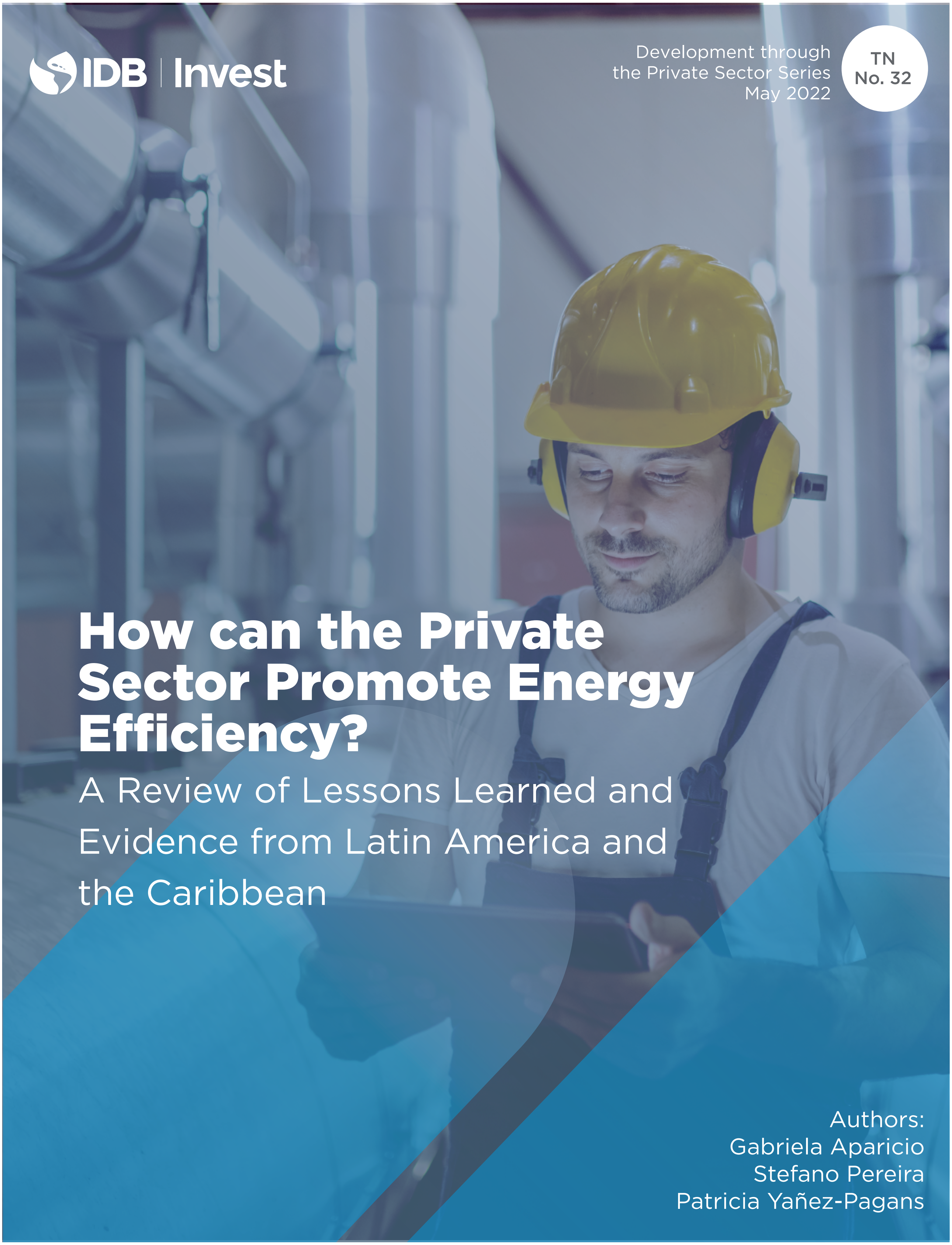

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# How can the Private Sector Promote Energy Efficiency?

## A Review of Lessons Learned and Evidence from Latin America and the Caribbean

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IDB | Invest

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May 2022

# How Can the Private Sector Promote Energy Efficiency? A Review of Lessons Learned and Evidence from Latin America and the Caribbean

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*May 2022*

## Abstract

Improving energy efficiency is among the top development objectives for the next decade, and this goal cannot be achieved without the commitment of the private sector. This paper analyzes energy efficiency trends in the private sector for a range of countries in Latin America and the Caribbean, combining data from the World Bank Enterprise Surveys and the Inter-American Development Bank/Compete Caribbean Productivity and Innovation Surveys. The paper also reviews the evidence on the effectiveness of interventions promoting the adoption of energy efficiency practices and technologies. This review considers not only interventions focused on traditional market forces that may promote the uptake of energy efficient technologies, but also behavioral factors that can influence investment decisions in such technologies. While most available evidence has focused on programs that encourage household adoption of energy efficiency, these results provide valuable insights that can guide the design of interventions through private sector firms and highlight the importance of producing more rigorous impact evidence at the firm level. The study concludes by offering recommendations on how to promote more investment in energy efficiency through the private sector.

**JEL Codes:** D22, D62, D91, L23, O12, O33, Q40

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## 1. Introduction

Many countries around the world have started incorporating climate goals into their national development agendas. As of 2021, 191 countries have committed to the United Nations Framework Convention on Climate Change (otherwise known as the Paris Agreement) via Nationally Defined Contributions (NDCs), which include goals to reduce their greenhouse gas (GHG) emissions and, in turn, their climate impact. Energy consumption is the dominant contributor to climate change, accounting for around 60% of total GHG emissions (UN, 2020). These emissions are mostly driven by firms that use combustible fuels in their production and operational activities[1], and to a lesser degree by households for heating and cooking.

Energy efficiency, defined as the rate of output per unit of energy consumed, has the potential to boost private sector growth by enhancing the productive capacity of firms in a sustainable way (Adhvaryu et al., 2020; Filippini et al., 2020). Not only can adoption of energy efficiency enhancing technologies help minimize external environmental costs, but it can also reduce firm operational costs and, in turn, increase profitability. Hence, any global strategy for GHG mitigation should also incorporate green investments and promote the adoption of sustainable practices by the private sector. Given this win-win situation, energy efficiency is often one of the driving forces behind corporate sustainability efforts (DeSimone and Popoff, 2000).

Increasing energy efficiency also constitutes an integral part of meeting several UN Sustainable Development Goals (SDGs). For instance, one of the targets of SDG 7 is to double the global rate of improvement in energy efficiency by 2030, as proxied by energy intensity. Energy intensity is the quantity of energy required to produce a unit of output or perform a particular task. In 2018, the average annual improvement needed to reach this goal was 2.6%. However, in that same year, the average energy efficiency gains fell below this mark mostly as a result of weak energy efficiency policy and high demand in energy-intensive sectors (IEA, 2019). For Latin America and the Caribbean (LAC), the average country was able to reduce its energy intensity by approximately 2.1% since the establishment of the SDGs, meaning that there is still a need for improvement if the region hopes to meet its NDCs.

As the LAC region begins to recover from the COVID-19 pandemic, rising growth will likely be accompanied by increasing energy demand. Energy efficiency is critical to support this growth without compromising the environment (Ravillard et al., 2019). In addition, the pandemic has provided an opportunity for firms to ride a wave of rapid technological change (Serebrisky et al., 2020), which may lead them to be more open to exploring new technologies and practices. To date, energy efficiency adoption by firms, particularly smaller ones, has been low both due to financial constraints and a lack of knowledge about these technologies and the technical capabilities to implement them, among other barriers (Allcott & Mullainathan, 2010; Gillingham & Palmer, 2014; Allcott & Taubinsky, 2015). Within this “new normal” context, finding effective approaches to better promote energy efficiency practices in private sector firms is key.

How can we boost energy efficiency adoption in the private sector? This study begins by presenting a simple theoretical framework to better understand the drivers of energy efficiency adoption at the firm level and the main barriers to uptake. We then use data analytics to describe the current energy efficiency landscape in LAC and explore its relationship with firm-level

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[1] For example, using data from 2019 the EU estimated that firm activities accounted for approximately 74% of energy usage in Europe. See Eurostat (2021).

productivity. For this, we exploit firm-level data from the World Bank Enterprise Surveys and the Inter-American Development Bank (IDB)/Compete Caribbean Productivity and Innovation Surveys. Our combined dataset includes over 6,000 firms across 19 countries. Finally, we review the knowledge base related to the effectiveness of interventions promoting energy efficiency with a particular focus on causal evidence. We attempt to identify knowledge gaps and potential areas of work that can help to move the needle in this topic through the private sector.

Our findings indicate that several sectors dominate energy consumption in LAC, with differences across countries. The food & retail and wholesale sectors account for the largest shares of energy consumption, with an average of 16% and 26%, respectively. Interestingly, the number of firms within a sector is not always the main determinant of energy consumption. In some cases, sectors with the highest shares of energy consumption are those with the fewest firms. The data also shows that large differences still exist that cannot be explained by production levels alone, both within sectors and across countries. Unsurprisingly, large firms are responsible for the lion's share of energy consumption (87% on average) as they account for more than double the value of output as compared to small and medium-sized enterprises (SMEs).

Despite the figures above, when looking at energy intensity measures, SMEs have significantly higher levels of intensity compared to large firms. Our analysis also shows wide variability in energy intensity across countries and sectors. Most energy efficient firms in the region are found in the services sector. In contrast, energy intensity levels are highest in the textiles & garments, plastics & rubbers, and hotels & restaurants sectors, which could be potential areas to target for improvement. In terms of other firm-level characteristics correlated with energy intensity, results indicate that firms with a track record of conducting business innovations ("innovative firms") are significantly more energy efficient than their non-innovative counterparts. Moreover, the analysis reveals the importance of access to credit to support higher levels of energy efficiency, particularly for larger firms, where energy efficiency gaps are wider.

We also explore the association between energy intensity and firm productivity. The analysis reveals that the relationship between energy efficiency and productivity is positive for low efficiency firms, however this begins to taper for mid-efficiency firms and then becomes positive again for high-efficiency firms. Thus, our findings are more nuanced than the available literature. A recent study by Yepez et al. (2021) presents evidence for four Latin American countries (Brazil, Chile, Mexico, and Peru) of a positive relationship between productivity and energy efficiency. However, this analysis is limited to manufacturing and industrial firms. Building on this study, our analysis also includes the retail and services sectors, as well as 19 countries including those in the Caribbean. Our analysis shows that Caribbean countries are the least energy efficient in the LAC region and require extra attention in the discussion around energy efficiency solutions.

Lastly, we review the evidence base on which interventions can be effective in improving energy efficiency for the private sector. Although other literature reviews have been carried out on this topic, they focus primarily on residential energy efficiency or public policy rather than on the role of firms.[2] Moreover, unlike earlier papers, we focus on evidence from developing countries where energy use is increasing at a more rapid rate, and consequently more carefully planned action is needed to ensure countries meet their economic and environmental needs.[3] In addition, in recent years new empirical evidence has become available, which relies on larger samples and more sophisticated methodologies. These more recent studies include the use of behavioral science

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[2] For instance, see Gillingham et al. (2009) and Gillingham & Palmer (2014).

[3] According to the World Bank World Development Indicators, in the last 5-year timespan available (2009-2014), energy consumption, measured in kWh per capita increased in LAC at an average rate of 2.01% per year. The global average rate during the same time period was 1.65% per year.

insights and the analysis of more sophisticated technologies that did not receive as much attention in the past.

Overall, our review shows that there is not much empirical evidence on energy efficiency interventions with firms. Most of the causal studies in this area have focused on interventions to promote energy efficiency at the household level. They often include the dissemination of information to nudge energy users towards more efficient options. The results of these studies are nonetheless valuable to inform potential interventions that could be implemented through the private sector. For example, besides facilitating access to credit for the adoption of green technologies, it is important for private sector interventions to strengthen firms' understanding of these technologies and their benefits, as well as build firm capabilities to adopt them and follow through over time. For this, generating more evidence on the effectiveness of different communication strategies, energy audit approaches, and training is still needed. Lessons from our review of the evidence highlight the role of incorporating behavioral insights into training design and approaches to promote uptake of new technologies and monitor use over time.

The remainder of this document is organized as follows. In Section 2, we present a conceptual framework on energy consumption and energy efficiency among firms. Section 3 uses firm-level data to provide a cross-sectional analysis of energy consumption and energy efficiency, in addition to exploring the link between productivity and energy efficiency across firms in LAC and the main determinants of energy efficiency levels among firms. In Section 4, we review the empirical literature on the effectiveness of different interventions to promote energy efficiency, focusing on those that can be implemented by the private sector. Lastly, in Section 5 we conclude with some recommendations and offer areas for future research.

## 2. Conceptual Framework

Do firms fail to invest more in energy efficiency because such investments are not desirable, or because they face barriers that disincentivize them from investing? A conceptual framework is useful to understand the complexities in addressing this question. The framework presented in this section explains how firms make choices about production and energy efficiency adoption, and the assumptions under which these choices hold. The framework also describes different barriers to the adoption of beneficial energy efficient investments including market failures, such as externalities, information asymmetry, and credit constraints, as well as behavioral failures. Understanding these topics is important to design effective energy efficiency interventions.

**Firms decide whether to invest in energy efficiency based on a standard profit maximization (or cost minimization) model**, such as the one presented in Ryan (2016). Given input prices, firms choose an amount of capital, labor, and energy services, which they deploy in their production process. Different bundles of these inputs will result in different levels of production, which determine profits. For example, a simple model begins by assuming that there are no market or behavioral failures: firms have perfect information regarding the true costs and benefits of investing in energy efficiency (such as future energy operating costs of each alternative, etc.), prices are not distorted, and there are no externalities. Under these assumptions, rational profit-motivated firms will choose input bundles, including the level of the energy input, which are most beneficial for themselves (privately optimal) but also most beneficial for society as a whole (socially optimal). In this simple framework, the main determinants of energy efficiency adoption are the direct costs associated with efficiency improvements, such as the market price of capital, the rate at which future savings are discounted, and expected energy prices (See Annex II for more details on the model).

**It is important to distinguish between the concepts of energy conservation and energy efficiency,** both of which can reduce energy consumption. Energy conservation consists of reductions in energy use, holding the energy use per unit of output constant, implying reductions in output (Allcott 2011a). For example, some policies target curtailment behavior through reduced usage of existing equipment (e.g., using air conditioning units less). Energy efficiency consists of reductions in energy use per unit of output (Jaffe & Stavins, 1994, Gillingham & Palmer, 2014). For example, some interventions target efficiency behavior through the adoption of energy efficient technologies (e.g., adopting more modern air conditioning units). The conceptual distinction between energy conservation and energy efficiency has important policy implications. For instance, firms may respond to a relative increase in the energy price by curtailing energy use in the short-run, while investing in more energy efficient production technologies in the long-run.[4]

**The rebound effect.** When energy efficiency technology becomes cheaper or energy prices increase, a firm's energy consumption response is expected to be largest in the short-run, as the firm substitutes towards more energy efficient investments and reduces energy consumption. Instead, in the long-run, firms may also respond by expanding their production, offsetting the initial reduction in energy consumption. This response is known as *the rebound effect*. If the rebound effect is sufficiently large, policies promoting energy efficiency may backfire as consumers respond to more energy efficient investments by also increasing their energy usage in an effort to maximize their welfare (Gillingham et al. 2016).[5] For example, Jin et al. (2018) find that for manufacturing firms in China, technology adoption induces a rebound effect, thereby increasing energy consumption. However, there is also evidence from China suggesting that technology adoption reduces energy consumption (Du & Yan, 2009). Hence, the actual magnitude of the rebound effect is ambiguous and depends on firms' demand as well as the substitutability of energy and other factors of production.

**The energy efficiency gap.** When barriers to energy efficiency adoption are present, profit-motivated firms will no longer choose input bundles that are both privately and socially optimal, and policy interventions may be needed to bring firms closer to the optimal levels of investment. The energy efficiency gap can be thought of as the difference between the cost-minimizing level of energy efficiency (the level that is privately optimal) and the actual level realized, in other words, the improvement potential of energy efficiency that firms could achieve (Allcott and Greenstone, 2012; Jaffe and Stavin, 1994; Allcott and Wozny, 2014).[6] From a policy perspective, it is not only relevant whether the gap exists but also its magnitude– a small gap would call for limited intervention while a larger gap would require much more effort to address. However, evidence on whether firms benefit from energy efficiency investments is largely ex-ante and may overstate the net benefits from these investments (implying a small energy efficiency gap).[7] Instead, post-installation analysis taking into account real world parameters may be more useful to understand the economics of energy efficiency improvements (Fowlie et al., 2018; Gillingham and Palmer, 2014). Despite the empirical difficulties, previous data-driven work on energy trends have determined that it is possible for firms to invest in energy efficiency without sacrificing performance (Bostian et al., 2016).

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[4] See Popp (2004) on "price-induced" technological change in the energy sector.

[5] In consumer theory, this is underpinned by the assumption that consumers have monotonic preferences with respect to energy (i.e., consumers derive higher satisfaction from obtaining more of this good). See Antonio et al. (2020) for evidence of the rebound effect among low-income households.

[6] Ryan (2016) defines the energy efficiency gap more rigorously as the point where the discounted value of the marginal profits earned as a result of investing in an additional unit of the capital input exceeds the price of that factor. See Annex II for more detail.

[7] Examples of ex-ante studies include Siller et al. 2007; Cheng and Steemers 2011; Nord and Sjøthun 2014, among others. Energy savings may be overstated due to hidden costs, errors modeling actual consumer behavior, consumer heterogeneity, uncertainty, non-ideal circumstances of individual installations, etc.

**Market failures.** Why do firms fail to make energy efficiency investments that have a positive net present value? Market failures arise when market conditions (e.g., price distortions such as taxes on capital investments or information asymmetry) cause firms' decisions to depart from what is socially and/or privately optimal (Gillingham and Palmer, 2014). At the firm-level, overcoming these barriers is likely to improve competitiveness and corporate sustainability (Kitzmueller & Shimshack, 2012). The following are some examples of market failures:

- Externalities are costs or benefits to a third party (not involved in the market transaction) that stem from the production or consumption of a good or service. For instance, most energy use (particularly those involving the consumption of fossil fuels) causes harm to human health and climate change via the emission of GHG. Firms may maximize profits, while not considering these other negative effects, resulting in more energy consumption and more GHG emissions than is socially optimal. Different approaches, such as Pigouvian taxes, may help firms internalize the cost of these negative externalities, which are otherwise not considered in their decision making, and to improve their energy management (Pigou, 1924).

- Information asymmetry may cause firms to forgo energy efficiency investments that are not only socially beneficial but also privately beneficial. For example, potential adopters may have varying levels of imperfect information vis-à-vis the operating cost of a particular technology which influences the estimated benefit they place on the investment. The same may be true of buyers and sellers of the technology where information is not conveyed in a credible manner (principal-agent issues).[8] In such cases, interventions such as energy audits and information campaigns could help firms adopt investments that are cost-effective in the long-run while simultaneously reducing negative externalities associated with energy use.

- There are also important barriers for the adoption and diffusion of innovative energy efficiency technologies. In LAC, some examples of these barriers include lack of awareness, regulatory failures, lack of a skilled workforce, access to finance, and lack of innovation ecosystems (Parente & Prescott, 2002; Alvarez & Crespi, 2015; Maffioli et al., 2013; Martin et al., 2020). As a result, although it may be socially optimal for early adopters to invest in innovative energy efficiency solutions (because marginal social benefits outweigh the marginal private costs for early adopters), there may be a slow uptake (because marginal private benefits might not outweigh the marginal private costs). Providing incentives to early adopters may help to mitigate risk and stimulate knowledge diffusion regarding the use of new technologies.[9]

**Behavioral failures**. Contrary to the assumptions thus far, recent insights through behavioral science have shown that rationality does not always hold in real world scenarios. Hafner et al. (2019) conducted an extensive literature review about the psychological barriers to adoption of energy efficient technologies. They find that factors affecting the adoption decision include: action inertia (remaining at the default choice), social norms (mimicking peer behavior), perceived behavior control (uncertainty about the feasibility of change), among others. Moreover, as presented in Kahneman & Tversky's seminal work (1979), firms have different reference points (such as their asset level), which determine how much weight they place on losses and gains in their decision-making. For example, firms with low levels of assets tend to be more risk averse than firms with more assets, and risk averse firms are less inclined to invest in energy efficient technologies if there is a small probability of incurring losses. Similarly, firms tend to weigh payoffs in the domain of losses higher than equivalent payoffs in the domain of gains. Hence, a firm may

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[8] For example, sellers of technologies may want to provide complex (and presumably expensive) solutions whereas a simpler technology may be a better investment for a firm. We return to how firms can identify the best energy efficient technologies for their businesses in Section 5.

[9] E.g. Credit facilities or low-interest credit lines to support R&D in energy efficiency.

not adopt a technology even if it has a net-positive benefit that is larger than an equally probable but smaller loss. In addition, firms may exhibit time-inconsistent preferences, undervaluing future larger payoffs relative to smaller current payoffs (Laibson, 1997). This may explain why firms purchase less expensive but also less efficient technologies, as opposed to a substitute that is more expensive but may generate cost savings over time.[10] Importantly, behavioral barriers may arise even when potential adopters are rational. Decisionmakers can face "hassle factors" that discourage them from taking beneficial investments in energy efficiency (Vries et al., 2020). For example, information about energy efficiency may be too complex, or the installation process may be too disruptive.

**Empirical evidence.** Different barriers to adoption appear to exist in the real world. Give that firms are faced with competing interests, energy efficiency investments may not be attractive for various reasons, including limited resources and a corporate culture for managing risks. Trianni & Cagno (2014) conducted an in-depth evaluation of perceived barriers to adoption of energy efficiency measures among SMEs. They found that the top three barriers to adoption were: (i) competing priorities (such as core business functions); (ii) lack of technical competencies to implement the interventions; and (iii) lack of time. These findings are especially important given that most firms in LAC are SMEs (79%).[11] The authors also infer that the ease of implementation once a firm has decided to invest in energy efficiency can vary based on investment requirements, the type of measure, and how quickly costs can be recovered. Table 1 provides a summary of some of the most common energy efficiency measures or investments observed in SMEs. The adoption decision may also be affected by the macroeconomic context. For example, using firm-level data in Mexico, Gutierrez and Teshima (2018) find evidence that trade liberalization improves the adoption rate and level of investment in energy efficiency technologies as well as reduces emissions. These findings are likely a result of increased pressures to compete.

## Table 1. Selected Energy Efficiency Measures Typically Adopted by SMEs

| Measure | Implementation costs | Payback time | Activity type | Ease of Implementation |
|---|---|---|---|---|
| More efficient light sources | Moderate | Moderate | Retro | Not |
| Reduce illumination to minimum necessary levels | Low | Short | Opt | Easy |
| Install occupancy sensors | Moderate | Moderate | New | Easy |
| Eliminate leaks in inert gas and compressed air lines/valves | Low | Short | Pro | Easy |
| Install compressor air intakes in coolest locations | Low | Moderate | New | Dep |
| Reduce the pressure of compressed air to minimum required | Low | Short | Opt | Easy |
| Use most efficient type of electric motors | Moderate | Moderate | Retro | Easy |
| Utilize energy-efficient belts | Moderate | Short | Retro | Dep |
| Use variable speed drives | Moderate | Moderate | Retro | Easy |
| Install timers and/or thermostats | Low | Short | New | Dep |
| Reduce space conditioning during non-work hours | Low | Short | Opt | Easy |
| Use radiant heater for spot heating | Low | Moderate | New | Easy |

Source: Adapted from Trianni & Cagno (2013)

Activity Type: New=New Installation; Opt=Optimization; Retro=Retrofit; Pro =Procedure
Ease of Implementation: Easy = Easy to Implement; Not = Not Easy to Implement; Dep= Context Dependent

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[10] In behavioral economics this is referred to as hyperbolic discounting. For examples specific to energy efficiency, see Tsvetanov and Segerson (2013) or Karp and Tsur (2011).

[11] Inter-American Development Bank/ Compete Caribbean Firm-level Survey (PROTEqIN) & World Bank Enterprise Surveys.

Given the complexities in firms' decisions to adopt energy efficiency technologies, having a careful understanding of the context where firms operate as well as the drivers of firm behavior is key to design effective interventions for different types of firms. Section 3 presents stylized facts from firm-level data analysis in the LAC region, which suggest some firm characteristics that are correlated with higher energy efficiency. Section 4 presents a review of the available empirical evidence on the effectiveness of different interventions to encourage adoption.

## 3. Data

We combine the latest available World Bank Enterprise Surveys (WBES) for 12 countries in Latin America with data for 7 countries under the IDB/Compete Caribbean Productivity, Technology, and Innovation Survey. Both surveys use the same sampling methodology and are constructed to be representative at the country and sector levels. Definition of variables related to energy consumption are equivalent across the two surveys, which allows us to merge them into a single combined dataset with information on sales, value added, and energy expenditures for each firm. Although the year when surveys were conducted varies slightly by country, ranging from 2014 to 2017, this timespan (3 years) is considered short enough for results to be comparable across countries. The final dataset consists of 6,022 firms across 19 countries in the LAC region.

Table 2 presents a detailed breakdown of the sample. As many as 44% of firms in the sample are small (1-19 employees), 35% are medium-sized (20-99 employees) and 21% are large (100+ employees). Firms can be classified into two broad sectors: Manufacturing (2,773) and Services (3,249), and they can be further broken down into 15 sub-sectors, although surveys are not representative at the sub-sector level. See Table 5c in the Appendix for further details. Approximately 85% are 10 years or older (mature firms). Approximately 53% of firms in the sample are considered innovative, defined as those that have introduced a new or significantly improved product or process within the last 3 years. Lastly, among firms that we were able to identify the ownership composition, 34% were women-owned/led.[12]

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[12] Data on gender composition of ownership was only available for 3,665 firms (61% of the sample). Women-owned\led are defined as firms that are either more than 50% owned by women or those at least 20% owned by women and have a woman as its top manager.

### Table 2. Breakdown of the Sample[13]

| | Small | Medium | Large | Manufacturing | Services | Mature | Young | Innovative | Non-innovative | Other | Women-owned | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Argentina | 273 | 240 | 178 | 468 | 223 | 609 | 81 | 326 | 353 | 338 | 69 | 691 |
| Barbados | 37 | 41 | 32 | 46 | 64 | 89 | 15 | 24 | 86 | 91 | 19 | 110 |
| Belize | 59 | 42 | 7 | 51 | 57 | 101 | 7 | 6 | 102 | 93 | 15 | 108 |
| Bolivia | 132 | 61 | 43 | 78 | 158 | 180 | 55 | 150 | 84 | 60 | 100 | 236 |
| Colombia | 359 | 323 | 177 | 501 | 358 | 660 | 196 | 602 | 257 | 375 | 204 | 859 |
| Dominican Republic | 99 | 84 | 52 | 69 | 166 | 186 | 48 | 98 | 134 | 36 | 34 | 235 |
| Ecuador | 147 | 138 | 76 | 103 | 258 | 269 | 92 | 276 | 79 | 151 | 81 | 361 |
| El Salvador | 286 | 141 | 111 | 305 | 233 | 453 | 84 | 199 | 339 | 70 | 119 | 538 |
| Guatemala | 116 | 75 | 69 | 108 | 152 | 241 | 17 | 162 | 97 | 20 | 40 | 260 |
| Guyana | 57 | 28 | 16 | 37 | 64 | 70 | 31 | 44 | 57 | 84 | 16 | 101 |
| Honduras | 146 | 66 | 19 | 70 | 161 | 198 | 31 | 104 | 127 | 53 | 65 | 231 |
| Jamaica | 81 | 99 | 42 | 87 | 135 | 186 | 16 | 27 | 195 | 175 | 47 | 222 |
| Nicaragua | 124 | 130 | 42 | 96 | 200 | 254 | 41 | 182 | 114 | 21 | 77 | 296 |
| Paraguay | 107 | 95 | 70 | 80 | 192 | 242 | 30 | 158 | 107 | 125 | 60 | 272 |
| Peru | 318 | 224 | 171 | 398 | 315 | 642 | 67 | 485 | 228 | 207 | 172 | 713 |
| Suriname | 44 | 47 | 10 | 55 | 46 | 98 | 3 | 42 | 59 | 89 | 11 | 101 |
| The Bahamas | 41 | 48 | 22 | 32 | 79 | 98 | 11 | 27 | 84 | 94 | 13 | 111 |
| Trinidad & Tobago | 138 | 117 | 84 | 115 | 224 | 308 | 30 | 80 | 259 | 295 | 42 | 339 |
| Uruguay | 81 | 95 | 62 | 74 | 164 | 207 | 31 | 174 | 61 | 62 | 39 | 238 |
| Total | 2645 | 2094 | 1283 | 2773 | 3249 | 5091 | 886 | 3166 | 2822 | 2439 | 1223 | 6022 |

## 4. Empirical Analysis of Energy Efficiency

Energy consumption in LAC has steadily risen since the 1990s (Sadorsky, 2012). Accompanying this trend is a decline in productivity despite growth in factor accumulation (Crespi et al. 2014, Ruprah et al.,2014, Grazzi & Pietrobelli, 2016). The seminal work of Porter & Van der Linde (1995) theorizes that firms' attempts to become more energy efficient may induce eco-innovations, which ultimately drive productivity growth. More recent work covering multiple countries worldwide supports this theory by providing evidence of a link between energy efficiency and economic growth (Rajbhandari and Zhang, 2017).[14] Specifically for LAC countries (Brazil, Chile, Mexico, and Peru), Yepez et al., (2021) use national industrial surveys to show that high energy expenses per unit of output are associated with low productivity, suggesting a positive relationship between energy efficiency (i.e., the inverse of energy intensity) and productivity. Also, for LAC, using firm-level data from 2010, Montalbano & Nenci (2019) find some evidence linking energy efficiency to improved productivity and better access to foreign markets for some sectors.[15] Thus, energy efficiency may be a win-win: adoption of sustainable measures can drive technological change which in turn improves the productive capacity of firms (Filippini et al.,2020). This section takes a deeper look at energy consumption and energy intensity trends in LAC, as well as the association between energy intensity and both productivity and innovation. It concludes by presenting some evidence on the determinants of energy efficiency levels in firms.

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[13] All sub-categories will not add to the same total because of missing data used for classification.

[14] This assertion follows the findings of Solow (1956) that the differences in economic growth are driven by differences in productivity levels.

[15] While on average there were no statistically significant results, by dissecting the analysis by sector, they find a positive significant relationship between energy efficiency and productivity in Textiles and Apparel, Chemicals and Mining, and Basic Metal and Other Manufacturing sectors. They also find that firms in Chemicals and Mining sectors that are more energy efficient are also more likely to export once factors that can influence the relationship between firm performance and energy efficiency are considered, such as foreign ownership, size, and technological innovation. Despite these promising results, several sectors did not show positive relationships, namely Food Production, Textiles, and Wood and Paper. The authors do not elaborate on why certain sectors might be more efficient than others. Thus, this level of heterogeneity warrants further investigation using more recent data.

Overall, the analysis presented in this section is exploratory and mostly based on descriptive or correlational evidence but can serve as a starting point for future research and discussion on the characteristics of firms in the region that are most likely to adopt new energy efficiency measures and maximize the benefits of these new technologies.

### *4.1 Energy Consumption*

We start by assessing the distribution of energy consumption in the region according to sectors (measured in Purchasing Power Parity (PPP)-adjusted dollars). See Figures 1.a-d for different country groups.[16] A few sectors, namely *food* and *retail & wholesale*, account for the largest shares in energy consumption in most countries. In some cases, a sector's large share of energy consumption is easily explained by the concentration of firms in that sector: the number of firms and the share of energy consumption are closely related in the *retail & wholesale* sectors in Ecuador, Jamaica, Nicaragua, Peru, and Uruguay (Figures 1.a-d). In El Salvador *other manufacturing* accounts for 26% of firms and 28% of private sector energy consumption (Figure 1.b). In The Bahamas *hotel & restaurants* account for 19% of firms and 17% of energy consumption (Figure 1.c), and in Colombia, *food (production)* accounts for 18% of firms and 17% of energy consumption.

Interestingly, the number of firms within a sector is not always the main determinant of energy consumption. For example, in Guyana *hotels and restaurants* account for 46% of energy consumption but only 9% of firms (Figure 1c), making the sector's share of energy consumption over four times the share of firms. Similarly, for *food* in Argentina, the sector's share of energy consumption is more than twice the share of firms.[17] However, the opposite relationship is observed in some cases. In the Dominican Republic, *wholesale & retail* accounts for 45% of firms but only 11% of energy consumption; in Belize *hotels & restaurants* account for 24% of firms but only 3% of energy consumption (Figure 1.d). Comparing energy consumption to the sector distribution of firms provides a first snapshot of potential differences in energy efficiency across sectors and countries, but it does not capture the entire picture. For instance, firms in different sectors may vary not only regarding their level of energy efficiency but also in terms of the output they produce, and their energy needs to produce it.

It is useful to compare shares of energy consumption with output shares per firm. To do this we compute the energy expenditure of the sector as a percentage of all private sector energy expenditure. We repeat the procedure for the value of the sales generated by each sector (both adjusted for PPP based on conversion rate at the time of data collection). While in some cases the number of firms, output, and energy consumption in a sector are very closely related (e.g., *wholesale & retail* in most countries), large differences still exist that cannot be explained by production levels alone. In Guyana, *hotels & restaurants* account for 46% of energy consumption but only 3% of output; in Guatemala *metal & minerals* account for 48% of energy consumption but 19% of output; in Argentina *food* accounts for half of energy consumption but 22% of output; in El Salvador the *textiles & garments* sector consumes approximately one quarter of the energy consumed by the entire private sector but accounts for only 8% of output. While these figures suggest that energy inefficiencies may exist, they are not an indictment. What is presented is indicative of relative energy efficiency. Given that energy requirements can vary according to the

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[16] For country groupings we use the same classifications as the IDB: Southern Cone, Andean, Central America, and the Caribbean.

[17] In Argentina *food* accounts for over 50% of energy consumption but only 23% of firms; in Nicaragua *wholesale & retail* accounts for 48% of energy consumption but only 17% of firms.

specific production process, further work is required to determine if absolute energy inefficiencies do exist utilizing methods that can take this type of variation into account. Some measures for capturing energy inefficiency have been proposed which consider technological gaps as well as undesirable outputs such as pollution (Hang et al., 2015; Christopoulos &Tsionas, 2002). Most importantly, measures of energy efficiency can vary both by country and sector, as will be explored in a later section.

Figure 2 shows the share of energy consumption, firms, and output for each country, but this time disaggregated by firm size (rather than sub-sector). Unsurprisingly, large firms are responsible for the lion's share of energy consumption (77% on average) across the region as they account for more than double the value of output as compared to SMEs. This is true even though SMEs make up the majority of firms across all countries. However, this is not the case for some smaller countries, namely Suriname and The Bahamas, where SMEs consume most of the energy.[18] While in these countries SMEs have higher than average shares of outputs (39% and 43% respectively), other countries, like Honduras and Belize, have SMEs with comparable shares of output but also have much lower energy consumption, relatively speaking.

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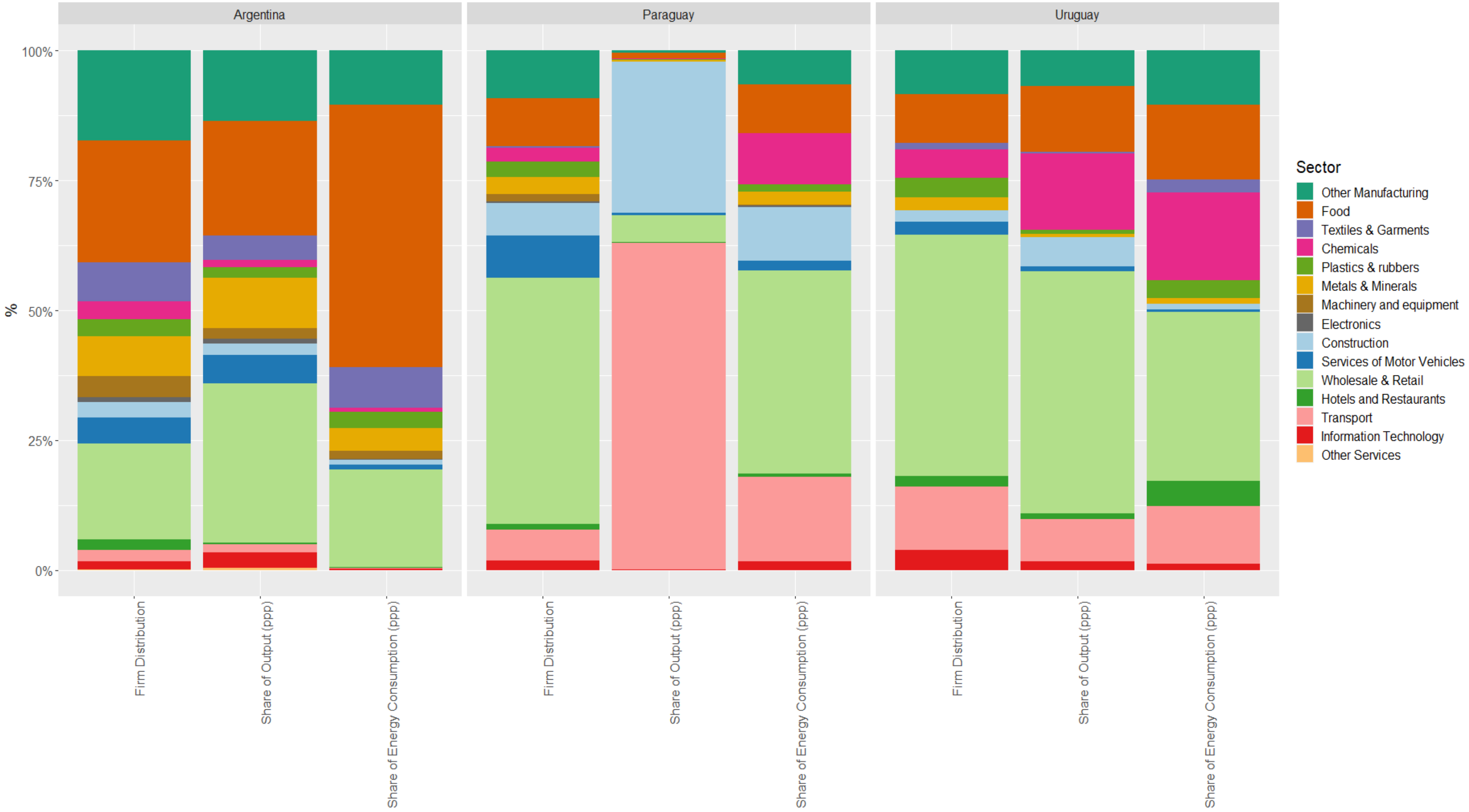
[18] For firm size we adopt the definition used by the World Bank Enterprise Surveys: Small <20 employees, Medium >= 20 employees & <=99 employees, Large>= 100 employees.

Figure 1.a Share of Firms, Output, and Energy Consumption by Sector (Southern Cone Countries)



Source: Inter-American Development Bank/ Compete Caribbean Firm-level survey (PROTEqIN) & World Bank Enterprise Survey (WBES). Note: ppp – adjusted for purchasing power parity.

**Figure 1.b Share of Firms, Output, and Energy Consumption by Sector (Andean Countries)**

Source: Inter-American Development Bank/ Compete Caribbean Firm-level survey (PROTEqIN) & World Bank Enterprise Survey (WBES). Note: ppp – adjusted for purchasing power parity.

## Figure 1.c Share of Firms, Output, and Energy Consumption by Sector (Caribbean Countries)

Source: Inter-American Development Bank/ Compete Caribbean Firm-level survey (PROTEqIN) & World Bank Enterprise Survey (WBES). Note: ppp – adjusted for purchasing power parity.

**Figure 1.d Share of Firms, Output, and Energy Consumption by Sector (Central American Countries + Dominican Republic)**

Source: Inter-American Development Bank/ Compete Caribbean Firm-level survey (PROTEqIN) & World Bank Enterprise Survey (WBES). Note: ppp – adjusted for purchasing power parity.

**Figure 2. Share of Energy Consumption and Output by Firm Size**

Source: Inter-American Development Bank/ Compete Caribbean Firm-level survey (PROTEqIN) & World Bank Enterprise Survey (WBES). Note: ppp – adjusted for purchasing power parity

### *4.2 Energy Intensity*

To determine where interventions targeting energy efficiency may have the most impact, we explore variations in the energy intensity of firms.[19] Energy intensity captures the amount of energy consumed to produce an economic unit of output. We compute it as the ratio of energy expenditure to sales for each firm (Ruprah & Sierra, 2016; Montalbano & Nenci, 2019). Relative to other measures, this is the most commonly used approach in the development community and is very intuitive in its interpretation (Ravillard et al. 2019). As shown in Figure 3.a, at the country level we see that Ecuador, Uruguay, and Paraguay require the least amount of energy to produce a unit of output. In the Caribbean, the most efficient countries are Trinidad & Tobago and Suriname. Countries like Bolivia, Guyana, Paraguay, and Peru are characterized by wide variability in intensity across firms.

Wide variability in energy intensity is not only observed across countries, but also within sectors, namely construction, transport, and basic metals. As shown in Figure 3.b, at the sector level, most energy efficient firms in the region are found in *services*, except for *electronics* (manufacturing) that has low energy intensity and *tourism* (services) that has high intensity. The sectors that require the least amount of energy to produce a unit of output are *construction, electronics,* and *information technology*. This is potentially because a substantial portion of the value-added in these sectors comes from manual labor and completed intermediate goods. Instead, sectors that could be potential areas of focus given their higher levels of energy intensity include *textiles & garments*, *plastics & rubbers,* and *hotels & restaurants (tourism).* Strategic intervention in these sectors could help the region meet its goals related to reducing energy intensity.

Figure 4 provides a breakdown of the energy intensity both by firm size and sector. Manufacturing shows a trend that is reminiscent of economies of scale: larger firms appear to require less energy to generate output than medium-sized firms, which in turn require less energy than small firms. Montalbano & Nenci (2019) find similar results when considering several measures of energy efficiency to account for any endogeneity concerns. In the services sectors, economies of scale are also observed, but they appear to kick-in only after firms reach a certain size threshold. Firms face competing priorities as they attempt to grow, and energy efficiency may become more important or more feasible only in a more advanced grow phase. The lower energy intensity for SMEs (particularly in the manufacturing sector), suggests that SMEs may be experiencing an energy efficiency gap. More rigorous regression analysis (in the following section) confirms that the difference in energy intensity by firm size is statistically significant, suggesting that interventions could be implemented to support SMEs in adopting more sustainable practices.

We also compare the energy efficiency of young versus mature firms (defined as those that have been in operation for 10 or more years). Mature firms may have made their initial investment decisions at a time when a more efficient technology did not exist. For these firms, it may be too costly to replace capital for more energy efficient technology prematurely, even when factoring in long-term cost savings. Hence, inertia can result in the retention of energy inefficient technologies and processes, a situation known as “carbon lock-in”. However, Figure 5 shows that the difference in energy intensity between mature and young firms is not statistically significant in our sample.

One way that the private sector can combat inertia is through innovation. We define an innovative firm as one that has introduced a new or significantly improved product or process, organizational

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[19] In the paper, we consider energy intensity to be the inverse of energy efficiency, however this is only by proxy. In technical terms there may be differences between these two concepts.

method, or marketing strategy within the last three years of operation.[20] As shown in Figure 5, we see that innovative firms are significantly more energy efficient than their non-innovative counterparts and that this result is statistically significant. This finding is consistent with prior evidence that more innovative firms are better equipped to overcome barriers related to improving energy efficiency (Trianni et al., 2013). A caveat to this analysis in the literature is that firms require an innovation ecosystem if they are to improve their innovative capabilities (Crespi et al., 2016; Mazzucato, 2016). These ecosystems include, but are not limited to, institutions dedicated to research and development and the dissemination of knowledge. The presence of these can vary widely by country and can require large coordination efforts between the public and private sectors. This variation could be in part responsible for the differences in energy efficiency between innovative and non-innovative firms.

Finally, when analyzing energy intensity differences across firms and designing interventions to improve energy efficiency, it is important to apply a gender lens to identify if women-owned firms are also significantly impacted by energy inefficiencies. We define a woman-owned firm as any enterprise in which a female has either more than half of the controlling interest OR more than 20% of controlling interest with a woman as the top manager.[21] Figure 5 shows that differences in energy intensity between women-owned firms and other firms are not statistically significant.

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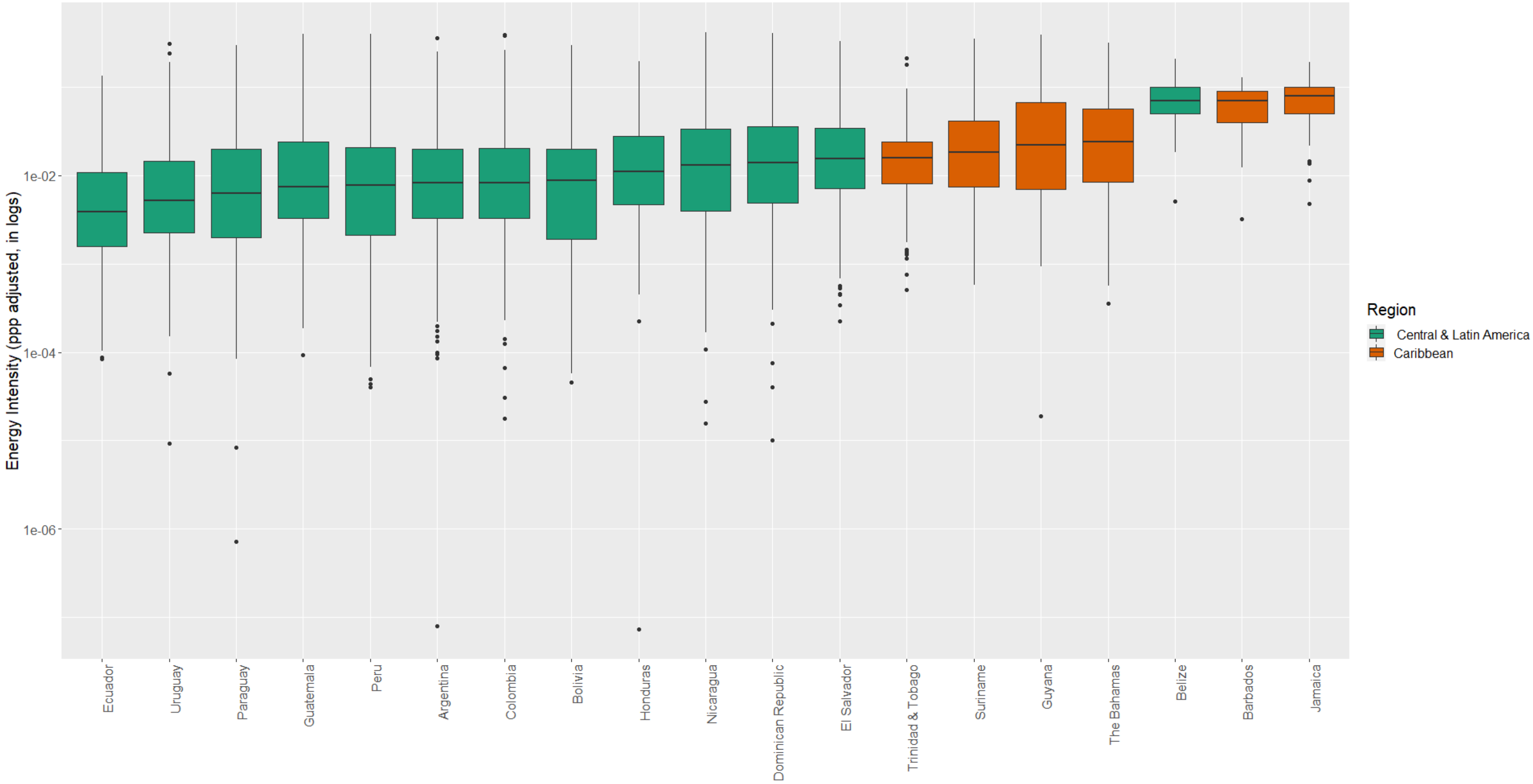
[20] This definition is in line with the OECD Oslo Manual on Innovation (2018).

[21] This definition is in line with Women Entrepreneurs Finance Initiative (We-Fi). We-Fi is a collaborative partnership among 14 governments, eight multilateral development banks, and other public and private sector stakeholders, hosted by the World Bank Group that seek to address financial and non-financial constraints faced by women-owned/led SMEs in developing countries.

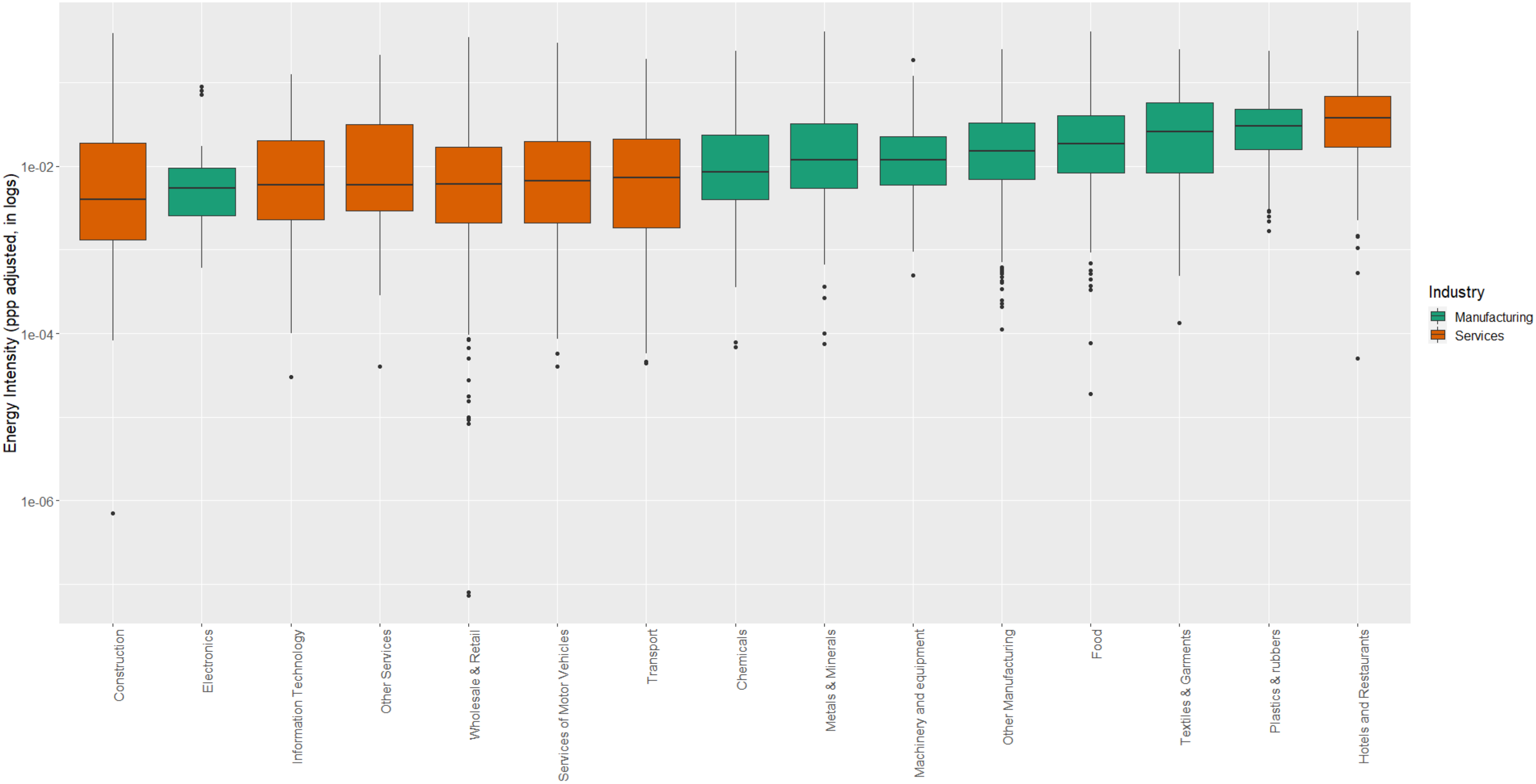
## Figure 3.a Energy Intensity by Country in Latin America and the Caribbean



Note: Energy Intensity is calculated as $\frac{\text{Value of Energy Consumption (adjusted to Purchasing Power Parity)}}{\text{Value of Sales (adjusted to Purchasing Power Parity)}}$

Source: Authors' elaborations from Inter-American Development Bank/ Compete Caribbean Firm-level survey (PROTEqIN) & World Bank Enterprise Survey (WBES)

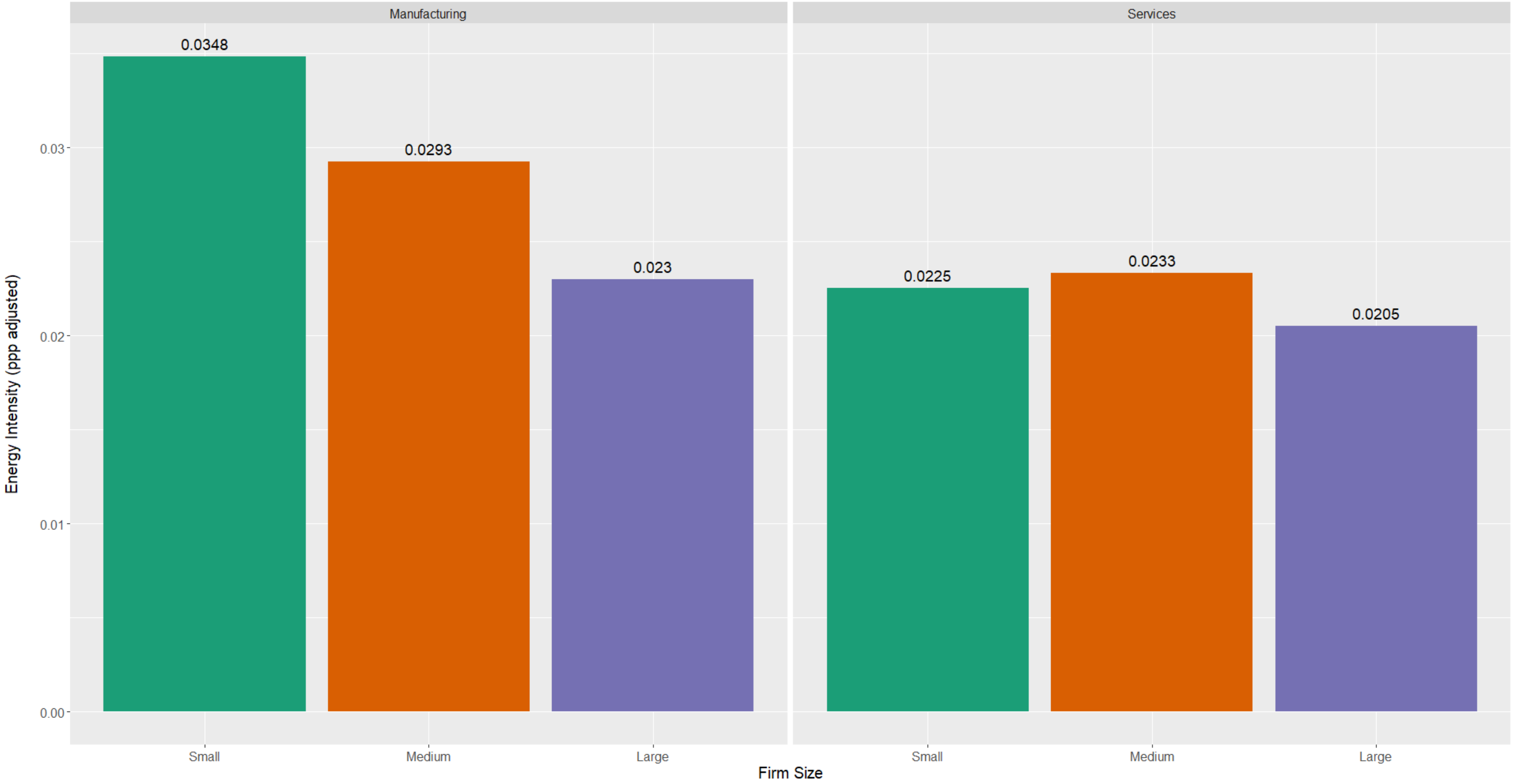
## Figure 3.b Energy Intensity by Sector in Latin America and Caribbean



Note: Energy Intensity is calculated as $\frac{\text{Value of Energy Consumption (adjusted to Purchasing Power Parity)}}{\text{Value of Sales (adjusted to Purchasing Power Parity)}}$

Source: Authors 'elaboration from Inter-American Development Bank/ Compete Caribbean Firm-level survey (PROTEqIN) & World Bank Enterprise Survey (WBES).

## Figure 4. Energy Intensity by Firm Size

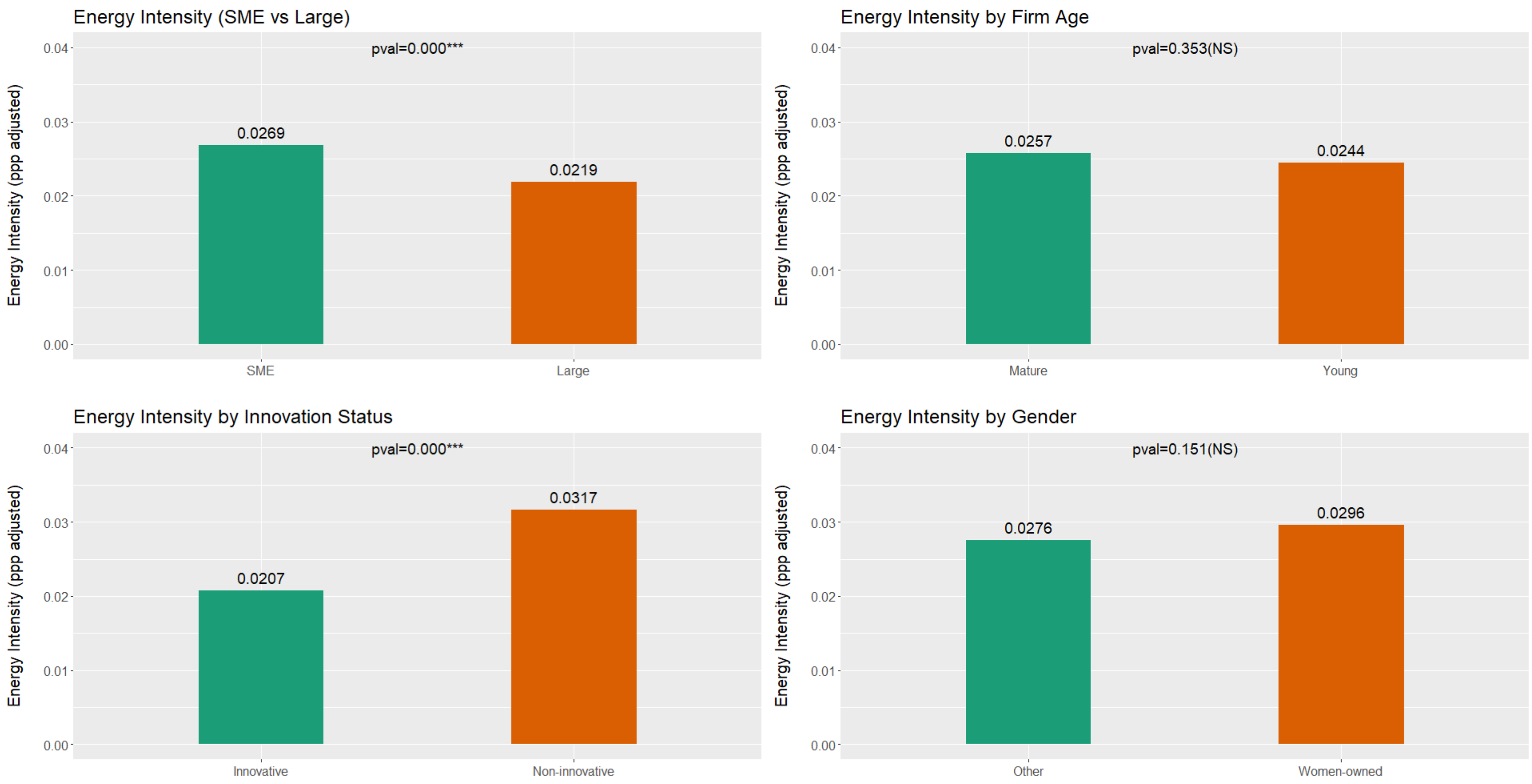


Note: Energy Intensity is calculated as $\frac{\text{Value of Energy Consumption (adjusted to Purchasing Power Parity)}}{\text{Value of Sales (adjusted to Purchasing Power Parity)}}$

Note: Sample sizes (n): Small = 2645; Medium=2094; Large=1283.

Source: Authors' elaborations from Inter-American Development Bank/ Compete Caribbean Firm-level survey (PROTEqIN) & World Bank Enterprise Survey (WBES).

## Figure 5. Energy Intensity by Firm Characteristics



Note: * Statistically significant at the 10% level; ** at the 5% level; *** at the 1% level; NS not significant.

Note: Energy Intensity is calculated as $\frac{\text{Value of Energy Consumption (adjusted to Purchasing Power Parity)}}{\text{Value of Sales (adjusted to Purchasing Power Parity)}}$

Note: Sample sizes (n): SME=4739; Large=1283; Mature=5091, Young=886; Innovative=3166, Non-innovative=2822; Other=2026, Women-owned=1639.

Source: Authors' elaborations from Inter-American Development Bank/ Compete Caribbean Firm-level survey (PROTEqIN) & World Bank Enterprise Survey (WBES).

### *4.3 Energy Efficiency and Productivity*

Empiricists have long sought to understand the link between firm productivity and energy efficiency. This research stems from the so-called "Porter's hypothesis" (Porter and Van der Linde, 1995) which posits that firms' pursuit of energy efficiency spurs innovation and eventually leads to productivity gains.

We test whether Porter's hypothesis holds in the region by estimating two variables: energy efficiency and total factor productivity (TFP). We construct a proxy for energy efficiency using the reciprocal of energy intensity, following the methodology in Montalbano & Nenci (2019). As explained before, energy intensity is measured as the ratio of energy expenditure to sales for each firm. We compute firm TFP in our dataset using capital, labor, and raw materials as inputs in a log-transformed Cobb-Douglas production function, as follows:

$$Y_i = A_i + \beta_1 K_i + \beta_2 M_i + \beta_3 L_i \tag{1}$$

Where $Y_i$ is the log of the value of output of firm $i$, $A_i$ is their TFP (i.e., the variability in output that cannot be explained by variability in factor inputs)[22], $K_i$ is the log of the value of capital, $M_i$ is the log of the value of intermediate inputs/raw materials, and $L_i$ is the log of the value of labor. All monetary values are adjusted for PPP.

Figure 6.a shows the relationship between energy efficiency (X-axis) and productivity (Y-axis). This association is positive and steep for low efficiency firms (although with wider levels of confidence intervals), suggesting that the first steps of adoption of energy efficiency measures are associated with higher levels of productivity. The relationship then begins to taper (becoming almost flat) until firms cross a threshold of efficiency. Then, as firms begin to move towards even more efficiency, the slope of the line becomes steeper (i.e., the relationship between energy efficiency and productivity is more elastic for the most energy efficient firms). These results indicate that the higher productivity gains from energy efficiency adoption come from first adopters (i.e., those in the lower part of the curve) and from more advanced or sophisticated adopters (i.e., those in the upper part of the curve). This provides an argument for offering targeted financial and technical assistance support to these two groups and devising strategies to help firms adopt efficiency measures that can help them cross the level of stagnation. This result is consistent with recent evidence that suggests a positive causal effect of energy efficiency on productivity, even after accounting for reverse causality (i.e., more productive firms self-selecting to adopting more energy efficient technologies) (Kalantzis & Niczyporuk, 2022). This highlights that there are potential non-energy benefits of energy efficiency. These findings also align with previous micro-level evidence exploring the link between productivity and energy efficiency in specific industries, including glass (Boyd & Pang, 2000) and manufacturing (Worrell et al., 2003; Yepez et al., 2021).

### *4.4 Energy Efficiency and Technology Development*

It is possible that the observed differences in energy efficiency across countries could be driven by variations in the level of information and communications technology penetration (ICT) within each country. To test this hypothesis, we compare our computed average energy efficiency levels in each country with data from the World Economic Forum on technological readiness. We contrast energy efficiency with a measure of country-level ICT penetration. We see that ICT use

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[22] The productivity term $A_i$ includes a constant $\alpha$, and an error term $\epsilon_i$.

is positively correlated with energy efficiency (see Figure 7). This means that firms operating in countries with higher levels of ICT penetration are also more prone to be more energy efficient, which potentially signals that high technology adoption is coupled with high energy efficiency. Another additionality to consider is the positive impact that ICTs may have on diffusing knowledge about energy efficient technologies. Firms that are better informed may be more likely to invest in these technologies. Types of knowledge fostered can include, but are not limited to, information about the environmental impact of energy consumption or the profitability benefits of being more energy efficient. We return to the topic of information and its role in promoting energy efficiency in the next section.

### *4.5 Understanding the Determinants of Energy Efficiency*

A traditional rule of thumb on investment posits that the rate of return from the uptake of a project to improve energy efficiency should be at least higher than the discount rate of possible projects with a similar risk profile. However, as alluded to earlier, potential investments with a positive net present value are not always undertaken. DeCanio and Watkins (1998) find evidence that firm characteristics such as size and performance (both current and expectations of future performance) have a positive (yet marginal) impact on investment decisions in energy efficiency. Similarly, the authors also found that the degree of insider control (the percentage of shares owned by officers or directors of the company) has a negative impact on the likelihood a firm will invest in energy efficient technologies.

To provide evidence on the determinants of energy efficiency at the SME level for the region, we estimate the following equation:

$$Y_{it} = \alpha + \beta_1 SME_{it} + \beta_2 credit_{it} + \beta_3 SME_{it} * credit_{it} + \beta_4 \widehat{A_{it}} + \beta_5 inno + \beta_6 female_{it} + \beta_7 age_{it} + \beta_8 exports_{it} + \beta_9 sole_{it} + \beta_{10} obstacle_{it} + \theta_i + \delta_t + u_{it} \quad (2)$$

Where $Y_{it}$ is the reciprocal of a firm's energy intensity in logs (a proxy for energy efficiency), operating in sector $i$ in country $t$. $SME_{it}$ is a binary variable that takes the value of 1 if the firm is small or medium-sized. $credit_{it}$ is an indicator variable for whether the firm had credit constraints.[23] $\widehat{A_{it}}$ is an estimation of firm's TFP computed in Equation 1. We also control for if a firm innovated within the last three years ($inno_{it}$); if a firm is woman-owned ($female_{it}$); the age of the firm, in logs ($age_{it}$); if the firm exports ($exports_{it}$); if the firm is a sole proprietorship ($sole_{it}$); and if the firm reports electricity access as an obstacle to business ($obstacle_{it}$). $\theta_i$ and $\delta_t$ are country and sector-specific fixed effects respectively. Standard errors ($u_{it}$) are robust to heteroskedasticity.

Column (1) reports a standard fixed effect estimation using only firm characteristics (i.e., SME status, productivity, innovation status, gender of owner, age, exporting status, and if the firm is a sole proprietorship), while Column (2) introduces both firm and market characteristics (credit constraints and electricity as a business obstacle). Column (3) repeats Column (2) but introduces

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[23] For our credit constraint variable, we had to harmonize an indicator across our two datasets due to some limitations in variable dictionaries. For the Enterprise Surveys, we follow the classification strategy of De Haas et al. (2021): we considered firms as credit constrained if they applied and were rejected for a loan within the last fiscal year or were discouraged from applying for credit for one of the following reasons: "Interest rates not favorable", "Collateral requirements are too high", "Size of loan and maturity are insufficient" or "Did not think it would be approved". For PROTEqIN, we consider a firm credit constrained if it was discouraged from applying for credit for the same reasons listed above or if at least half of the loans the firm applied for in the last fiscal year were rejected.

an interaction term between $SME_{it}$ and $credit_{it}$ to understand whether access to credit has differential effects for firms of different sizes.

Table 3 reports the results of the estimated models. Once country and sector-specific heterogeneities are accounted for, we see that being an SME is associated with a 19%[24] decrease in energy efficiency, all other things being equal. Similarly, we observe that having a track record in innovation is associated with a 20% increase in energy efficiency. Concurrently, a 1% increase in productivity is associated with a 0.4% increase in energy efficiency. Lastly, being credit constrained is associated with a 28% decrease in energy efficiency, which is consistent with results from Europe and Central Asia in recent literature (De Haas et al., 2021). Interestingly, the interaction between credit constraints and SMEs produces a positive coefficient. This is probably due to the larger energy efficiency gap between credit constrained and non-credit constrained large firms in comparison to the energy efficiency gap between credit constrained and non-credit constrained SMEs. Hence, solving the issue of credit access may be more important among large firms as opposed to SMEs.

As a robustness check, we include an alternative specification for energy efficiency proposed by Montalbano & Nenci (2019). We recompute energy intensity as the ratio of the total annual energy costs to total annual value added. Total annual value added is computed for each firm by subtracting the total annual costs of inputs (raw materials, intermediate goods, and energy costs) from the total annual sales. Columns (4) – (6) report the results using this alternative measure of energy efficiency. All monetary values are adjusted for PPP. Our results remain robust to this alternative specification in addition to electricity as an obstacle for doing business being marginally significant and with a negative contribution to energy efficiency in this new model.

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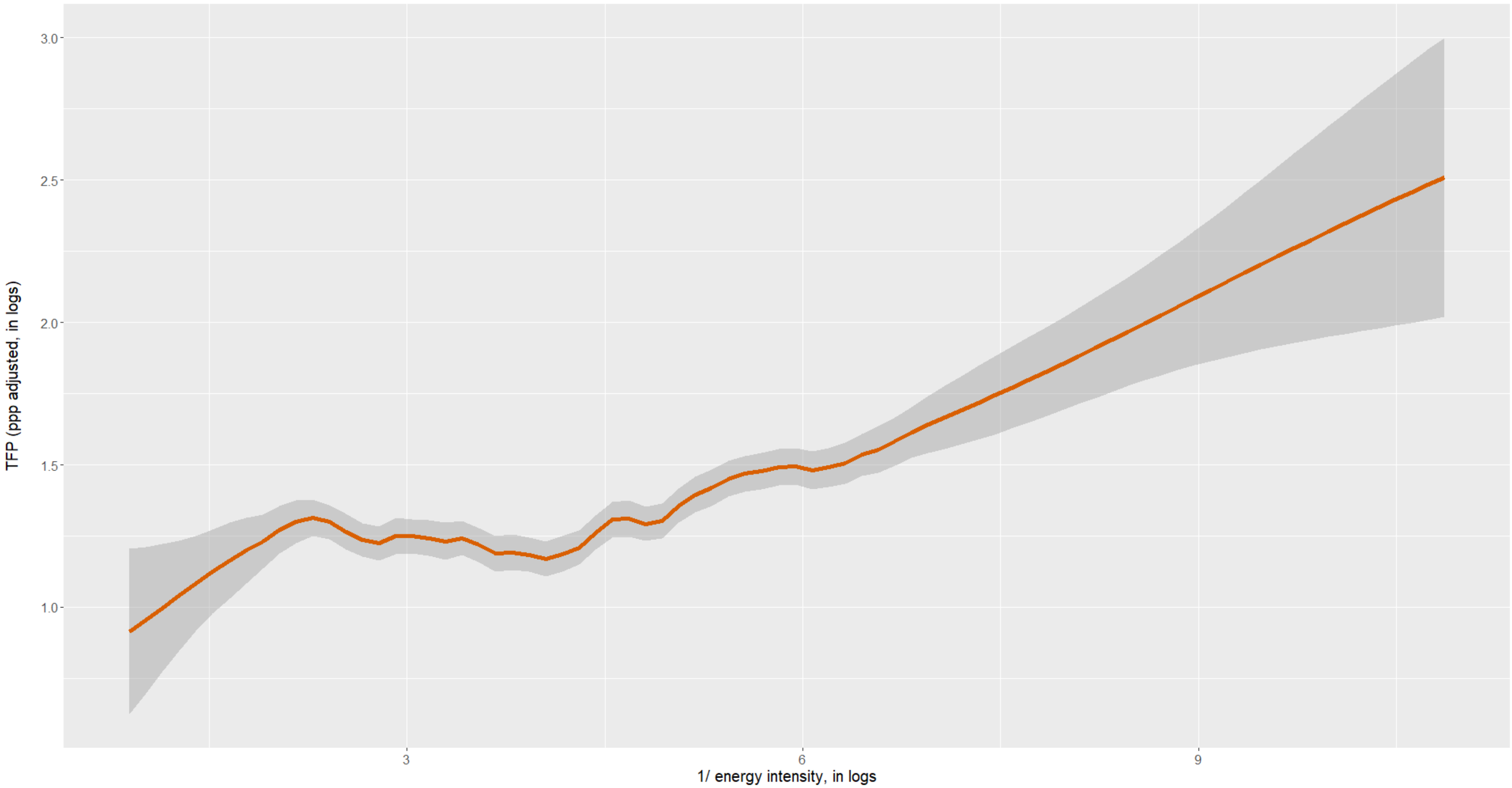
[24] This is approximated by the following formula and based on the estimated coefficient: $1 - \exp(-0.214)$

## Figure 6.a Energy Efficiency and Productivity within Firms



Source: Authors' elaborations using Inter-American Development Bank/ Compete Caribbean Firm-level survey (PROTEqIN) & World Bank Enterprise Survey (WBES).
Note: Grey areas represent 95% confidence intervals.

**Figure 7. Energy Efficiency and Technological Readiness Measures**

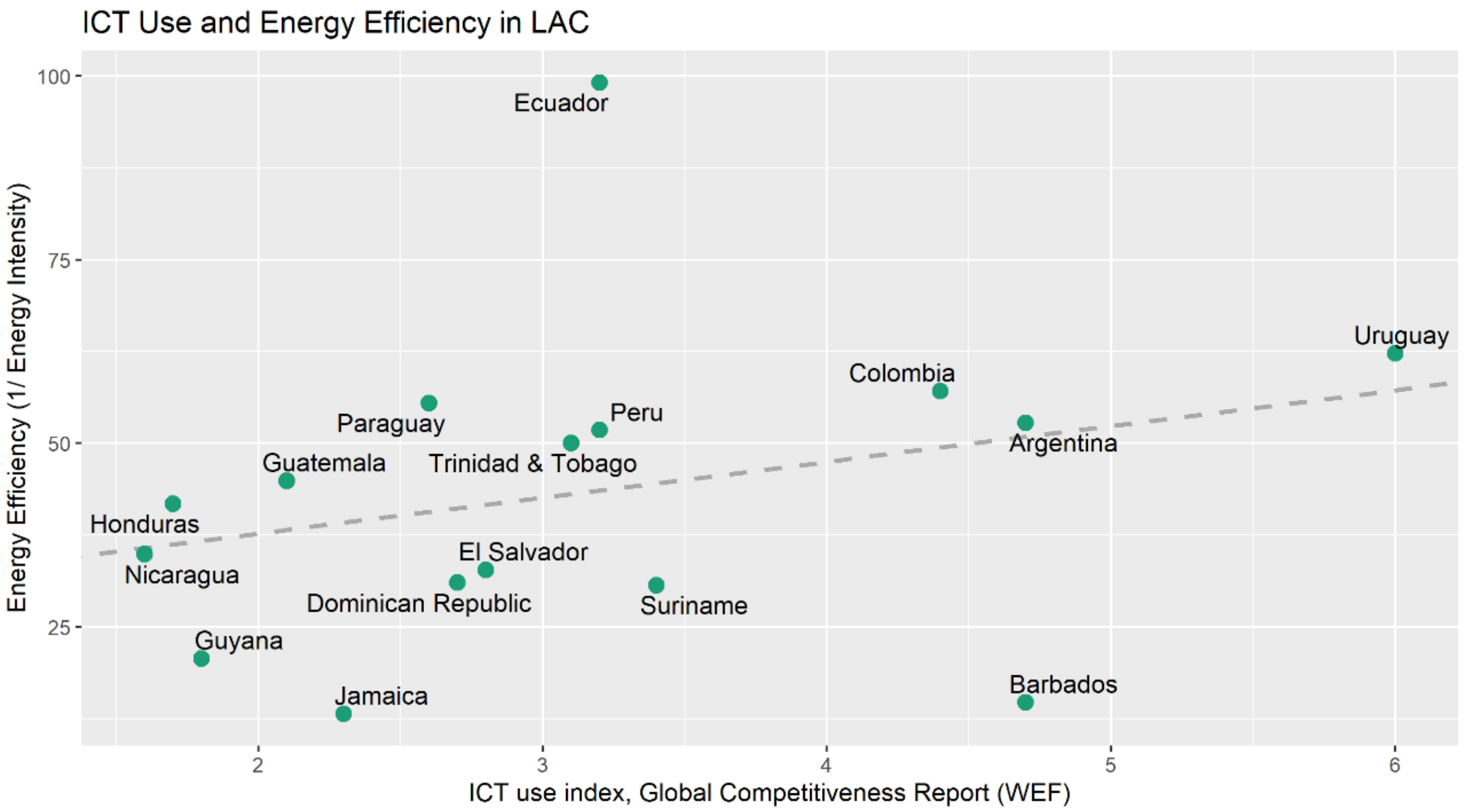


**Table 3. Regression Analysis Results**

| Dependent Variable: | Log(1/[annual energy expenditure/total annual sales]) | | | Log(1/[annual energy expenditure/total annual value added]) | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| VARIABLES | Firm Char | Firm Char+ Market Cond. | Firm Char+ Market Cond. | Firm Char | Firm Char+ Market Cond. | Firm Char+ Market Cond. |
| SME | -0.124* | -0.120* | -0.214** | -0.107 | -0.104 | -0.195** |
| | (0.0704) | (0.0701) | (0.0915) | (0.0713) | (0.0711) | (0.0912) |
| Credit Constraint (0/1) | | -0.0986* | -0.329*** | | -0.0626 | -0.285** |
| | | (0.0599) | (0.126) | | (0.0617) | (0.131) |
| SME* Credit Constraint | | | 0.275** | | | 0.266** |
| | | | (0.131) | | | (0.135) |
| Log (TFP) | 0.434*** | 0.430*** | 0.433*** | 0.720*** | 0.718*** | 0.721*** |
| | (0.0650) | (0.0650) | (0.0651) | (0.0681) | (0.0681) | (0.0682) |
| Innovation (0/1) | 0.193*** | 0.187*** | 0.182*** | 0.186*** | 0.182*** | 0.176** |
| | (0.0691) | (0.0690) | (0.0690) | (0.0699) | (0.0698) | (0.0698) |
| Female (0/1) | 0.0127 | 0.00695 | 0.0144 | 0.0469 | 0.0429 | 0.0501 |
| | (0.0607) | (0.0608) | (0.0607) | (0.0612) | (0.0613) | (0.0612) |
| Log (Age) | 0.0224 | 0.0215 | 0.0186 | 0.0290 | 0.0280 | 0.0251 |
| | (0.0372) | (0.0371) | (0.0372) | (0.0384) | (0.0383) | (0.0383) |
| Exporting Status (0/1) | -0.0490 | -0.0445 | -0.0369 | -0.0591 | -0.0542 | -0.0469 |
| | (0.0865) | (0.0861) | (0.0864) | (0.0889) | (0.0884) | (0.0887) |
| Sole Proprietor (0/1) | -0.0135 | -0.0164 | -0.0289 | 0.00927 | 0.00695 | -0.00516 |
| | (0.0607) | (0.0607) | (0.0607) | (0.0626) | (0.0626) | (0.0626) |
| Electricity as Obstacle (0/1) | | -0.157 | -0.159 | | -0.178* | -0.181* |
| | | (0.101) | (0.101) | | (0.106) | (0.106) |
| Constant | 4.336*** | 4.371*** | 4.436*** | 3.304*** | 3.330*** | 3.394*** |
| | (0.233) | (0.234) | (0.237) | (0.260) | (0.261) | (0.263) |
| Observations | 1,614 | 1,614 | 1,614 | 1,614 | 1,614 | 1,614 |
| R-squared | 0.386 | 0.388 | 0.390 | 0.409 | 0.410 | 0.411 |
| Country FE | YES | YES | YES | YES | YES | YES |
| Sector FE | YES | YES | YES | YES | YES | YES |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

## 5. How Can We Promote Energy Efficiency in Firms?

Which interventions can induce firms to change their energy consumption patterns and adopt energy efficiency measures? To promote evidence-based interventions, this section summarizes the available empirical evidence on the topic. We put emphasis on the more recent studies that seek to establish a causal relationship by using valid counterfactual scenarios or more sophisticated scientific methods. In contrast, early studies should be interpreted with caution as they have been subject to several methodological criticisms. For example, Allcott and Greenstone (2012) argued that most early studies were conducted using estimations of expected benefits rather than observed benefits, and that the comparability of results was limited due to large variations in approaches, parameter choices, and definitions of variables under consideration. Moreover, since some studies were simple before-after comparisons, engineering studies, or observational studies (which lacked a comparison group), results were prone to bias. Although we pay particular attention to studies in the context of firms, given the paucity of firm-level research on this topic, we also discuss household-level evidence when it can likely be extrapolated to firm decision-making.

Historically, the empirical literature on promoting energy efficiency has focused on interventions that are more easily promoted by the public sector, especially through price interventions. Price interventions affect energy prices to stimulate the adoption of energy efficient technologies. For instance, a tax on every unit of energy consumed beyond a certain threshold could stimulate increased demand for efficiency. Another common example includes “time-of-use pricing”, also known as non-linear or dynamic pricing, which involves raising the price of energy during periods of high demand (“peak”). Another example is “feed-in tariffs”, which are long-term purchase agreements for firms providing energy to electrical grids to incentivize the use of renewable energy technologies.[25] Under these agreements, firms make revenues based on their net energy consumption (i.e., when they provide more energy to the grid than they consume). This incentivizes them to be more energy efficient.

Recently, non-price interventions, which draw on the behavioral science concepts discussed earlier, have been gaining ground. These types of interventions have proved successful in other areas such as pension planning, which like energy efficiency, has both financial and social implications.[26] Importantly, non-price interventions do not rely heavily (if at all) on the actions of utility companies or public agencies responsible for administering energy policy. Hence, these interventions could be directly supported by the private sector. For instance, quick wins in improving energy efficiency may exist by reducing information asymmetry. For example, financial institutions could improve messaging about the firm benefits of energy efficiency to nudge potential borrowers to get “green” credit and adopt these technologies. However, as pointed out by Bunse et al. (2011), energy efficiency interventions (like other potential investments) must respond to firm-specific complexities, such as their level of performance, access to training, and organizational structure. Failure to adequately account for these heterogeneities could result in low uptake by firms. In this section, we focus on areas where the scientific evidence is strong,

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[25] Most studies looking at this type of intervention focus on household-level effects and are mostly concentrated in developed countries. For a more in-depth review of these, see Faruqui & George (2005), Faruqui & Sergici (2010), Newsham & Bowker (2010), and Allcott (2011b).

[26] For a more in-depth review of non-price interventions, see Kahneman et al. (1991) and Thaler & Sunstein (2009).

looking at various types of interventions: (i) information campaigns, (ii) energy audits, and (iii) other combined interventions.

### *5.1 Information Campaigns*

Some authors consider lack of information as a plausible explanation for the energy efficiency gap (Jaffe & Stavins, 1994; Anderson & Newell, 2004). At the same time, information provision has proven to be a successful mechanism for improving outcomes in a number of fields[27] and providing information is likely more cost-effective to implement than other types of interventions (Allcott & Mullainathan, 2010). Nevertheless, the effectiveness of an information campaign depends on various factors, including: the content of the message itself and whether it is relevant for making decisions, as well as how information is presented and framed.

**Messages about energy savings.** Available studies suggest that supplying consumers with information about potential savings from lower energy usage can successfully reduce their energy consumption. Morgenstern and Al-Jurf (1999) find that providing information to firms about the potential cost savings from adopting energy efficient lighting significantly contributes to the diffusion of this technology among commercial entities. In a field experiment with firm employees, Carrico and Riemer (2011) find that a treatment group receiving group-level feedback on energy use, and a second treatment group receiving information from peer-educators promoting energy savings, reduced energy use by 7% and 4%, respectively relative to a control group that had only received a monthly e-mail with educational information on energy savings. Moreover, many experiments at the household level suggest that providing information on energy consumption can lead to more energy efficiency; this occurs because by default, consumers receive very little information (Jessoe and Rapson 2014; Ito 2014; Asensio and Delmas 2016). For example, interventions requiring some products to include labels with their energy requirements, led to greater household uptake of more energy efficient products (Newell & Siikamaki, 2013; Davis & Metcalf, 2016). In the context of firms, decision-makers may also have deficient information, and thus could benefit from information campaigns.

***Peer effects.*** Additional insights are emerging regarding improving information efficacy by considering a psychological perspective: how peer energy usage may appeal to an individual’s instinct to adhere to social norms.[28] In a non-experimental study by Murtagh et al. (2013), with a small sample of 83 employees, the authors provide employees with individual feedback on their own energy use per hour at the work-desk, and how it compared with the overall firm average for 18 weeks. Although this information reduced energy consumption in months three and four of the trial, results should be interpreted with caution as the study did not include a control group. Evidence in the energy area shows that displaying peer information may be effective only for high energy users, and that it may be ineffective or even backfire for low energy users. Allcott (2011a) conducted a field experiment with a sample of 600,000 households across the U.S. The program sent letters to residential customers comparing their electricity use to that of their neighbors. While the average participant reduced energy consumption by 2%, smaller effects were observed for the lowest deciles (in terms of energy usage). The authors estimated that the magnitude of the effect was equivalent to that of a short-run electricity price increase of 11% to 20%. Similarly, in a field experiment that sent a normative message providing information on average neighborhood electricity usage in the U.S., Schultz et al. (2007) also found heterogenous effects. While the message resulted in energy savings for those with high electricity usage, it led to an undesirable rebound effect for those with low usage. This finding is also consistent with other similar experiments at the household level (Antonio et al., 2020).

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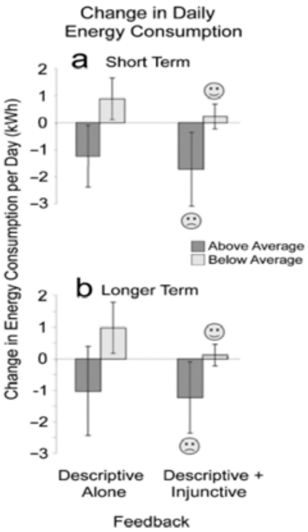
[27] For more information see Banerjee & Duflo (2007); Duflo, Kremer & Robinson (2008) & Abrahamse, *et al (*2005).

[28] A notable success case was in the use of peer comparison messaging to curb water wastage in Costa Rica (Cavallo et al., 2020).

**Framing.** Framing has long been explored in areas of psychology and behavioral economics[29] whereby decision-makers respond differently to alternative representations of the same choices (e.g., when a choice is framed in the domain of losses instead of gains). The study by Schultz et al. (2007), discussed earlier, shows the impacts of utilizing injunctive messages that convey social approval or disapproval. Injunctive messages may appeal to social norms, while also mitigating rebound effects by low energy users. For example, as shown in Figure 8, a normative message to users who consumed more energy compared to their own baseline is illustrated by a downward bar plot showing how much (in kWh) they overconsumed relative to the previous period. In contrast, the normative plus injunctive messaging for the same type of user is illustrated as a downward bar plot with a disapproving emoticon face if they consumed more than the neighborhood average. The converse is true for users who consumed less compared to the previous period or the neighborhood average: an upward bar plot showing how much they saved relative to the group with an approving emoticon face. While the normative messages produced the expected effects (i.e., energy consumers operating below the neighborhood average increased their energy consumption and consumers operating above the neighborhood average reduced their consumption), the authors found that the introduction of injunctive messaging reduced the likelihood that a consumer operating below the average would rebound into higher consumption after receiving information relative to peers.

**Figure 8. Example of Normative and Injunctive Information Messaging**



Source: Schultz et al. (2007)

Asensio & Delmas (2015 & 2016) find that messaging about environmental and health improvements that can result from lower energy consumption, led to users reducing their consumption by 8% to 10% relative to a control group. Additionally, the authors found that health and environmental messaging was more effective than receiving cost savings information, particularly among households with children. Moreover, the authors found that while in the short-run real-time information about potential cost savings can reduce energy demand, these effects attenuate over time before diminishing completely, approximately two months after receiving the first message. This raises the issue of novelty effects where repeat treatments are not very effective at enforcing durable behavioral changes. However, on the flipside, the effects induced by the previously mentioned health messaging are persistent over time in developing durable

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[29] See Kahneman & Tversky (1981); Levin et al. (1998); Levin & List (2009) among other peer-reviewed work on framing effects.

behavioral changes and could very well be relevant in fostering a culture of commitment with respect to energy efficiency. As hypothesized by Asensio & Delmas (2019), the importance of how a message is framed could explain why messages on the social losses from energy consumption are more effective either alone or in conjunction with cost saving messages. While there is still no evidence on this front at the firm-level, these results point to the importance of understanding the drivers of energy efficiency adoption for firms in each context to inform the design of effective communication campaigns.

***Price saliency.*** In consumer theory, the impact of information salience has been studied extensively to determine its impact on consumption (Bordalo et al., 2013). Theory suggests that users place higher relevance on observable characteristics when choosing goods or services. Although the same logic could be applied to the price saliency of energy efficiency measures, empirical evidence is mixed and limited. Based on household evidence, Sexton (2015) studied the introduction of automatic bill payment programs in the Southern U.S. in 2005, which eliminated the need for consumers to view recurring electricity bills. Forgoing inspection of recurring bills reduces price salience, which can in turn result in higher energy consumption and discourage uptake of energy efficiency measures. The results of the study found that enrollment in automatic bill payments increased commercial electricity consumption by as much as 8%. Alternatively, after conducting both an “artefactual”[30] and in-store experiment for choosing lightbulbs, Allcott & Taubinsky (2015) conclude that while price transparency and ease of reference to long-term energy cost information based on purchases increase the market share of compact fluorescent lamp lightbulbs by as much a 12% relative to traditional incandescent bulbs, a vast majority of users still choose the less energy efficient choice. This is indicative that although improving price saliency is a promising intervention, price transparency may not always be the driving force behind energy efficiency decisions.

**Monitoring effect.** In some cases, it is not the content of the message that drives the result, but the knowledge that the energy user is being monitored. Schwartz et al. (2013) examined the energy consumption habits of nearly 3,000 users. Over the course of a month one group of users was informed five times that their energy consumption was being monitored, leading to an approximate 3% reduction in usage among these users.[31] These results highlight that it may also be relevant for firms to track their progress on energy efficiency measures to encourage them to stick to their goals. For example, for firms that receive a green loan or an energy audit (more on this will be explained below), simple follow-up communications to learn if they actually adopted the energy efficient technologies, and if so, what their experience was like and what gains they obtained, can further encourage this behavior or keep firms engaged.

### *5.2 Energy Audits*

In some cases, messaging and pricing alone cannot sway a firm to pursue more energy efficient investments. Decision-makers require more firm-specific information before contemplating a move towards greater energy efficiency. This is where energy audits come into play. An energy audit is a comprehensive evaluation of the historical, current, and future energy needs of a firm. It also serves to recommend the most appropriate areas of investment to improve energy management.

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[30] An artefactual experiment can be considered a simulation of a field experiment with the same choice sets. The authors argue this is more reliable than a field experiment because the responses are weighted by population demarcations to be statistically representative.

[31] In behavioral science this is a phenomenon known as a “Hawthorne effect” which is essentially a reaction in which individuals modify an aspect of their behavior in response to their awareness of being observed.

Allcott & Greenstone (2017) study energy efficiency adoption and discuss the role of energy audits and subsides. Energy audits are crucial to the decision-making process because they move energy consumers closer to perfect information about the set of energy efficiency investments that are available to them and reveal investment choices that are potentially optimal given their current and future circumstances. Subsidies interact with this decision-making process. For example, economies with heavy fossil fuel subsidization may lead to distortions in the energy sector that make energy efficient investments less desirable because, relatively speaking, the opportunity cost of investing in more energy efficient technology increases. A potential solution is the recalibration of fossil fuel subsidies or better subsidies for energy efficient adopters. Notwithstanding, cautionary tales also exist where adopters may be over-subsidized, leading to a net welfare loss as taxpayers lose more than firms gain from adopting (Davies et al. 2014). Hence, it is evident that policy prescription could very well need to be tailored based on the nuances that give rise to failures. In practice the most desirable policy approach may involve a mix of interventions.[32]

Anderson & Newell (2004) conducted an analysis of manufacturing SMEs that received externally funded energy audits and their follow-up actions. Overall, only half of firms followed through with investment recommendations from the audits. In line with conventional wisdom, economic incentives such as low implementation costs and the quantity of energy that could be saved were heavily weighted by decision-makers who followed through with making investments. Additionally, there was high demand by firms for investments with quick repayment periods (less than two years); however, this may be a consequence of other factors, such as corporate pressure and short-term loss aversion.

Despite potential low uptake by firms, results on the effectiveness of audits are still encouraging. A meta-analysis encompassing 156 energy efficiency interventions over a 27-year timespan found that, on average, energy audits led to the largest improvements compared to other types of interventions in energy use curtailment, technological adoption, or a combination of both (Delmas et al., 2013). The average treatment effect of an energy audit was a 13.5% savings in energy costs.[33] In addition, some organizations that conduct energy audits have started to utilize peer information exchange networks as part of the audit process.[34] These networks collect and share energy consumption information and the results of audits at a building/site level within a community or municipality for the purpose of individual and collective decision-making with regards to the implementation of energy efficiency measures. Allcott & Rogers (2014) and Brandon et al. (2014) find experimental evidence for receiving peer information, especially if it shows that the user goes against social norms by having higher-than-average energy consumption, enforcing habitual energy efficiency in the long-run.

The extent to which firms take advantage of an energy audit depends on how costly it is to obtain feedback on the recommendations (i.e., the magnitude of transaction costs). In a study of a state-sponsored audit program for Dutch firms, firms were almost three times more likely to interact with reports and discuss them internally once they were more concise and easily accessible, such as reports that included direct hyperlinks (Rosenkranz et al., 2017). Schleich & Fleiter (2017) carry out a robust analysis on German SMEs, and whether audits improve their likelihood of adopting efficiency measures related to lighting, insulation, heating, and operations. While the likelihood of installing all measures improves with an audit, they conclude that the likelihood of installing

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[32] For example, as suggested in Gillingham et al. (2009), subsidizing the uptake of more efficient technologies may not be well suited for increasing investments in energy efficiency for which information asymmetry is very high among consumers.

[33] For reference, the second most effective measure was messaging at 11%.

[34] For more information, see work from the U.S. Department of Energy and the Department of Business, Energy and Industrial Strategy in the U.K.

insulation increases the most (arguably the measure with the most upfront costs, but also the highest potential for energy savings). Additional evidence suggests that audits become more effective as firms become larger (within a 1-50 employee bandwidth, all within the SME definition). This is potentially due to relatively larger firms having more resources to follow through with audit recommendations. One consideration when interpreting these results is that support schemes for undertaking energy audits vary by country. For example, in the EU, German SMEs can receive up to 80% of funding for an audit (to a maximum of 8,000 euros); in Sweden SMEs can receive up to 50% of funding for an audit (to a maximum of 5,500 euros) (Hirzel et al., 2016).

Moreover, Schleich & Fleiter also studied the impact of simple versus detailed audits. Simple audits are carried out within a maximum of two days and focus on identifying areas for major energy savings and measurements at the audited sites. Detailed audits are funded for up to 10 days and include more elaborate analysis, in-depth monitoring, and detailed action plans and recommendations. There was no strong evidence to suggest that detailed audits are more effective than simple audits, however the authors caution that the energy efficiency measures they studied were relatively simple and there is a possibility that detailed audits might improve the uptake of more complex measures.

Unfortunately, there are only a few documented cases in the LAC region where energy audits were done for the private sector in a systematic way. These were carried in Honduras, Nicaragua, and Mexico (Ravillard et al., 2019). Honduras implemented its Program for Energy Efficiency in the Industrial and Commercial Sector (CCEE), which performed 17 energy audits in 2005. In Nicaragua, the Development of Energy Efficiency Program conducted energy audits in major companies in the industry, trade, and services sectors between 2007-2011. In Mexico, the Energy Sector Management Assistance Program (ESMAP) supported detailed energy audits in six municipalities, including buildings' energy use. The role of these centralized schemes cannot be understated. Evidence presented by Brutscher & Ravillard (2019) examining firms in Europe suggests that being able to offer financial support improves the uptake of audits. The authors also compared the effectiveness of grants vs. tax credits as delivery methods for the support. They found that grants were more likely to improve the probability of audit uptake. While the usage of energy audits in LAC has been promising, future work in the area should be structured to evaluate the impact of said interventions.

Kimura et al. (2018) propose automation of the energy audit process via tools that collect and process data from smart meters and convert them into frequent, easy-to-interpret and actionable advice for firms. While the technology is still considered to be experimental, theoretically it would improve uptake of energy audits by reducing the associated transaction costs. This finding is aligned with Allcott & Rogers (2014) who find that receiving audit information "cues" users to make changes that result in more energy efficiency; however, backsliding is common in the short-run as users revert back to their original mode of operating. Consequently, the rate of reversion diminishes (i.e., users habituate energy efficiency) as they receive persistent information, making the case for automated, high-frequency auditing capabilities.

Cunha et al. (2020) conducted an analysis on the adoption of energy efficient technologies (e.g., more efficient lighting, better insulation, heating system replacement, and heating operations) among approximately 700 firms in Portugal. The findings suggest that firms that rent space rather than own it were less likely to install lighting or insultation, indicative of a potential principal-agent problem between the firm and the property owner. Firms that conducted an energy audit were more likely to replace their heating system or improve heating operations. Moreover, firms with a dedicated energy manager were more likely to successfully replace their heating systems. Lastly, manufacturing firms were less likely to implement technologies related to heating. These results point to firm characteristics that are important to consider when providing an energy audit and encouraging energy efficiency practices.

### 5.3 Other Combined Interventions

Energy efficiency objectives may not be obtainable through single interventions as different market and behavioral failures may be present simultaneously. Although there is limited firm-level evidence, we draw lessons from a growing set of household evidence employing a combination of interventions, which can ultimately lead to the desired effect of meeting energy efficiency goals.

**Enabling devices.** These technologies can transmit immediate information on energy usage and simultaneously help users to act on this information reducing transaction costs through automation. Examples include a two-way programmable communicating thermostat (e.g., Google Nest) or automatic cycling central air-conditioning systems. Enabling devices are often deployed in response to time-of-use (TOU) or dynamic pricing schemes set by energy companies, which vary electrical rates based on predefined schedules (e.g., peak and non-peak times). In LAC, some countries have experimented with TOU pricing. For instance, in 2011 the Brazilian Electricity Regulatory Agency (ANEEL) approved a new TOU tariff modality for retail consumers connected to low-voltage distribution grids. However, analysis of the impact of this change suggests that the intervention did little in terms of improving energy efficiency or the welfare of consumers (Azevedo & Calili, 2018). With this in mind, efforts have been devoted to analyzing how TOU pricing can be improved. There is significant literature on the effectiveness of price interventions, which goes beyond the scope of this document, as these are generally public sector interventions. From a private sector perspective, it is important to understand how the effectiveness of enabling devices as other incentives, different from TOU pricing, could be used to reduce energy consumption. For example, in-house displays could be used to transform opaque or scarce information about a firm's energy consumption into a transparent, and more importantly controllable, process where real-time information shows the need for adopting energy efficiency measures.

Additional information is available from studies on households. In a survey of 15 experiments regarding dynamic pricing of electricity, Faruqui and Sergici (2010) find that TOU rates induce a drop in peak demand ranging from 13% to 20% without enabling technologies, with drops increasing to 27% to 44% when accompanied with enabling technologies. This suggests that receiving information on how the price varies can potentially impact energy use, which echoes the importance of price saliency and shows that enabling devices could be useful tools for providing relevant information. More recently, Ivanov et al. (2013) conducted a field experiment with 1,000 participating households in the U.S. that were provided with programmable thermostats. They calculated that energy use declined by 15% on peak days relative to a control group, which was not provided with the thermostats. In a more naturally occurring setting in Northern Ireland, Gans et al. (2013) found similar results. By examining a sample of residential customers, the authors suggested that programmable cooling/heating devices were associated with a decline in usage of 11% to 17%. In these cases, the effect may come from either the information provided to consumers about their energy usage or the convenience of being able to program certain preferences.

***Comparing price vs. non-price interventions.*** Ito et al. (2018) conducted a field experiment with 700 households in Japan to understand the impact of both moral persuasion and economic incentives on electricity consumption. A first group received a morally persuasive message about the importance for the greater good of decreasing electricity usage during critical peak demand days due to relatively limited supply. A second group received an economic incentive and was charged a critical peak price (higher than the baseline price paid by the other groups) on peak demand days. Relative to a control group, the moral persuasion reduced energy consumption for only a few days. Instead, price incentives had larger and more long-lasting effects, with a sustained reduction in energy use during peak periods—from 14% to 17% depending on the critical peak price, but also during non-peak periods.

**Complementarity or substitutability between various interventions.** Jessoe and Rapson (2014) conducted an experiment involving 400 households in the U.S. In this case, households experienced higher energy prices that ranged between 200% and 600% in selected periods. The authors varied the timing when users received notifications about the incoming price hikes. Notifications were either provided one-day or as little as 30 minutes in advance.[35] In this experiment, the results indicated that users who experienced price increases alone decreased demand between 0% and 7% and those that also received information feedback decreased usage between 8% and 22% with the greatest effects occurring when households were given maximum advance notice (1 day). Interestingly, energy demand was inelastic for the group that received a notification of a price change only 30 minutes ahead of time, suggesting that users did not have enough time to adjust to price changes. In all, this highlights that a positive impact can come from providing consumers with decision-relevant information and the importance of the timing of such information. Alternatively, Pellerano et al. (2017) conducted a randomized experiment in Quito, Ecuador with 28,000 users. They found that social comparison messages reduced consumption by about 1%. However, when financial incentives in the form of messages about potential cost savings were added to the social comparison, this combined approach backfired, as gains from the social comparison message were wiped out. The authors concluded that when the price point was made available to users, they deduced that they gained more from additional consumption than from social acceptance. This is to say that combining interventions may or may not be effective. Allcott & Sweeney (2015) show that the combination of information and monetary incentives do improve consumer uptake of energy efficient products where each method alone proves ineffective.

**Variations of the same intervention.** LaRiviere et al. (2014) explore this line of thinking with a multi-nudge field experiment in which users receive different variations of an informative message that compares their energy consumption with peers either in (i) kilowatts per hour (kWh); (ii) expenditure; or (iii) an approximation of carbon dioxide emission. After users received this letter, the authors offered varying degrees of subsidies to conduct an energy audit and install an energy efficiency measure conditional on the audit. The results implied that all versions of messages seemed to backfire in terms of monthly energy consumption. However, messages about consumption in kWh improved the likelihood of a user undertaking an audit. Additionally, on average, users were more likely to install a measure to improve energy efficiency having undertaken an audit, but the probability of this decreases if the user received messaging about emissions. This is potentially another example of a rebound effect.

**Structuring feedback to optimize interventions.** A review of energy studies conducted by Ehrhardt-Martinez & Laitner (2010) established that the most effective interventions for promoting energy efficiency were those that combined technology adoption with people-centered messaging that promotes frequent stocktaking and the habitual use of said technologies. Likewise, employing these measures can in fact dampen potential rebound effects. Through an analysis of 38 studies,

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[35] This differed from the information provision experiments where users were provided with an in-home display providing real-time information about electricity consumption, prices, and bills.

Abrahamse et al. (2005) examine both antecedent strategies (e.g., commitment, goal-setting) and consequence strategies (e.g., feedback, rewards), as well as various methods of information provision, such as workshops, mass-media campaigns, and tailored energy audits. The findings indicate that improved information results in greater knowledge, but this does not necessarily result in behavior change towards more energy efficiency, and that feedback can be effective once received frequently. This review is complemented by a meta-analysis conducted by Ehrhardt-Martinez et al. (2010) of 36 studies over a 15-year period. The results suggest that average savings from reduced energy consumption vary from 4% to 12% depending on the feedback type, with the most effective being either continuous or real-time feedback. Other evidence on this topic includes: (i) making smart meter readings continuous, attractive, clear, and accessible; and (ii) framing audits in common language for maximum clarity (Darby, 2001).

### 5.4 The Impacts of Adopting Energy Efficient Technologies

As important as it is to learn what type of interventions can be most effective to encourage the adoption of energy efficiency in firms, it is also relevant to consider the literature that looks into the willingness to pay for different energy efficiency technologies and the impacts of energy efficient technologies themselves.

**Willingness to pay (WTP).** This concept determines the maximum price that consumers are willing to bear in order to procure energy efficient technologies. Several studies have attempted to estimate firm WTP for buildings that have been built or retrofitted with energy efficiency measures certified by local energy authorities.[36] Green-certified buildings have a rent premium between 3% and 9% and a premium on sale prices between 16% and 26%, after controlling for property characteristics, such as location and price variations over time (Eichholtz, Kok, and Quigley, 2010; Fuerst and McAllister, 2011; Miller, Spivey, and Florance, 2008). One caveat to this line of research is highlighted by Wiencke (2013) who found that WTP tends to dissipate when firms have a choice to lease. This could imply that businesses are not willing to lock themselves into longer-term lease agreements with such premiums (as opposed to short-term rental agreements) or expect a higher standard of energy efficiency under lease agreements.

The WTP literature for residential properties is more developed although it is very concentrated in the U.S.[37] Nonetheless evidence from outside the U.S. does exist, such as the work by Banfi et al. (2008) which estimates people's marginal WTP for different energy-saving measures in Switzerland. In the study, respondents of a choice experiment were asked to choose between their actual housing situation and a hypothetical one with different energy efficiency standards[38] and corresponding prices. Their results suggest a significant WTP for energy efficiency attributes. The WTP varies, approximately 3% above the reference price for an enhanced insulated facade (in comparison to standard insulation) and 8% to 13% above the reference price for a ventilation system in new buildings or insulated windows in old buildings (compared to old windows), respectively. The results are similar to a study by Kwak et al. (2010) in Korea.

In Section 2, we discussed "hassle factors" that could affect uptake of technologies (e.g., clearing an area to install insulation). Conclusions from a study conducted by the U.K. Department of Energy and Climate Change suggest that WTP can play a role in de-hassling interventions. Homeowners interested in installing insulating floorboards were faced with not only the installation process but also the hassle of clearing areas for installation, which could discourage uptake. Their

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[36] Examples of this type of certification include Energy Star in the United States and Minergie in Switzerland.

[37] For further details see Gillingham & Palmer (2014), Allcott & Greenstone (2017), and Gillingham & Tsvetanov (2018).

[38] These standards included air renewal systems and insulation of windows and facades.

results show homeowners were prepared to pay more for a combination of these services compared to offers of each service separately (either the application of the boards or clearing). One caveat presented by the authors was that their sample was too small to be externally valid. Nevertheless, these results allow for a better understanding of how WTP can address the hassle factor associated with attaining energy efficiency.

**Payback period of energy efficient technologies.** In terms of the efficacy of technologies, by using a 5-year panel of industrial survey data, Filippini et al. (2020) find that Chinese firms in the iron and steel sectors undertaking investments in energy efficiency improved their productivity growth by approximately 3%, as improving energy efficiency drove technical change within firms. Parallel to this, the authors also posit that contrary to popular belief there is potential for energy efficiency investments to have shorter payback periods (less than a year). However, this result is possibly affected by any subsidies for technical assistance firms may receive. In line with this finding, Adhvaryu et al. (2020) used firm-level data to measure the impact of more efficient LED bulbs in garment factories. They found that once productivity gains are considered, the payback period of adopting the bulb was as low as one-sixth of the time period originally expected. This work is encouraging as it provides firm-level evidence that an energy efficiency agenda and innovation go hand-in-hand.

**Eco-innovations.** Cheng et al. (2014) studied manufacturing firms in Taiwan using industrial surveys. They found that not only was there a correlation between business performance and eco-innovation but also between eco-process innovation and eco-organizational innovation. Eco-process innovation is the introduction of a new or significantly improved energy efficient way of producing output (e.g., using an energy efficient belt of motors in a production line). Eco-organizational innovation is the way in which a firm structures itself to achieve efficiency (e.g., having a unit or manager responsible for energy management). However, "Eco-innovation" is subject to its own share of skepticism. Pons et al. (2018) analyzed a subset of European firms[39] and found that while firms that have successfully implemented energy efficiency measures improve their environmental performance (i.e., their emissions relative to their output), their economic performance does not improve.

**Building technologies.** Adan and Fuerst (2015) investigated the impact of energy efficiency upgrades, such as cavity wall insulation, loft insulation, and new efficient boilers on household gas and energy consumption based on a difference-in-difference analysis. Observed energy consumption decreased significantly in households following the treatment. The single most effective energy efficiency measure was cavity wall insulation, which reduced annual gas consumption by 10.5% and annual total energy consumption by 8% in the year following installation. Comparing different bundles of energy efficiency measures, dwellings retrofitted with both cavity wall insulation and a new efficient boiler experienced the largest reductions in annual gas and total energy consumption of 13.3% and 13.5%, respectively. This is followed by a mean annual reduction of 11.9% and 10.5% in gas and total energy consumption for dwellings with all three energy efficiency measures installed in the same year. These findings provide useful insights for the private sector as insulation and boilers are technologies that are readily deployed by firms (although perhaps on a different scale). Scheer et al. (2012) evaluate the energy savings realized by households participating in a government-sponsored residential retrofit scheme in Ireland. Retrofits included insulation upgrades, installation of high efficiency-boilers, and/or improved heating controls. Their study uses an ex-post analysis of billing to examine the change in gas consumption for a sample of households pre- and post-scheme participation relative to a

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[39] One caveat is that the subset of firms is only from Spain and Slovenia.

control group.[40] An average reduction of about 3,664 kWh or 21% following installation of energy efficiency measures is reported. However, compared to an ex-ante estimation of energy savings, this is a shortfall of approximately 36% between theoretical potential savings and the actual measured savings.

A study for LAC confirms that actual gains may be lower than the gains expected ex-ante. In 2018, the IDB commissioned an impact evaluation to determine the impact of energy efficiency improvements/eco-technologies in a new housing development in Mexico. The improvements included thermal insulation and ventilation systems. Sensors installed in the homes captured high-frequency data on indoor temperature and humidity over a 16-month period. The results suggest that there was no statistical difference in electricity consumption and thermal comfort between the homes with and without the eco-technologies, even when controlling for household characteristics. Two explanations are provided: 1) a low rate of air conditioner ownership; the upgrades and the engineering models predicting reduced energy use assumed that reductions would take the form of decreased air conditioning use; and 2) many homes keep their windows open. Because the full benefits of the eco-technologies did not materialize, the evaluation found the installations to be cost-ineffective (Davis et al., 2018). Another study covering a light retrofitting program in Peru found that adopting energy efficient LED bulbs over traditional bulbs reduced energy consumption on average but that the poorest households responded to the change by increasing energy consumption. While the evidence is mixed, these studies provide a learning opportunity for the design of future interventions in LAC, which should take into consideration both socioeconomic conditions and human behavior.

## 6. Conclusion

Energy efficiency is a cornerstone of sustainable development for the private sector. Not only does the pursuit of an energy efficiency agenda reduce the emissions produced by firms, but the evidence suggests it can have positive impacts on firm sustainability and productivity. The COVID-19 pandemic has reminded us of how vulnerable firms can be to external shocks, as well as the importance of getting firms on a path of sustainable growth in the post-pandemic period. Within this context, energy efficiency is one way for the private sector to rethink how it operates and help contribute to environmental sustainability, while also creating firm-level benefits.

Supporting an energy efficiency agenda requires an understanding of how firms perceive choices to invest in energy efficient technologies, as well as the market and behavioral complexities that accompany these decisions. Firms are heterogeneous in this respect and therefore solutions for improving energy efficiency in LAC can take advantage of evidence and lessons learned from other contexts and from related interventions to determine the most effective approaches.

This study provides a comprehensive snapshot of the energy efficiency landscape in the region and reviews a catalogue of potential solutions that can help guide policy makers, utility companies, and development finance institutions (DFIs) in deploying financing and technical assistance to support the energy efficiency agenda. Firm-level data in the region suggests that energy efficiency varies both by country and sector, and that the propensity for innovation may be a key driver behind differences in energy efficiency across firms. The data also suggests that there is room to work both with SMEs and larger firms since the former have higher energy intensities while the latter consume a higher share of energy. The evidence also supports the strategic targeting of the manufacturing and tourism sectors in the region. In addition, evidence shows a positive link between energy efficiency and productivity in LAC but some firms may

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[40] This study uses a difference-in-difference methodology that relies on matching a comparison group by dwelling characteristics.

require additional support to maximize these gains. The analysis of determinants of energy efficiency levels in our sample of LAC firms reveals the importance of access to credit to support higher levels of energy efficiency in the private sector and highlights how providing access to credit, particularly for larger firms where energy efficiency gaps are larger, has the highest impact potential.

In terms of the available evidence on energy efficiency interventions, while most is concentrated in household-level studies, findings suggest that information campaigns are a potentially effective and relatively inexpensive way to promote energy efficiency among firms by increasing awareness of opportunities and availability of energy efficient technologies. Moreover, these findings also suggest that improving price transparency can guide a more efficient allocation of resources and that how messages are framed is quite relevant. Concurrently, energy audits provide firms with information tailored to their energy needs and by communicating useful insights in a language that "speaks" to a firm's management team, audits can help firms maximize their investments. The evidence further suggests that audits are especially useful for manufacturing firms, particularly SMEs which may have specific lighting, heating, and insulation requirements in their production processes. To maximize the efficacy of audits, the transaction costs for firms to digest the information must be minimized. Monitoring and constant feedback to energy users has also proved to be key in encouraging and sustaining adoption and maximizing gains from these green technologies.

While the findings of this review are focused on firms, in light of the critical role of access to credit to support energy efficiency adoption in the private sector, some of these results can guide financial institutions in implementing strategies to better promote energy efficiency. Despite an initial reluctance from the financial sector to lend for energy efficiency projects (ECLAC, 2014), green lending is increasing in the LAC region. One explanation for this reluctance is that financial institutions suffer from asymmetric information with respect to the advantages of energy efficiency on a firm's prospects as a borrower (e.g., through improved competitiveness) (Brutscher et al., 2021). As shown in this review, providing supplemental information to firms about the long-term benefits of adopting more energy efficient technologies can potentially make a significant difference in the uptake of these lines of credit, and more generally in the enabling environment for adopting more efficient solutions. In this setting, financial institutions in the region serving the SME segment have an important role to play. They should start by training their own staff on how to communicate the benefits of adoption to potential clients and how their financial products can facilitate this process. They also have the opportunity to move the needle in this area through their work with large corporations in sectors with the largest shares of energy consumption.

While the focus of this review is on private sector-driven interventions, we do not disregard the role of governments and publicly-owned utility companies in helping to promote energy efficiency. Combining policy tools such as dynamic energy pricing models and real-time information campaigns can complement the adoption of energy efficiency technologies among firms. Moreover, policymakers should also evaluate the role of other areas such as international trade regimes and their potential impact on the diffusion of state-of-the-art energy efficiency technologies. While historically there has been a reliance on the public sector to maintain national energy efficiency agendas, given the fiscal pressures placed on countries during the COVID-19 pandemic, more can be done directly by the private sector.

Overall, this review attempts to illuminate the complexities involved with promoting energy efficiency in the private sector. Interventions should be well thought out with a foundational understanding of what has worked and what has not in other contexts. Navigating these idiosyncrasies is not simple but hopefully this review can serve as a guide to help practitioners maximize development outcomes and generate more rigorous evidence on the impacts of firm-level energy efficiency interventions. A final point that should be stressed is that interventions aimed at improving energy efficiency can have significant lead time before tangible results can be observed (ECLAC, 2003). Therefore, changes in energy efficiency should be evaluated over medium to long-term horizons greater than three years. Moving forward, further evidence on the effectiveness of interventions promoting energy efficiency adoption in firms and the impact of adoption is needed in LAC to help guide the environmental agenda and design well-targeted approaches.

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# ANNEXES

## ANNEX I – Data

### Table 4. Breakdown of Datasets Used

| Country | Year | # of observations | Source |
|---|---|---|---|
| Argentina | 2017 | 691 | World Bank Enterprise Surveys |
| Barbados | 2014 | 110 | IDB/Compete Caribbean PROTEqIN Survey |
| Belize | 2014 | 108 | IDB/Compete Caribbean PROTEqIN Survey |
| Bolivia | 2017 | 236 | World Bank Enterprise Surveys |
| Colombia | 2017 | 859 | World Bank Enterprise Surveys |
| Dominican Republic | 2016 | 235 | World Bank Enterprise Surveys |
| Ecuador | 2017 | 361 | World Bank Enterprise Surveys |
| El Salvador | 2016 | 538 | World Bank Enterprise Surveys |
| Guatemala | 2017 | 260 | World Bank Enterprise Surveys |
| Guyana | 2014 | 101 | IDB/Compete Caribbean PROTEqIN Survey |
| Honduras | 2016 | 231 | World Bank Enterprise Surveys |
| Jamaica | 2014 | 222 | IDB/Compete Caribbean PROTEqIN Survey |
| Nicaragua | 2016 | 296 | World Bank Enterprise Surveys |
| Paraguay | 2017 | 272 | World Bank Enterprise Surveys |
| Peru | 2017 | 713 | World Bank Enterprise Surveys |
| Suriname | 2014 | 101 | IDB/Compete Caribbean PROTEqIN Survey |
| The Bahamas | 2014 | 111 | IDB/Compete Caribbean PROTEqIN Survey |
| Trinidad & Tobago | 2014 | 339 | IDB/Compete Caribbean PROTEqIN Survey |
| Uruguay | 2017 | 238 | World Bank Enterprise Surveys |
| TOTAL | | 6022 | |

Additionally, in accordance with best practices set by the World Bank for analyzing Enterprise survey datasets, we filter observations that are greater than +/- 3 standard deviations with respect to variables of interest. See https://www.enterprisesurveys.org/en/about-us/frequently-asked-question.

## Table 5. Breakdown of Sample Sub-sectors

| | Chemicals | Construction | Electronics | Food | Hotels and Restaurants | Information Technology | Machinery and equipment | Metals & Minerals | Other Manufacturing | Other Services | Plastics & rubbers | Services of Motor Vehicles | Textiles & Garments | Transport | Wholesale & Retail | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Argentina | 23 | 20 | 7 | 163 | 14 | 11 | 28 | 53 | 119 | 1 | 23 | 35 | 52 | 15 | 127 | 691 |
| Barbados | 4 | 6 | 0 | 12 | 29 | 5 | 0 | 6 | 16 | 0 | 2 | 1 | 6 | 8 | 15 | 110 |
| Belize | 4 | 3 | 0 | 19 | 26 | 0 | 1 | 3 | 22 | 0 | 1 | 3 | 1 | 8 | 17 | 108 |
| Bolivia | 8 | 12 | 2 | 15 | 11 | 6 | 3 | 17 | 27 | 0 | 4 | 20 | 2 | 16 | 93 | 236 |
| Colombia | 39 | 32 | 7 | 155 | 15 | 46 | 26 | 52 | 172 | 1 | 25 | 6 | 25 | 26 | 232 | 859 |
| Dominican Republic | 7 | 7 | 0 | 17 | 15 | 5 | 2 | 13 | 24 | 5 | 4 | 20 | 2 | 8 | 106 | 235 |
| Ecuador | 11 | 24 | 1 | 22 | 14 | 8 | 3 | 11 | 34 | 0 | 13 | 27 | 8 | 23 | 162 | 361 |
| El Salvador | 11 | 18 | 1 | 93 | 15 | 1 | 8 | 21 | 140 | 9 | 6 | 27 | 25 | 3 | 160 | 538 |
| Guatemala | 9 | 19 | 0 | 27 | 28 | 2 | 4 | 17 | 42 | 8 | 3 | 12 | 6 | 9 | 74 | 260 |
| Guyana | 3 | 2 | 0 | 14 | 9 | 6 | 1 | 3 | 13 | 0 | 0 | 4 | 3 | 2 | 41 | 101 |
| Honduras | 10 | 13 | 1 | 13 | 8 | 6 | 9 | 6 | 29 | 4 | 1 | 12 | 1 | 9 | 109 | 231 |
| Jamaica | 3 | 7 | 1 | 24 | 18 | 5 | 2 | 8 | 36 | 0 | 3 | 17 | 10 | 12 | 76 | 222 |
| Nicaragua | 6 | 11 | 0 | 27 | 38 | 2 | 4 | 6 | 49 | 6 | 2 | 18 | 2 | 11 | 114 | 296 |
| Paraguay | 7 | 17 | 1 | 25 | 3 | 5 | 4 | 9 | 25 | 0 | 8 | 22 | 1 | 16 | 129 | 272 |
| Peru | 34 | 15 | 7 | 102 | 28 | 2 | 12 | 48 | 132 | 1 | 26 | 30 | 37 | 41 | 198 | 713 |
| Suriname | 1 | 6 | 0 | 15 | 8 | 1 | 0 | 5 | 28 | 0 | 3 | 1 | 3 | 14 | 16 | 101 |
| The Bahamas | 6 | 21 | 1 | 16 | 21 | 3 | 4 | 4 | 0 | 0 | 0 | 3 | 1 | 9 | 22 | 111 |
| Trinidad & Tobago | 15 | 26 | 4 | 22 | 26 | 4 | 3 | 24 | 34 | 0 | 5 | 14 | 8 | 21 | 133 | 339 |
| Uruguay | 13 | 5 | 0 | 22 | 5 | 9 | 0 | 6 | 20 | 0 | 9 | 6 | 3 | 29 | 110 | 237 |
| Total | 214 | 264 | 33 | 803 | 331 | 127 | 114 | 312 | 962 | 35 | 138 | 278 | 196 | 280 | 1,934 | 6,021 |

Note: Sector unidentified for 1 firm.

## ANNEX II – Conceptual Framework In-depth

Energy efficiency is viewed as an investment allowing firms to produce a given amount of output using less energy input. Firms decide whether to invest in energy efficiency by considering the trade-off between the higher initial capital costs associated with energy efficiency investments versus the lower expected future energy operating costs. A firm's optimization problem is given by:

$$max\, f(K_i, H_i) \;=\; \frac{\Pi(A_E, A_X)}{1-\delta} - K_i p_K - H_i p_H \qquad (1)$$

Where $\Pi$ is profit which is determined by a level of energy efficiency that firm $i$ realizes $(A_E)$ once they decide on the level of capital $(K)$ they will deploy at price $p_K$. The capital input also determines the level of energy efficiency $A_E = f(K_E)$. Firms also employ skill/labor $(H)$ at price $p_H$. $\delta$ is a standard discount factor. Firm's profits ($\Pi$) are determined by the following model:

$$\Pi = A_X X + A_E E - p_X X - p_E E \qquad (2)$$

Where $X$ is a composite of inputs, such as capital and labor, and $E$ is the firm's energy consumption. Note that each factor has its own factor-specific efficiency. $A_E$ is an energy efficiency factor, and hence $A_E E$ is the input of energy services that goes into the production function. In this respect, energy is not valuable on its own, but only as a result of the energy services it provides (e.g., powering industrial equipment or running a commercial heater). It is assumed that firms first choose an energy efficiency level, and in the following period they produce with that level of efficiency.

Firms must choose bundles of capital, labor/skill, and energy ($K_E, H_E, E$ respectively) to maximize profit. In this scenario, firms' private decision leads to an outcome that is both privately optimal and socially optimal. Taking the first order conditions with respect to capital gives:

$$\frac{\frac{\partial \Pi(A_E)}{\partial A_E}\frac{\partial f}{\partial K_E}}{1-\delta} = p_k$$

Similarly, taking the first order conditional with respect to labor gives:

$$\frac{\frac{\partial \Pi(A_E)}{\partial A_E}\frac{\partial f}{\partial L_E}}{1-\delta} = p_L$$

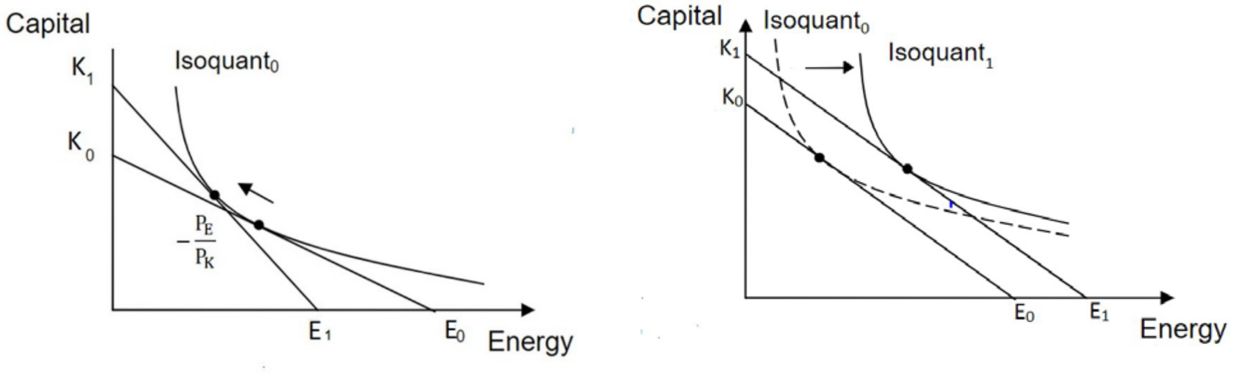
These conditions state that firm profits are maximized where the present discounted value of the product of the marginal profits from efficiency and the marginal energy efficiency from investment in a factor (that produces said efficiency) exceed the price of said factor. With these conditions in mind one can mathematically define an energy efficiency gap. Using capital as an example, when a firm has still not met its first order conditions can be written as:

$$\frac{\frac{\partial \Pi(A_E)}{\partial A_E}\frac{\partial f}{\partial K_E}}{1-\delta} > p_k$$

This means that a firm can continue to increase its profits because the efficiency gained by the firm increases profits by more than it costs to deploy (in today's dollars).

Graphically, we can depict the choice firms face when choosing input levels as the most feasible level of output for a firm given the factor of production at their disposal that also maximizes profits (minimizes costs). In Figure 1a, with line $K_0E_0$ representing the combinations of inputs that the firm can afford and isoquant$_0$ representing the various combination of inputs that produce the same level of output, the optimal level of energy efficiency for the firm is the one that minimizes the present value of costs, while holding production of the output constant  the level of output with the specific combination of inputs at the lowest point along the line $K_0E_0$.

**Figure C1: Conceptual Framework**



(a) Energy efficiency-improving substitution

(b) Energy-saving technological change

Source: Adapted from Gillingham et al. (2009)

The concept of energy efficiency can be depicted in Error! Reference source not found. **C1**. As a first example, in response to a reduction in the relative price of capital (higher $P_E/P_K$ shown graphically as a steeper isocost line), firms choose an input bundle that is more capital intensive and uses less energy, while holding constant the amount of output (i.e., move upward along the Isoquant$_0$ curve). Second, technological change may allow for more energy services by shifting out the isoquant (**Figure C1 (b)**), with an outward shift from *isoquant*$_0$ to a new *isoquant*$_1$), allowing for a higher cost-minimizing level of output due to energy efficiency gains. In contrast, energy conservation, not driven by energy efficiency improvements, can be represented by a lower level of energy services (**Figure C1(b),** shifting from Isoquant$_1$ to Isoquant$_0$).

This graphical representation of the framework can also aid in showing how the prevalence of market failures can affect a firm's decision to adopt energy efficient technologies. Different market failures, like environmental externalities and missing information, can be shown as a divergence between the relative prices used for decision-making and the socially optimal relative prices. For example, if due to information asymmetries, a firm underestimates the potential cost savings from adopting a more efficient technology (e.g., an Energy Star refrigerator), this may lead firms to invest operating along line $K_0E_0$ in **Figure C1(b),** when firms choose inputs but true input prices are reflected by line $K_1E_1$ meaning the firm can improve by shifting to production schedule Isoquant$_1$.

Up until now, we have abstracted away from additional factors that can affect the uptake of energy efficient technologies. Here we draw on the work of Allcott & Greenstone (2017) that introduces the role of two prominent factors when it comes to the investment decision: energy audits and subsidies. Energy audits are crucial to the decision-making process because they move energy consumers closer to perfect information about the set of energy efficiency investments that are available to them and reveal investment choices that are potentially optimal given their current and future circumstances. Subsidies interact with the decision process in a similar manner: they are meant to offset distortions borne by the investor. Let $\vartheta_i$ be a set of potential investments each firm $i$ can make. The decision to conduct an audit can be denoted by $A_i = \{0,1\}$ where 0 represents no audit and 1 represents an audit undertaken. Additionally, let the decision to undertake a potential investment revealed by the audit can be denoted by $I_{ij} = \{0,1\}$ where $j$ is a particular investment under consideration by firm $i$. Firms do not invest before conducting an audit. An investment decision can be represented by

$$I_{ij} = \begin{cases} 1, & s_{ij} - c_{ij} + e_{ij} + \xi_{ij} + \gamma_{ij} > 0 \\ 0, & s_{ij} - c_{ij} + e_{ij} + \xi_{ij} + \gamma_{ij} \leq 0 \end{cases}$$

Where $s_{ij}$ is an investment subsidy set by policymakers, $c_{ij}$ is an investment cost that varies by firm, $e_{ij}$ is the estimated savings from improved energy efficiency, $\xi_{ij}$ captures non-monetary benefits (costs) and $\gamma_{ij}$ is a distortion that can drive wedge between investment uptake and actual benefits (e.g., market failure or behavioral phenomenon).

We can therefore represent the net benefit from investments of a particular firm as $\lambda_i = \sum_{j=\vartheta} I_{ij} . (s_{ij} - c_{ij} + e_{ij} + \xi_{ij} + \gamma_{ij})$.The audit decision that will maximize benefits accrued to the firm can be represented as[41]

$$A_i = \begin{cases} 1, & s_{Ai} - c_A + \lambda_i + \xi_{Ai} + \gamma_{Ai} > 0 \\ 0, & s_{Ai} - c_A + \lambda_i + \xi_{Ai} + \gamma_{Ai} \leq 0 \end{cases}$$

Where $s_{Ai}$ is an audit subsidy, $c_{Ai}$ is the price of an audit which is constant across firms, $\xi_{Ai}$ captures non-monetary benefits (costs) of an audit and $\gamma_{Ai}$ capture any informational or behavioral distortions affecting audit take up and $\lambda_i$ is the net benefit of the energy efficiency investment. In general, if the non-monetary distortions ( $\gamma_{ij}$ or $\gamma_{Ai}$) are positive (negative) then firms will be more (less) likely to invest and perform an audit, respectively. To better explain what these variables ($\gamma_{ij}$ or $\gamma_{Ai}$) capture we draw on the work of Hafner et al. (2019) who conducted an extensive literature review about the psychological barriers to adoption of energy efficient technologies. In line with the next section on behavioral failures, they find that possible factors affecting the adoption decision include: action inertia (remaining at default), social norms (mimicking peer behavior), emotion, perceived behavior control (uncertainty about the feasibility of change), and inconsistent discounting of future benefits.

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[41] Note that the decision to invest is embedded in the audit decision.