0.37%	-0.04%	-0.07%	-0.02%	0.014
Professional, Scientific, and Technical	-0.37%	-0.04%	-0.07%	-0.02%	0.013
Administrative/Support, Waste Management	-0.77%	-0.04%	-0.13%	-0.02%	0.042
FIRE and Rental and Leasing	-0.87%	-0.03%	-0.14%	-0.02%	0.049
Health and Social Services	-0.82%	-0.03%	-0.14%	-0.02%	0.045
Arts, Entertainment, and Recreation	-0.68%	-0.04%	-0.12%	-0.02%	0.035
Accomodation and Food Services	-0.76%	-0.04%	-0.13%	-0.02%	0.041
Other	-1.13%	-0.03%	-0.18%	-0.01%	0.066

Note: Columns 1 and 2 display the reduction in TFP, for each industry, resulting from a sector-specific 18-per-cent improvement target relative to a flat energy tax that achieves identical reductions in total energy use. Columns 3 and 4 display the reduction in TFP for a similar intensity target but with the option to pay a fine. Column 5 reports the energy intensity of each industry, measured by energy's share of output.

For the first decomposition, we take the amount of labour and energy in each industry, after imposing the standard, as given and calculate the level of industry output if TFP was unchanged relative to its initial level. We then aggregate these counterfactual industry levels of output into a counterfactual GDP. Comparing this to the initial level of GDP reveals the effect on aggregate GDP of labour and energy reallocations across industries. If labour and energy move to less productive or less desirable industries, then aggregate GDP declines. We find that 18 per cent of the aggregate loss is due to input reallocation across industries under the standard. In contrast, 92 per cent of the loss due to a flat energy tax is from this channel. This reveals that the main reason for lower GDP from sector-specific standards is because productivity is lower *within industries*.

Our second decomposition provides insight into what is driving this lower within-industry TFP. First, note that the number of exiting firms is significantly higher under the standard (over 12.2 per cent) than under the uniform tax (only 0.34 per cent). There will be a direct effect on industry TFP from a decline in the number of active firms. There will also be an indirect effect from differences in energy costs across firms, which leads the value of energy to differ across firms. We can determine the relative importance of each of these two effects with a simple counterfactual. Based on our expression for industry TFP in Appendix A, we know that — in the absence of input price differences — each industry's TFP is a function of only the number of operating firms in that industry. Simply put, an industry's TFP can change only if the number of firms operating in it changes. We construct the counterfactual level GDP by using the post-policy number of firms and the pre-policy levels of labour and energy. Therefore, the only cause of a change in GDP (calculated in this way) is firm exit. Comparing this counterfactual aggregate GDP to the initial level provides an estimate of the effect of firm exit on aggregate GDP. We find that over 86 per cent of the aggregate loss under a standard is due to firms shutting down.

Why would firm exit contribute so much to aggregate losses in GDP? To answer this question, recall that each firm produces a slightly different product. The greater the substitutability between within-industry goods, the lower the importance of any particular variety — since there are many substitutes — and the smaller the effect of firm exit on TFP. On the other hand, exiting firms are low-productivity firms, which means exit has an offsetting positive effect on TFP, as the average productivity of remaining producers is higher. The greater the variation in productivity across firms, the stronger is this positive effect on TFP. In Tombe and Winter,[27] we review evidence that suggests a 12-per-cent reduction in the number of firms results in a one per cent reduction in productivity. While different industries experience different degrees of firm exit, the overall effect on aggregate GDP from the exit under sector-specific standards is -1.44 per cent (or, 86 per cent of the total effect, as stated above). We examine ways of mitigating these losses in a later section.

We began this section with a discussion of the administrative feasibility of sector-specific targets. While they are indeed implementable when there are a large number of firms that require monitoring, there are significant negative effects on productivity and aggregate GDP from this type of policy. Unless firms have very similar productivity, which they do not, or their output is very similar — which may be true in specific instances, but certainly not in general — sector-specific intensity targets can be extremely damaging economically. There is a third type of regulation, where only large firms are subject to a facility-specific intensity standard. If enough of an industry's output is concentrated amongst these firms, it may be effective and maintain the benefits of the facility-specific targets. We examine this type of regulation in the next section.

[27] Trevor Tombe and Jennifer Winter, "Taxes vs Standards (Again): Misallocation and Productivity Consequences of Energy and Emissions Intensity Targets," 2012.

Threshold-Based Targets for Large Emitters

Sometimes an intensity standard uses an emissions threshold, below which a firm is not required to comply. Alberta, for example, imposes a firm-specific emissions-intensity reduction target of 12 per cent for firms in certain sectors, relative to the firm's baseline, if those firms emit more than 100,000 tonnes of CO_2-equivalent annually. This threshold introduces differences in energy costs between regulated and unregulated firms within an industry but no differences between regulated firms. To examine the effect of this type of policy, we use our model to find the threshold where the cumulative energy use of firms that exceed the threshold accounts for 50 per cent of total energy use in the economy. For firms above this threshold, we impose a facility-specific energy-intensity improvement target. For comparability with the other standards examined, we set the improvement target at 18 per cent rather than the 12 per cent selected by Alberta.

We report the results of this simulation in the final two columns of Table 2. Aggregate GDP declines by 0.29 per cent, while a tax only reduces GDP by 0.26 per cent. The number of firms that exit is small under both policies, though fewer exits occur under the standard compared to the tax. This interesting departure from our earlier results is because imposing a tax on only the largest firms will increase the price that smaller, unregulated firms are able to charge. Since the output of each firm is substitutable to some degree with output from another, if one firm faces increased production costs that cause it to increase its price then another firm will also increase its price, even if its costs are unchanged. With a higher price charged by the smaller firms, there is less incentive for marginal firms to exit.

In contrast to facility-specific targets, which lower total energy use by almost 16 per cent when the intensity target is an 18-per-cent improvement, the threshold-based target imposed on the largest firms results in substantially less conservation, at 7.6 per cent. To more effectively compare with the efficiency results of the facility-specific targets that bind on all firms, we increased the improvement target in this threshold-based simulation to match total energy reduction under the facility-specific standard. These results are reported in Table 4. An improvement target of 52.3 per cent for firms above the threshold is required to generate a 15.92-per-cent reduction in total energy use. In this scenario, aggregate GDP declines by 0.87 per cent, which is much larger than the 0.61-per-cent decline in the facility-specific simulation. We conclude threshold-based targets are a less effective policy than facility-specific ones, although they are easier to administer and enforce. The need for a large improvement target declines as the threshold is lowered (more firms are regulated), but the administrative burden of measuring the baseline-intensity increases.

TABLE 4: COMPARING THE COSTS OF FACILITY- AND THRESHOLD-BASED TARGETS

	Facility-Specific		Sector-Specific		Threshold-Based	
	Standard	Tax	Standard	Tax	Standard	Tax
Improvement Target	**18%**		**18%**		**52.30%**	
GDP	-0.615%	-0.613%	-0.290%	-0.260%	-0.870%	-0.613%
Number of Firms	-0.640%	-0.630%	-0.010%	-0.270%	-0.050%	-0.630%
Total Energy Use	-15.920%	-15.920%	-7.610%	-7.610%	-15.920%	-15.920%
Uniform Energy Tax Rate		20.920%		9.090%		20.920%

Note: Displays results of various simulations of regulatory energy- and emissions-intensity standards. The "standard"' corresponds to: (1) Facility-Specific, an 18-per-cent reduction in energy intensity; (2) Threshold-Based, an 18-per-cent energy-intensity reduction target that is firm specific for the largest firms (cumulatively accounts for 50 per cent of total energy use); and (3) Threshold-Based, a reduction target required to match the energy reduction from the Facility-Specific policy. The results are contrasted to a flat, economy-wide energy tax that achieves equivalent energy conservation.

Comparisons of Different Policy Targets

The previous paragraph shows us that we can learn something from changing targets. While it is useful to know what distortions result from different policy choices, it is also important to compare distortions under stricter and weaker policies. This section systematically compares three different policy options for all three types of standards. Table 5 shows how energy use, GDP and the number of firms are affected as we move from a 10-per-cent energy-reduction goal to a 30-per-cent energy-reduction goal, for the policies outlined above.

TABLE 5: COMPARISON OF POLICY OPTIONS

	Facility-Specific		Sector-Specific		Threshold-Based	
	Standard	Tax	Standard	Tax	Standard	Tax
10% Standard						
GDP	-0.33%	-0.33%	-1.44%	-0.26%	-0.15%	-0.15%
Number of Firms	-0.35%	-0.34%	-11.11%	-0.27%	-0.01%	-0.15%
Total Energy Use	-9.48%	-9.48%	-7.68%	-7.68%	-4.63%	-4.63%
Uniform Energy Tax Rate		11.56%		9.18%		5.35%
20% Standard						
GDP	-0.69%	-0.68%	-1.72%	-0.35%	-0.32%	-0.28%
Number of Firms	-0.72%	-0.70%	-12.42%	-0.36%	-0.01%	-0.29%
Total Energy Use	-17.40%	-17.40%	-9.87%	-9.87%	-8.28%	-8.28%
Uniform Energy Tax Rate		23.27%		12.08%		9.96%
30% Standard						
GDP	-1.06%	-1.05%	-2.00%	-0.43%	-0.49%	-0.40%
Number of Firms	-1.09%	-1.07%	-13.55%	-0.45%	-0.02%	-0.41%
Total Energy Use	-24.11%	-24.11%	-11.99%	-11.99%	-11.21%	-11.21%
Uniform Energy Tax Rate		35.12%		15.03%		13.93%

Note: Displays results of various simulations of regulatory energy and emissions intensity standards, for various improvement targets. The "Standard" corresponds to: (1) Facility-Specific, a 10-per-cent, 20-per-cent, and 30-per-cent reduction in energy intensity; (2) Sector-Specific, an energy intensity target for all firms to meet or exceed that corresponds to 10 per cent, 20 per cent, and 30 per cent less than the sector's prior average; and (3) Threshold-Based, a 10-per-cent, 20-per-cent, and 30-per-cent energy-intensity reduction target that is firm specific for the largest firms (cumulatively accounts for 50 per cent of total energy use). The results are contrasted to a flat, economy-wide energy tax that achieves equivalent energy conservation.

Overall, higher improvement targets achieve greater energy conservation but at increasing economic costs. Moving from a 10-per-cent facility-specific target improvement to a 30-per-cent target will increase the level of conservation by more than 250 per cent. This represents a 24-per-cent reduction in energy use compared to nine per cent. The economic costs in terms of GDP reductions to achieve this conservation, however, grow by more than 320 per cent — from a 0.33 per cent reduction in GDP to lower energy use by nine per cent to a 1.06-per-cent reduction in GDP to lower energy use by 24 per cent. The sector-specific target, however, has lower economic costs per unit of energy reduction at higher targets. As the target increases, an increasing number of high-productivity firms will be subject to the improvement. When the target is low, many of these firms will achieve the goal without further action. In any case, under all scenarios, a flat energy tax is superior to any of the standards. The benefits of a tax are also, generally, more evident when intensity-improvement targets are high.

The Option to Pay a Fine

The previous policy experiments presumed that firms would undertake whatever actions were required to achieve the imposed target. The compliance costs were significant for low-productivity firms facing sector-specific targets. These costs also often led firms to shut down and exit the market. Existing regulations, however, provide firms an option: meet the target or pay a fine.

Depending on the regulations, the magnitude of the fine varies. Under the federal government's Air Emissions Framework, the fine for non-compliance is $20 per tonne in 2013. To put this in perspective, we first must calculate how much Canadian businesses spend on their energy inputs relative to the quantity of greenhouse gas emissions attributable to them. Using data on total energy input spending and greenhouse gas emissions of Canadian industries from Statistics Canada, we find that in 2007, more than $84.27 billion was spent on energy inputs and this was associated with emissions of 581.3 megatonnes of CO_2-equivalent.[28] This implies that firms are spending approximately $145 on energy inputs for each tonne of GHG emitted. A fine of $20 per tonne is therefore equivalent to a 13.8-per-cent tax on energy inputs. This rate varies slightly by year, and is slated to increase over time, so we round up to 15 per cent in all simulations that follow.[29] To capture the option for firms to pay a fine, we simulate each of the above intensity targets when firms can opt to pay a 15-per-cent tax or incur the compliance costs associated with achieving the intensity target.

The decision rule of firms is simple: pick the option with the lowest overall cost of compliance. When energy-intensity targets are set based on a sector's average, low-productivity firms have a difficult time achieving them and there are significant GDP losses relative to an equivalent energy tax. When firms have the option to pay a fine, the lowest-productivity firms will opt to pay instead of reducing emissions. This dramatically lowers compliance costs for those firms, leading far fewer of them to exit. The productivity consequences of this policy, therefore, are far less than without the fine. A second benefit of the fine is that, among firms choosing to pay it, the change in energy costs is the same; this means there are no within-industry differences in energy costs for fine-paying firms. As for the other firms, the moderately productive firms will choose to achieve the target, incurring the necessary costs directly. For these firms, there will be within-industry differences in energy costs. The highest-productivity firms will already be compliant and face no additional costs. We illustrate the two options across the entire distribution of productivity in manufacturing in Figure 2 as an example.

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[28] Source data from CANSIM Tables 153-0034 and 383-0022. Note that these figures reflect only the emissions recorded at the sector level for 2007 for which we have energy input spending data. This represents nearly 80 per cent of Canada's total emissions. For a detailed accounting of Canada's greenhouse gas emissions see Environment Canada's "National Inventory Report."

[29] For example, the same calculation for 2002 yields $120 in spending per tonne of GHG, implying a $20 per tonne tax equivalent of over 16 per cent.

The option to pay a fine dramatically reduces the costs of imposing energy-intensity standards. While we still find standards inferior to taxes, the differences are not nearly as stark as they are without the option to pay a fine. We report the results in the second panel of Table 6. For facility-specific standards, the difference is completely eliminated — all firms covered by this regulation opt to pay the fine instead of achieving the target. In this case, the fine acts like a tax, and a fine that is too small may not be as effective as policy-makers envision, as the standard no longer binds. For sector-specific targets, the effect on GDP is reduced from five times larger than a tax (-1.67 per cent relative to -0.33 per cent) to slightly over two times larger (-0.35 per cent relative to -0.15 per cent). The two are not directly comparable, however, since the option to pay a fine means energy use is higher — it falls by 4.74 per cent instead of 9.44 per cent. This should not be surprising, as those that opt to pay a fine will use more energy than they would have under the target. To achieve the same level of conservation, the sectoral-improvement target would have to be enormous; as the target increases more firms opt to pay the fine. One can potentially adjust the fine and target simultaneously, though, to achieve the same energy-use reduction. An improvement target of 33 per cent coupled with a fine of 33 per cent, for example, will lower energy use by the same amount as an 18-per-cent improvement target without a fine. In this case, GDP falls by nearly 0.77 per cent, less than half the decline without the fine. The combination of standard and fine causes less distortion than a standard alone, but is more distortive than the flat tax.

TABLE 6: LOWERING THE COSTS OF STANDARDS RELATIVE TO TAXES

	Facility-Specific		Sector-Specific		Threshold-Based	
	Standard	Tax	Standard	Tax	Standard	Tax
(1) Baseline Results						
GDP	-0.61%	-0.61%	-1.67%	-0.33%	-0.29%	-0.26%
Number of Firms	-0.64%	-0.63%	-12.17%	-0.34%	-0.01%	-0.27%
Total Energy Use	-15.92%	-15.92%	-9.44%	-9.44%	-7.61%	-7.61%
Uniform Energy Tax Rate		20.92%		11.50%		9.09%
(2) With Option to Pay Fine (15% Energy Tax Equivalent)						
GDP	-0.43%	-0.43%	-0.35%	-0.15%	-0.20%	-0.19%
Number of Firms	-0.45%	-0.45%	-2.14%	-0.16%	0.00%	-0.20%
Total Energy Use	-11.96%	-11.96%	-4.74%	-4.74%	-5.81%	-5.81%
Uniform Energy Tax Rate		15.00%		5.49%		6.81%
(3) Fixed Number of Firms (No Entry or Exit), With Option to Pay Fine (15% Energy Tax Equivalent)						
GDP	-0.40%	-0.40%	-0.17%	-0.15%	-0.20%	-0.17%
Number of Firms	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total Energy Use	-11.96%	-11.96%	-5.01%	-5.01%	-5.79%	-5.79%
Uniform Energy Tax Rate		15.00%		5.82%		6.78%

Note: Displays results of various simulations of regulatory energy- and emissions-intensity standards. The "standard" corresponds to: (1) Facility-Specific, an 18-per-cent reduction in energy intensity; (2) Sector-Specific, an energy-intensity target for all firms to meet or exceed that corresponds to 18 per cent less than the sector's prior average; and (3) Threshold-Based, a 18-per-cent energy-intensity reduction target that is firm specific for the largest firms (cumulatively accounts for 50 per cent of total energy use). The results are contrasted to a flat, economy-wide energy tax that achieves equivalent energy conservation. Panels two and three report the results when: (1) firms have the option of paying a fine equivalent to a 15-per-cent tax on energy use; and (2) firms are compensated through a lump-sum tax-and-transfer system to keep the number of active firms constant.

Preventing Firm Exit

We conclude our quantitative evaluation of these various policies by considering an additional means of lowering the GDP-cost of intensity standards: preventing firm exit. If, in addition to an intensity standard and the option to pay a fine, compensation is provided to prevent firms from exiting, the negative effect on GDP can be reduced even further. Recall our earlier discussion of sector-specific targets, where we found that the majority of the negative GDP effects were due to within-industry factors, which are mostly due to firm exit. If (lump-sum) taxes on households can be transferred to firms (also in a lump-sum fashion), then the number of exiting firms will decline.

We repeat all of the earlier experiments under a tax-and-transfer scheme that fully eliminates any firm exit. The results of this are reported in panel three of Table 6. For all three types of regulatory approaches, standards become almost indistinguishable from flat energy taxes. Sector-specific intensity standards targeting an 18-per-cent improvement, with fines and compensation, will result in a five-per-cent reduction in energy use and a 0.17-per-cent reduction in GDP. These are very similar to the costs under an energy tax, which lowers GDP by 0.15 per cent.

POLICY EVALUATION AND RECOMMENDATIONS

Here, we present a convenient means of comparing the overall costs of each type of policy. Expressed as foregone income per tonne of carbon abated, we can evaluate the social benefits of each policy by comparing their costs to the benefits of lower carbon emissions. We conclude this section with specific policy recommendations for Canada.

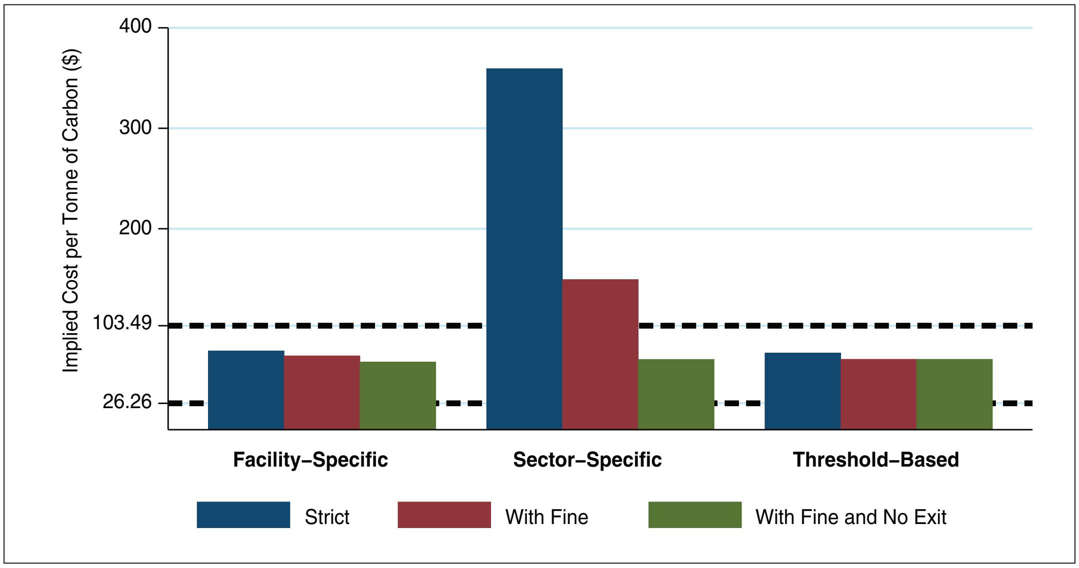
Policy Evaluation and the Cost of Carbon

We can more effectively compare these policies, as well as judge their relative value from society's point of view, by converting their effect on GDP and total energy use into an implied cost of carbon. To achieve this, we use the same data as in Table 5 and find total revenues of $1.182 trillion in 2007 associated with GHG emissions of 581.3 megatonnes. This implies over $2,000 in revenue per tonne of GHG emitted. Our simulations provide an estimate of the percentage change in GDP and the percentage change in total energy use. For example, under the sector-specific standard without a fine, GDP declines by 1.67 per cent and energy use declines by 9.44 per cent. In 2007 dollars, revenue declines by $19.74 billion and emissions fall by 54.87 megatonnes.[30] Thus, the implied cost of carbon is $359 per tonne. The corresponding cost of carbon for an energy tax that achieves the same level of energy conservation is only $70 per tonne. We display the cost of carbon under all policy experiments in Figure 3.

[30] This assumes a one-to-one relationship between energy use and greenhouse gas emissions.

While we can clearly rank the effectiveness and efficiency of the policies considered, we must also consider the benefit of these policies, which are not incorporated by the model. If the estimates of the cost of carbon exceed estimates of the gains from lower carbon-related costs such as climate change, then this suggests the policies do not pass the cost-benefit test. There are a variety of estimates of the social cost of carbon, which represent the value to society of lowering emissions by one tonne. Drzymala et al[31] note that "simple compilation of the results of various studies of the issue over the past 20 years without further triage based on assessment of the underlying data and methodologies indicates a range of values for [the social cost of carbon] extending from -$1.60 to $1,052.00 (in 2009 $CAN per t$CO_2$)." The central estimate suggested by Environment Canada for 2010 is $26.26 per tonne of CO_2 (2007 dollars).[32] The suggested 95th-percentile estimate, which accounts for the possibility of low-probability catastrophic events, is $103.49 (2007 dollars). Only under the worst-case scenario estimates for a social cost of carbon is the benefit greater than the cost, and then only if the energy tax is used. While laudable, the benefit of these emission-reduction policies is not obvious.

FIGURE 3: IMPLIED COST-OF-CARBON OF VARIOUS POLICIES



Note: Displays the implied cost of carbon for each policy considered. The vertical axis represents the foregone income per tonne of carbon abated. The two dashed lines mark the location of Environment Canada's central estimate of the social cost of carbon (SCC), at $26.26/tonne, and the 95th-percentile estimate within their range of SCC estimates, at $103.49/tonne. See text for details.

31 Alexandre Drzymala, Rachel Samson, Judith Hamel, Jon Graham and Luis Leigh, "Selecting a value for emissions in Government of Canada Regulatory Impact Analysis Statements," Economic Analysis Directorate (Environment Canada), working paper, 2012.

32 From Drzymala et al (2012), converted from 2009 Canadian dollars. The earliest year for which a social cost of carbon estimate for Canada is available is 2010. As the calculation of the social cost is based on the concentration of GHGs in the atmosphere, and emissions have increased between 2007 and 2010, the 2010 value is an overestimate for 2007.

Policy Recommendations

Before moving into specific policy recommendations, a brief review is in order. The broad lesson outlined in this paper is that considering productivity differences between firms has important implications for whether taxes or regulatory standards are the superior means of achieving emission-reduction goals. When policies change the input prices faced by some producers more than prices faced by others, firm exit and input misallocations result. Using a model economy that is consistent with industry-level data in Canada, we simulate three types of standards: targets that are firm-specific; sector-specific targets that are common across firms within an industry; and targets that apply only to sufficiently large emitters. We also consider these policies when there is an option to pay a fine for violating the intensity standard and when there is a tax-and-transfer scheme in place to prevent firm exit. In all cases, and especially for sector-specific targets, we find that a flat tax on energy is less costly in terms of GDP reduction.

Our analysis suggests a number of concrete steps that regulators can take to lower GHG emissions in Canada. Above all, energy taxes are superior to intensity standards, which cannot be overemphasized. They result in lower reductions in GDP per unit of GHG emission reduction. We recognize that political considerations may constrain governments from enacting so-called carbon taxes. With that in mind, there are ways of lowering the effective cost of imposing intensity standards. First, allowing for fines dramatically lowers the degree of misallocation and therefore lowers the economic cost of imposing intensity standards. Second, compensatory mechanisms can ensure intensity standards do not lead existing plants to shut down. When intensity standards are combined with fines and compensatory mechanisms to prevent exit, the economic costs of standards, even sector-specific standards, are similar to energy taxes. Policy-makers need to be aware, however, that the energy-use reductions are much lower under standards combined with fines compared to a tax.

The magnitude of the fine, however, is important. It is not desirable to set a fine too high, as firms would then opt to comply with the intensity targets. As the goal of the fine is to avoid some of the problems associated with intensity targets, misallocation and exit will result in larger productivity costs with a high fine. It is also undesirable to set a fine too low, as most firms would then opt to pay the fine and the total level of energy conservation and greenhouse-gas-emission abatement would be small, substantially reducing the effectiveness of the policy. The “optimal” fine should be set at a level equal to the optimal energy tax. The corresponding regulatory target for energy-intensity reductions should then be set such that a large fraction of low-productivity firms simply opt to pay the fine. Simply put: the target should be ambitious. The greater the fraction of firms that opt to pay an optimally set fine, the lower the productivity costs of achieving a desired level of total energy reduction. If energy taxes are politically impracticable, then targets combined with fines can be nearly as good.

As for compensatory mechanisms, their specific form does not matter, so long as they are independent of each firm’s decision to produce additional output or use additional inputs. They should be structured in a lump-sum fashion. Rebating a portion of the fine payment — so long as the rebate is independent of the firm’s input and output choices — would serve this purpose. In this form, the fine is charged on all units of energy purchased, and a lump-sum rebate cheque is issued. This is similar to the GST rebate program for lower-income Canadians. It is nominally meant to return the household’s spending on GST, when in reality it is independent of a household’s actual spending choices.

Special provisions for capital depreciation that lower a firm's income-tax burden represent another potential policy. Ideally, these would be refundable, as firms close to exiting are not likely earning taxable net income. The magnitude of the transfer need not be large. In our simulation of sector-specific targets without a fine, which is the case requiring the largest transfer, the total lump-sum transfers amount to just over 0.04 per cent of total income. This is approximately $500 million in 2007 dollars. If a fine is permitted, this figure declines to less than $120 million, which is offset from revenue accruing to the government through the fine. Further analysis of this issue should be undertaken, as we consider our exercises as merely illustrative of broad principles. The important conclusion is that some lump-sum rebate sufficient to prevent firm bankruptcy, which may even require case-by-case analysis by regulators, would improve the efficiency of imposing intensity standards.

CONCLUSION

The above analysis shows that productivity variation across firms is an important consideration for environmental policy. When one recognizes that productivity varies significantly across firms and industries, policies that are *neutral* — ones that do not differentially affect the cost of inputs across firms or industries — are more efficient and have smaller negative consequences. Flat taxes have this feature. We recognize political realities may not allow governments to implement carbon taxes and have demonstrated that regulatory standards, coupled with reasonably set fines and mechanisms to ensure firms do not exit, can be nearly as good.

APPENDIX A

THE MODEL IN BRIEF

In this appendix, we present only a sketch of the model structure, and neglect a full characterization of the model's equilibrium, which can be found in Tombe and Winter.[33]

Let the economy be composed of N industries, each containing a large number of firms with differing productivity levels (denoted φ). A firm in industry-i produces a unique variety of output (denoted $y_i(\varphi)$) using only labour ($l_i(\varphi)$ and energy ($e_i(\varphi)$ with the following production function,

(1) $$y_i(\varphi) = \varphi \, l_i(\varphi)^{\alpha_i} \, e_i(\varphi)^{1-\alpha_i}.$$

Emissions result from the use of energy, so that all industries are "dirty" but vary in their "dirtiness." The intensity with which energy is used in the production process is governed by the parameter α_i (lower α_i implies a higher energy intensity). Each firm's productivity differs and follows a known distribution given by $F_i(\varphi) = 1-\varphi^{-\theta}$, where θ governs the dispersion across firms (lower θ implies higher dispersion).

The production of all firms within industry-i is combined into a single good using the function,

(2) $$Y_i = \left(\int y_i(\varphi)^{\frac{\sigma-1}{\sigma}} \, g_i(\varphi) \, d\varphi\right)^{\frac{\sigma}{\sigma-1}},$$

which has a constant elasticity of substitution, given by σ. Low-productivity firms are able to remain operational in the presence of more productive competitors since all firms produce slightly different products. Not all varieties are available or required to generate the aggregate industry good, as some firms do not produce. We incorporate endogenous entry and exit as in Melitz,[34] where firms decide whether to produce or not depending on their marginal production costs relative to their output prices. If there is more spending on industry-i goods in general, there will be a greater number of firms that decide to operate in this industry. Total demand for an industry's output comes from a representative household, to which we now turn.

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[33] Trevor Tombe and Jennifer Winter, "Taxes vs Standards (Again): Misallocation and Productivity Consequences of Energy and Emissions Intensity Targets," 2012.

[34] Marc J. Melitz, "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica* 71, 6 (2003): 1695–1725.

The representative household strives to maximize utility given by

$$(3) \qquad U = \left(\sum_{i=1}^{N} \xi_i Y_i^{\frac{p-1}{p}} \right)^{\frac{\mu}{p-1}},$$

where ξ_i is the weight given to goods form industry-*i* and ρ is the elasticity of substitution across goods. The preference-weight parameter ξ_i allows us to match the actual allocation of spending across industries that we observe in the Canadian economy. The household spends income earned from labour (wL), transfers from the government (T), and dividends from all profits earned by firms (Π). The total spending of the household cannot exceed its total income, which implies the following budget constraint,

$$(4) \qquad \sum_{i=1}^{N} P_i Y_i \leq wL + T + \Pi,$$

where P_i is the price of good-*i*. The household supplies labour inelastically in a competitive labour market, so L is fixed and normalized to one.

Finally, energy is supplied by a perfectly competitive producer that uses labour (l_e) and a natural resource (n) as inputs with the following technology, $E = l_e^{\beta} n^{1-\beta}$. The natural resource is in fixed supply and is rented to the firm by the government. Revenues from the use of resources are rebated by the government, lump-sum, to the household.

In the model, prices are normalized such that household utility equals total income in the economy, which also equals the total value of output. That is, GDP = total income = utility = welfare, and the terms can be used interchangeably.

With this basic structure, many useful results can be derived. We will omit from this paper a full characterization of the model's equilibrium, as this can be found in Tombe and Winter.[35] Very broadly, in equilibrium, labour supply equals labour demand; the sum of energy use in each industry equals energy supplied; and total consumption demand for each good must equal the total output of each industry. Firms must also behave optimally, minimizing the cost of producing their output. This final point implies a certain optimal combination of labour and energy that depends on the wage for labourers and the price of energy. If a firm also faces a tax on energy inputs or an energy-intensity compliance cost that effectively increases the price of using energy, then the optimal labour and energy combination will change, becoming more labour insensitive. From this result, one can show that the equilibrium energy intensity (energy per unit of output) will be

$$(5) \qquad \frac{e_i(\varphi)}{y_i(\varphi)} = \varphi^{-1} \left(\frac{1-\alpha_i}{\alpha_i} \; \frac{w}{q\tau_i(\varphi)} \right)^{\alpha_i},$$

where q is the price of energy faced by all firms and $\tau_i(\varphi)$ is the (potentially firm-specific) energy tax or regulatory compliance cost. All revenue generated from this tax is rebated lump-sum to the household. In our simulations, we can use the above expression to find a $\tau_i(\varphi)$ in order to match any energy-intensity target. The target intensity that we will match will depend on the policy being simulated. If $\overline{ey}_i$ is the target level of energy intensity, then a tax of

$$(6) \qquad \tau_i(\varphi) = \left(\frac{1}{\varphi \, \overline{ey}_i} \right)^{1/\alpha_i} \frac{1-\alpha_i}{\alpha_i} \; \frac{w}{q},$$

[35] Trevor Tombe and Jennifer Winter, "Taxes vs Standards (Again): Misallocation and Productivity Consequences of Energy and Emissions Intensity Targets," 2012.

will induce a firm with productivity φ to meet the target. So, if two firms within the same industry face an identical target, then the energy-tax rates they each face will differ according to their productivity. If one firm has productivity φ while another has φ', then $\tau_i(\varphi)/\tau_i(\varphi') = (\varphi'/\varphi)^{1/\alpha_i}$.

This is important since *differences* in tax rates have implications for an industry's overall productivity. The intuition behind how differences in input prices between firms can lower productivity is straightforward. First, one can show that the model implies an *optimal* size distribution across firms. Specifically, the output of a firm with productivity given by φ relative to the output of another firm with productivity φ' is

$$(7) \qquad \frac{y_i(\varphi)}{y_i(\varphi')} = \left(\frac{\varphi}{\varphi'} \frac{\tau_i(\varphi')^{1-\alpha_i}}{\tau_i(\varphi)^{1-\alpha_i}} \right)^{\sigma}.$$

This implies, in the absence of energy price differences, that a firm with twice the productivity of another will have 2^{σ} larger output. When $\tau_i(\varphi)$ differs across firms, however, the relative size will deviate from this optimal ratio. A similar result holds between industries, where the optimal relative expenditures between two industries depends on preference weights, input costs, and productivity. Differences in average energy input costs across industries will distort the allocation of spending across industries.

With these two distortions in mind — (1) between firms within an industry and (2) overall spending between industries — we can present an expression for an industry's overall productivity. If we define the average energy tax in industry-*i* as $\bar{\tau}_i$ and the number of operating firms in this industry as M_i, then this industry's *TFP* is

$$(8) \qquad TFP_i = M_i^{1/(\sigma-1)} \; \tilde{\varphi}_i \; \bar{\tau}_i^{\,1-\alpha_i} ,$$

where

$$(9) \qquad \tilde{\varphi}_i = \left(\int_{\varphi_i^*}^{\infty} \left(\frac{\varphi}{\tau_i(\varphi)^{1-\alpha_i}} \right)^{\sigma-1} \mu_i(\varphi)\, d\varphi \right)^{\frac{1}{\sigma-1}} ,$$

is an adjusted measure of average productivity of operating firms, $\mu_i(\varphi) = g_i(\varphi)/M_i$, and φ_i^* is the minimum productivity a firm must possess in order to profitably operate in industry-*i*. In the case of no energy taxes (or common tax rates across firms), one can show $TFP_i \propto M_i^{1/(\sigma-1)-1/\theta}$. Given a technical requirement that $\theta > \sigma-1$, an industry's productivity will be negatively affected by firm exit.

We leave a full discussion of the subtleties of this expression to our main paper cited above, but a further discussion of τ_i is helpful. A proper average of tax *rates* across firms turns out to be what is called a harmonic mean of the rates faced by each individual firm. Harmonic means have a property whereby they are influenced heavily by the smallest elements over which the average is taken. In this context, an industry's overall energy-tax rate (the harmonic-mean tax rate) will decline if the dispersion in tax rates across firms increases, even if the simple average tax rate (the arithmetic-mean tax rate) is constant. So, policies with larger differences in energy-tax rates or compliance costs across firms will have a greater negative effect on an industry's productivity. Finally, note that there is also a direct negative effect on productivity from firm exit (smaller M_i).

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