ELECTRIC ENERGY COSTS AND FIRM PRODUCTIVITY
IN THE COUNTRIES OF THE PACIFIC ALLIANCE

A Thesis
submitted to the Faculty of the
Graduate School of Arts and Sciences
of Georgetown University
in partial fulfillment of the requirements for the
degree of
Master of Public Policy in Public Policy

By,

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Washington, DC
April 10, 2015
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ABSTRACT

This paper explores the relation between energy as an input of production and firm-level productivity for Chile, Colombia, Mexico and Peru, all country members of the Pacific Alliance economic bloc. The empirical literature, has explored the impact of infrastructure on productivity; however there is limited analysis on the impact of particular infrastructure variables, such as energy, on productivity at the firm level in Latin America. Therefore, this study conducts a quantitative assessment of the responsiveness of productivity to energy cost and quality for Chile, Colombia, Mexico and Peru. For this, the empirical strategy is to estimate a Cobb-Douglas production function using the World Bank’s Enterprise Survey to obtain comparable measures of output and inputs of production. This approach provides estimates of input factor elasticities for all of the factors of production including energy. The results indicate that electric energy costs explain cross-country differences in firm level productivity. For the particular case of Colombia, the country exhibits the lowest capital and labor productivity of the PA, and firm output is highly responsive to changes in energy use. As a result, the evidence suggests that policies reducing electric energy costs are an efficient alternative to increase firm performance, particularly in the case of Colombia.

Key words: firm-level productivity, energy, business-enabling environment, Pacific Alliance, Latin America
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1 Introduction

The policy discussion in Latin America, and in particular in the countries of the Pacific Alliance\(^1\) (PA), has emphasized the need to boost economic growth by fostering productive activity of businesses and firms in the private sector. As a result, there is growing attention among governments in the region and multilaterals,\(^2\) to design policies and push reforms to foster a business-enabling environment that promotes private sector activity. According to Eifert et al. (2005), the business environment is defined as the nexus between “policies, institutions, physical infrastructure, human resources and geographic features that influence the efficiency with which different firms and industries operate”. At the firm level, the business environment directly influences the costs of production, especially of firms in the traded sectors in open market economies (Eifert et al. 2005), as is largely the case in the countries of the PA: Colombia, Chile, Mexico and Peru.

The empirical evidence supports the claim that improving firm performance should be in the policy agenda of Latin America. For example, Pages (2010) shows that limited productivity gains in manufacturing and services firms is preventing Latin America from catching up with the developed world. Also, Saliola and Seker (2011) estimate that profitability and labor productivity growth at the firm level in Latin America is lower than that of other regions with similar income levels, in the developing world.

From a policy perspective, it is relevant to identify particular aspects of the business environment that affect firm efficiency, in order to take affirmative action. To provide

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\(^1\) Member countries of the Pacific Alliance economic and trade integration agreement, as of March of 2015 are: Colombia, Chile, Mexico and Peru.

insight on the drivers of firm performance in the PA, this paper explores the relation between energy, a component of physical infrastructure, and productivity at the firm level. For this, the empirical strategy is to estimate a Cobb-Douglas production function using Ordinary Least Squares (OLS), and comparable measures of inputs (capital, labor and raw materials) and outputs (sales, and value added) for the selected countries using the World Bank’s Enterprise Survey of 2010. Then, this study provides an estimation of the production function including energy, and other indirect costs to identify their effect on output. The coefficients of the Cobb-Douglas production function for each of the inputs, including energy, represent the input factor elasticity of production (i.e. the responsiveness of firm sales to changes in inputs). The estimation of input factor elasticities at the country level, are useful to identify sources of cross-country differences in firm level productivity and in particular, the role of energy costs in explaining productivity divergence among the countries of interest.

This study finds that the average input factor elasticity to output for the countries of the PA are: 0.03 for capital, 0.44 for labor, and 0.52 for intermediate materials. These results indicate that while a 10 percent increase in capital results in only a 0.3 percent increase in output, while a 10 percent increase in labor is associated with a 4.4 percent increase in output in the PA. When energy is included in the estimation of the production function the empirical results indicate that energy matters for firm level productivity in the PA. On average, a 10 percent increase in energy use is associated with a 0.7 percent increase in output for the countries of the PA. The magnitude of this effect is significant taking into account that the input factor elasticity of energy is larger than that of capital, thus increasing energy use has a larger effect on final output than similar increases in capital
use holding all other factors of production constant. In addition, the results indicate that energy as an input also explains cross country differences in productivity. For the case of Colombia, energy exhibits the largest input factor elasticity (0.13) while for Mexico the input factor elasticity of energy is four times less than that of Colombia. These results indicate that policies that allow firms to increase the use and reduce cost of energy will have a positive impact in firm level productivity, and performance.

The remainder of this document is organized as follows: Section 2 presents an overview and background on the Pacific Alliance, and on firm and energy sector characteristics of the four countries of interest. Section 3, provides an overview of the academic literature related to the drivers of firm level productivity, and its relationship with physical infrastructure, including energy. Then, Section 4 introduces the motivations to investigate the link between energy costs and firm performance, as well as the main research hypothesis regarding the relation between energy and productivity at the firm level. Section 5, describes the data and empirical strategy to estimate firm level productivity, and the input factor elasticity to production of energy. Next, Section 6 presents the research results and the analysis of the empirical findings. Finally, Section 7 concludes and presents the policy implications of the key empirical results on the intersection between electric energy and productivity at the firm level in the countries of the Pacific Alliance.
2 Background

This section includes an overview of the PA and the economic relation between its four member countries (Section 2.1); a description of firm performance and firm characteristics in each country of the PA (Section 2.2); and a review of the energy sector and electricity systems in the countries of interest (Section 2.3). The objective is to identify relevant firm and energy sector characteristics to inform the analysis of the drivers of firm performance in the PA. Also, this section provides relevant information to make a strong case as to why it is relevant to find cross-country comparisons of firm performance among Chile, Colombia, Mexico and Peru.

2.1 The Pacific Alliance and the Economic Relation between Chile, Colombia, Mexico and Peru

Chile, Colombia, Mexico and Peru, are all founding members of The Pacific Alliance, a regional integration initiative created on April 28, 2011. The PA is an economic and trade bloc between four Latin American countries that pursues commercial and political integration, and aims to increase economic ties with Asian markets. As a whole, the PA constitutes the eighth largest economy, and represents the seventh largest exporting entity worldwide. In Latin America and the Caribbean, the block represents 36 percent of regional GDP, concentrates 50 percent of the total trade, and attracts 41 percent of foreign direct investment that flows to the region. The four countries have a combined population of 212 million people with an average GDP per capita of 10 thousand dollars.3

According to the mission statement of the PA, it is an “open and non-exclusive integration process, consisting of countries with related visions of development that

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promote free trade as a driver for growth”⁴. Regarding its values, the PA argues that it is focused “on modernity, pragmatism and political will to establish an initiative to address the challenges required by the international economy”⁵. Finally, its vision is to become “an area of deep economic integration and to move gradually toward the free circulation of goods, services, capital and persons”⁶.

Given the size of the combined economies of the four countries of the PA, and the potential of the PA to become an area of free trade of goods, capital and services, it results relevant to identify regional and country specific characteristics that affect firm performance. Also, for policy makers in each country, it is useful to identify how national firms compare to those in peer countries in absence of trade barriers.

2.2 Firm characteristics in the countries of the Pacific Alliance

This section presents some of the characteristics of firms in the countries of the PA that can potentially affect firm profitability using the information provided by the World Bank Enterprise Survey (ES) of 2010. The ES offers information on 4,455 firms surveyed in the PA (See 7Appendix A); allowing to present an overview of the performance of firms in the PA, and to compare firm characteristics across the four countries of interest.

Firm Size
The number of employees of a firm is used as a measure of firm size. According to the ES, on average, the firms of the PA have 32 employees. Colombia has smaller firms on average (17 employees) and Mexico the largest firms (38 employees). Figure 2.1, shows that on average large firms have a higher sales margin than the average firm in the PA.

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⁵ Ibid.
⁶ Ibid.
The opposite holds for firms that have a single employee. For the purposes of this study, and given the average size of firms in the PA, a large firm is defined as a firm with 150 employees or more. In the sample, 9 percent of the firms of the PA are large firms and 2 percent of the firms have a single worker.

**Figure 2.1: Sales Margin by Country and Firm Size**

![Sales Margin by Country and Firm Size](image)

Source: Authors calculation based on World Bank Enterprise Survey 2010

**Foreign Trade and Foreign Ownership**

Of the sample of surveyed firms in the PA, 18 percent of the firms are exporters. A firm is considered an exporter if at least 5 percent or more of their total direct sales go to foreign markets. A shown in Figure 2.2 firms that export have a larger sales margin than that of the average firm in the PA. This holds for exporting firms in Colombia, Mexico and Chile. However in Peru the average margin of exporting firms is below of the average sales margin for a Peruvian firm.

In the Pacific Alliance, on average 7 percent of the firms have foreign ownership. In this study firms classified as having foreign ownership are those in which at least 5 percent
of the firm is foreign owned. As in the case of exporting firms, firms that have foreign ownership are more profitable than the average firm in the Pacific Alliance. This also holds for firms in Colombia, Mexico and Chile.

**Figure 2.2: Sales Margin for Exporting and Foreign owned Firms by Country**

![Sales Margin Graph]

Source: Authors calculation based on World Bank Enterprise Survey 2010

**Production Costs**

Production costs for the firms of the PA are divided into direct and indirect costs. Direct costs include the cost of capital, labor and intermediate goods. Indirect costs are divided into energy costs and other indirect costs (including transport costs). On average, for firms of the PA, the cost of raw materials, or intermediate goods, represent the largest share of total costs (44 percent), followed by the cost of labor (23 percent). Figure 2.3 presents the distribution of costs for each of the countries.
Figure 2.3: Input costs as a percentage of total costs

Table 2.1 presents in detail the share of energy in total costs. On average, energy costs represent 3 percent of total costs in the region. For firms in Mexico, energy costs as a share of total costs are above the average of that in the PA, and only in Peru the share of energy costs is below than that for the PA.

Table 2.1: Energy Costs as a Percentage of Total Costs and Total Sales

<table>
<thead>
<tr>
<th></th>
<th>Sales</th>
<th>Total Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colombia</td>
<td>2.30%</td>
<td>2.59%</td>
</tr>
<tr>
<td>Mexico</td>
<td>3.21%</td>
<td>3.37%</td>
</tr>
<tr>
<td>Peru</td>
<td>2.35%</td>
<td>2.23%</td>
</tr>
<tr>
<td>Chile</td>
<td>2.77%</td>
<td>2.84%</td>
</tr>
<tr>
<td>Pacific Alliance</td>
<td>2.74%</td>
<td>2.90%</td>
</tr>
</tbody>
</table>

Source: Author’s calculations based on World Bank’s Enterprise Survey 2010

2.3 Electricity Systems in the countries of the Pacific Alliance
The electricity systems in the countries of interest vary widely in size (Table 2.2), both in terms of demand and capacity of generation. Mexico has the largest electricity system of the four countries.
In terms of prices, the average tariff ranges from 0.2 US$ to 0.1US$, with Chile having the highest tariff. The average tariff includes the price paid by households and firms.

Table 2.2: Electricity Systems in Countries of the Pacific Alliance

<table>
<thead>
<tr>
<th>Country</th>
<th>Peak Demand (MW)</th>
<th>Installed Generation Capacity (MW)</th>
<th>Gross Generation (GWh)</th>
<th>Avg. Tariffs (US$/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chile</td>
<td>6,059</td>
<td>17,949</td>
<td>65,713</td>
<td>0.20</td>
</tr>
<tr>
<td>Colombia</td>
<td>9,295</td>
<td>14,466</td>
<td>61,822</td>
<td>0.10</td>
</tr>
<tr>
<td>Mexico</td>
<td>38,000</td>
<td>61,512</td>
<td>295,837</td>
<td>0.14</td>
</tr>
<tr>
<td>Peru</td>
<td>5,575</td>
<td>8,557</td>
<td>39,223</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Source: Inter-American Development Bank Country Energy Outlooks

According to the Planning Unit of Mining and Energy of Colombia, in Latin America electricity prices are homogeneous among different industrial sectors; they vary only in terms of the level of connection. This means that large energy consumers, often industrial consumers, have different electricity tariffs than those of domestic or small energy consumers. As shown in Figure 2.1 the electricity prices for industries connected at 57.7 KV or above range from $US0.041 in Peru to $0.11 in Chile. Also, Figure 2.1 indicates that Chile and Colombia have shown the largest increases in electricity prices in the period ranging from 2005 to 2010. Also, with the exception of Peru the other countries of the PA have higher electricity tariffs for the industry than those of the US.
In terms of the sources of electricity generation, there are also significant variations among the countries of interest (Table 2.3). Hydroelectricity is the most important source of electricity generation in Colombia, and it accounts for 55 percent of generation in the region. Natural gas is the most important source for Mexico, and among the sampled countries it has the largest share of oil as a source for generation. Chile has the most balanced energy matrix, and in the case of Peru both hydro sources and natural gas are the most significant sources. Other generation such as biomass, geothermal, wind, and solar makes up less than eight percent of electricity generation in the countries of interest (IDB, Country Energy Outlook 2013).

The sources of electricity generation are associated with particular fuels, which are one of the drivers of electricity generation costs in each of the countries. Therefore, it is expected that countries like Colombia that rely more heavily on hydropower are less vulnerable to energy cost increases associated with the price of fossil fuels such as oil or...
coal. However, countries relying on renewable but seasonal or non-firm energy sources are also vulnerable to changes in the availability of the primary energy source; and in the case of hydropower availability is dependent upon hydrological and weather cycles.

Table 2.3: Sources of Electricity Generation at Utility Scale

<table>
<thead>
<tr>
<th>Country</th>
<th>Oil Products</th>
<th>Natural Gas</th>
<th>Coal</th>
<th>Hydro</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chile</td>
<td>10%</td>
<td>21%</td>
<td>30%</td>
<td>32%</td>
<td>8%</td>
</tr>
<tr>
<td>Colombia</td>
<td>1%</td>
<td>13%</td>
<td>3%</td>
<td>79%</td>
<td>3%</td>
</tr>
<tr>
<td>Mexico</td>
<td>16%</td>
<td>53%</td>
<td>12%</td>
<td>12%</td>
<td>7%</td>
</tr>
<tr>
<td>Peru</td>
<td>6%</td>
<td>36%</td>
<td>2%</td>
<td>55%</td>
<td>2%</td>
</tr>
<tr>
<td>Regional Total</td>
<td>11%</td>
<td>22%</td>
<td>6%</td>
<td>53%</td>
<td>8%</td>
</tr>
</tbody>
</table>

Note: Regional Total includes all countries in Latin America

2.3.1 Energy Access and Service Quality
Access to electricity is high in Latin America, on average countries in the region have a 93 percent access to electricity (Figure 2.5); and in the four countries of interest, 90 percent or more of the population has access to electricity. Only in Peru, access to electricity is below the regional average, while Chile and Mexico exhibit an almost universal access to electricity service.

7 Average for all countries, not weighted by population.
Electricity service quality varies across the region, (Figure 2.6: Quality of Electric Supply). According to the rating of energy quality of the World Economic Forum’s Competitiveness Report 2014, all the countries of the Pacific Alliance fair above the average of Latin American. The rating on energy quality is based on respondents’ qualitative assessment of the quality of electricity supply going from 1 to 7, with 1 being “insufficient and suffers frequent interruptions” and 7 being “sufficient and reliable”. For the rating, the respondents take into account lack of interruptions and lack of voltage fluctuations in the supply of electricity, as an indication of quality (World Economic Forum’s Competitiveness Report 2014). Chile and Colombia exhibit the best quality among the countries of the Pacific Alliance. Mexico is the only country with electricity service quality similar to the mean of Latin America.

Source: World Bank Indicators 2012
Another measure of energy quality is the number of electricity outages reported by users in a typical month. According to the ES, on average firms in the Pacific Alliance experience 2 outages on a typical month with an average duration of 4.5 hours. Mexican firms report the largest number of outages with an average duration of 6.3 hours. This information is consistent with the results of the energy quality index of the WEF’s Competitiveness Report. By contrast, Colombia shows the smallest number of power outages on average, with duration of 3 hours.

Table 2.4: Number of Power Outages Reported by Firms in a Typical Month
2.3.2 Electricity Regulatory Systems

Most electricity sectors in Latin America have competitive environments for generation and a single independent regulator with responsibility for setting tariffs and other aspects of electricity generation, such as service standards. Table 2.2, provides an overview of the regulatory structures in the countries of interest. It is important to note that in all the countries the electricity regulator is responsible for setting tariffs. This is true for tariffs paid by households, but not necessarily for large energy consumers that can negotiate tariffs directly with generators.

Table 2.5: Regulatory Structures in the Latin American Electricity Sector

<table>
<thead>
<tr>
<th>Country</th>
<th>Electricity Regulator</th>
<th>Entity Responsible for Setting Tariffs</th>
<th>Incumbent has exclusive right to generate?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chile</td>
<td>Comisión Nacional de Energía (CNE) and the Superintendencia de Electricidad y Combustibles</td>
<td>CNE</td>
<td>No</td>
</tr>
<tr>
<td>Country</td>
<td>Electricity Regulator</td>
<td>Entity Responsible for Setting Tariffs</td>
<td>Incumbent has exclusive right to generate?</td>
</tr>
<tr>
<td>---------</td>
<td>-----------------------</td>
<td>----------------------------------------</td>
<td>--------------------------------------------</td>
</tr>
<tr>
<td>Colombia</td>
<td>Comision de Regulacion de Energía y Gas (CREG) and Superintendencia de Servicios Publicos (SSPD)</td>
<td>CREG</td>
<td>No</td>
</tr>
<tr>
<td>Mexico</td>
<td>Comisión Reguladora de Energía (CRE)</td>
<td>CRE</td>
<td>No</td>
</tr>
<tr>
<td>Peru</td>
<td>Organismo Supervisor de Inversion en Energia y Mineria (OSINERG)</td>
<td>OSINERG</td>
<td>No</td>
</tr>
</tbody>
</table>

Source: Website of regulatory authorities. CNE, CREG, CRE, OSINERG

Electricity market regulations, and competition in the electricity sector, are relevant determinants of energy costs in each of the countries of interest. As an example, the energy reform in Mexico described in Box 2, illustrates the impact and relevance that regulation in the energy sector has on energy costs, quality and electricity provision.
Box 2.1: Energy Reform in Mexico

In December of 2013, the Mexican government passed a comprehensive reform for the energy sector in order to increase competition, investment and private participation in the sector. The reforms allow the state owned, National Electricity Utility (CFE) and individuals to engage in electricity generation freely. The regulation and operation of the electricity market will no longer be an exclusive activity of CFE.

The National Center of Energy Control (CENACE) will manage the Mexican electrical system. This implies a new model of generation, transmission, distribution and sale of electricity that will increase competition in generation and possibly increased private participation and investment in power transmission and distribution. This could potentially alter prices in Mexico and result in significant reductions of energy costs for big industrial consumers and manufacturing firms.

Source: SENER. “Reforma Energética Resumen Ejecutivo “

3 Literature Review

There is an extensive body of literature that explores the drivers of total factor productivity (TFP), which is associated with the efficiency with which firms turn production inputs into outputs. The interest in characterizing the drivers of TFP, was partly spurred by seminal work of Solow (1957) that indicated that TFP is one of the most important drivers of economic growth.

In order to identify particular elements that explain differences and drivers of TFP, several authors turned to investigate the relation between TFP, and infrastructure stock and growth. In this vein, Aschauer (1989) explored the relationship between TFP and infrastructure in the US, and he finds that the stock of public infrastructure capital – including electricity – is a significant determinant of aggregate TFP. After the work by Aschauer other empirical studies have investigated the relation between growth,
productivity and infrastructure, at the macro level. However, several authors (Straub, Vellutini and Warlters 2008) suggest interpreting the evidence with caution. They point out that the primary function of infrastructure investments may not be to directly promote economic growth but rather relieve constraints and bottlenecks to growth as they arise. Also, Ayogu (2007) conducts an extensive review of the empirical literature that examines the intersection between infrastructure and productivity and concludes that the question of whether infrastructure matters for growth has not been satisfactorily resolved. Moreover, the author proposes to focus future research efforts on analyzing how much infrastructure matters looking at different contexts.

While the overall effect of infrastructure, and in particular of electricity infrastructure, at the macro-level has not been resolved, the evidence points at a significant relationship between electricity and productivity at the firm level. The stock and quality of physical infrastructure, that includes energy access and affordability, is considered as one of the elements that impact productivity and production costs at the firm level. For example, Moya (2013) identifies the relation between power infrastructure and manufacturing productivity at the firm level in African countries. Also, according to the 2014 World Bank Doing Business Report, electricity matters for private sector development. Unreliable electricity supply and high connection costs hinder business activity, because it can potentially limit firm productivity. In an analysis of investment climate surveys from 26 African countries, Escribano et al. (2009) find that a low infrastructure quality has a significant negative impact on total factor productivity. In particular, they find that poor-quality electricity supply is the infrastructure element that has the strongest negative effect on enterprise productivity. Also, there are a number of studies that find evidence
of links between electricity access and quality of electricity supply, with productivity of small and medium sized firms (WEF Competitiveness Report, 2013). One of the early works is Barnes and Binswanger (1986) that finds that rural electrification has a positive impact on agricultural productivity through investment on water pumps. Later, several studies find evidence of a positive relation between electricity access and firm productivity in developing countries. For instance, Blalock and Veloso (2007), find for a sample of 20,000 Indonesian firms that power supply problems are of considerable relevance to firm productivity. For a number of African countries, Arnold, Mattoo and Narcisco (2008) find for a sample of 1000 manufacturing firms that unreliable electricity supply has a significant negative impact on a firm’s total factor productivity, while generator possession has a significant positive effect. In Bangladesh, Fernandes (2008) finds a significant that power supply problems are of considerable relevance to firm productivity.

Most of the evidence for developing countries focuses on the effects of access and quality of electricity on productivity rather than on the effects of energy costs on firm level productivity. However, Eifert et al. (2005), investigate the relationship of energy costs and productivity at the firm level in Africa. The authors show that indirect costs (of which energy costs comprise the largest share) are a major factor for explaining the low productivity of enterprises in Africa using World Bank’s firm level data on Investment Climate Assessments. Also, Fisher et al. (2014) analyzing an unbalanced panel of 23,000 energy-intensive Chinese firms from 1999 to 2004, find that in presence of electricity shortages, firms re-optimize among inputs of production by substituting materials for energy to avoid substantial productivity losses. Also, they find that while productivity is
not hurt by changes in the electricity supply, unit production costs increase by eight percent. For the case of Latin America, Alvarez et al. (2008) evaluate the impact of recent cost shocks caused by energy prices on the productivity of Chilean manufacturing plants. The authors use firm level information for the period 1999-200 and find a negative statistical relationship between productivity and energy costs. In particular, they estimate that a 10% increase in the energy price is associated to a reduction of productivity around 1% in the short-run and 2% in the long run. This effect tends to be larger for larger plants.

4 Hypothesis and Motivation
The evidence on the relationship between energy access, costs and quality of energy supply tends to be highly country and context specific. In addition, most of the evidence that finds a relationship between energy and productivity has been on countries in Africa and South East Asia. Thus, a comprehensive and comparative study on specific aspects of physical infrastructure that affect firm level productivity, in selected Latin American countries, is still missing. This paper aims to expand the literature on the intersection of energy as a component of physical infrastructure, and productivity at the firm level for the four member countries of the PA.

Given the characteristics of the PA, it is relevant to study and compare the drivers of productivity specifically in these countries for 3 reasons: (i) the relative size of the PA in Latin America, (ii) the economic and trade integration potential among the member countries, and (iii) the potential development of a shared energy agenda and common energy policies. In addition, Saliola and Seker (2011), indicate that total factor productivity (TFP) should be one of the indicators used by policymakers to promote private sector activity, given that TFP is a measure of efficiency at the firm level. In
consequence, this study aims to characterize the drivers of productivity in the PA, to inform the debate regarding the policy options that can improve firm performance in the region and in each particular country.

**Research Hypothesis**
The countries of the Pacific Alliance have differences in their electricity systems, electricity tariffs, and in their energy demand and use. Thus, the hypothesis of this paper is that energy costs explain cross-country differences in productivity. In addition, for the case of the selected countries, it is expected that electricity costs have a significant relation with firm level productivity measured as TFP. In turn, it is expected that the input factor elasticity of energy to production is positive and significant.

In order to test these hypotheses, it is necessary to have a comparable measure of TFP at the firm level across the selected countries, using the information provided by the World Bank Enterprise Survey on the outputs and inputs of the firms, and their energy costs.

**5 Data and Empirical Analysis**
This section describes the empirical strategy, the data, and the variables used to estimate a comparable measure of firm productivity for the PA countries. Also it presents the strategy to estimate the factor input elasticity of production of energy for the PA and for each country (Colombia, Chile, Mexico and Peru). Section 5.1 presents the empirical model used to estimate total factor productivity at the firm level and input factor elasticity of each of the inputs of production. Then, Section 5.2 describes the data used and the definition of the key variables included in the estimation of TFP.
5.1 Empirical Model

According to Eifert et al. (2011) productivity examines the relation between physical outputs produced for a given quantity of physical inputs. Econometric analyses of productivity often use data on the value of sales as a measure for output and the value of labor, and capital as a measure of inputs to estimate TFP. There are multiple methodologies that can be used to estimate productivity at the firm level, using different functional forms to describe the relation between outputs and inputs. I propose to use the approach of Saliola and Seker (2011), who employ a standard Cobb-Douglas production function with three factors of production—capital, labor, and intermediate goods—to estimate cross-country productivity at the firm level. Equation 1a presents the specification of the standard Cobb-Douglas production function, and formulates a relationship between output \( y_i \), and the factors of production labor \( L_i \), capital \( K_i \), and intermediate goods \( M_i \) for a particular firm (subindex \( i \)). In the Cobb-Douglas specification, all of the variables are expressed as logarithms, and as a result the coefficients of each of the inputs represent the elasticity of labor, capital and intermediate materials to production. Alternatively, equation 1b, presents a second approach to estimate the Cobb-Douglas production function, using as an independent variable a measure of net output or value added \( VA_i \). In equation 1b, value added is measured as the difference between the value of final output \( y_i \) and the value of intermediate goods \( M_i \). Also, in equation 1b the variables are expressed as logarithms. In turn, the coefficients of labor and capital, represent their respective elasticity to value added, or the percentage of net output that is produced by an additional unit of labor or capital.
\[ y_i = \alpha_0 + \alpha_1 L_i + \alpha_2 K_i + \alpha_3 M_i + \tilde{\beta}_2 Z_i + \epsilon_i \]  
\[ VA_i = (y_i - M_i) = \alpha_0 + \alpha_1 L_i + \alpha_2 K_i + \tilde{\beta}_2 Z_i + \epsilon_i \]  
\[ (TFP_i) = y_i - \hat{\alpha}_0 - \hat{\alpha}_1 L_i - \hat{\alpha}_2 K_i - \hat{\alpha}_3 M_i = \hat{\epsilon}_i \]

In addition to the standard Cobb-Douglas specification, Equations 1a and 1b include a vector of dummy variables \((Z_i)\) for each sector of production to control for sector fixed effects\(^8\). This vector of dummies is included to account for possible sector heterogeneity. According to Moya (2008), these dummies can also capture the differences in factor endowments across sectors that are correlated with firm performance.

Finally, equation 1c, demonstrates that in the Cobb-Douglas production function total factor productivity \((TFP)\) of a particular firm can be calculated as the residual term of the production function specified in equation 1a.

In order to identify the relationship between energy costs and productivity, this research follows the empirical methodology used by Eifert et. al (2005). The authors include in the Cobb-Douglas production function (Equation 1a) variables to account for indirect costs, which can be desegregated in energy costs and other indirect costs. This specification considers both energy and other costs of production as additional inputs that impact TFP. This approach is presented in equation 2a, in which energy \((Energy_i)\) is measured as the value of electric energy costs in logarithms, and the variable of other costs is also measured as the value of other costs of production in logarithms. Equation 2b follows the same strategy, using value added or net output as the independent variable.

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\(^8\) Appendix A presents a description of the sectors included in the specification.
\[ y_i = \alpha_0 + \alpha_1 L_i + \alpha_2 K_i + \alpha_3 M_i + \hat{\beta}_3 \text{energy}_i + \hat{\beta}_4 \text{other}_i + \hat{\beta}_1 X_i + \hat{\beta}_2 Z_i + \epsilon_i \]  

(2a)

\[ VA_i = (y_i - M_i) = \alpha_0 + \alpha_1 L_i + \alpha_2 K_i + \hat{\beta}_3 \text{energy}_i + \hat{\beta}_4 \text{other}_i \hat{\beta}_1 X_i + \hat{\beta}_2 Z_i + \epsilon_i \]  

(2b)

\[ TFP_i = \hat{\beta}_0 + \hat{\beta}_1 X_i + \hat{\beta}_2 Z_i + \hat{\beta}_3 \text{energy}_i + \hat{\beta}_4 \text{other}_i + \mu_i = \hat{\epsilon}_i \]  

(2c)

In addition, equations 2a and 2b include a vector \((X_i)\) of observable variables of firm characteristics that potentially affect productivity. The vector of firm characteristics include variables for firm age, a dummy variable for foreign ownership, a variable to account for firm size (measured in terms of the number of employees), and a dummy variable to identify exporting firms. The variables included in vector \((X_i)\) are consistent with the approach used by Moyo (2011) to estimate firm level productivity for African firms, and with the evidence that suggests that productivity is affected by the age of firms and foreign ownership (De Kok et al. 2006). It is relevant to note that sector and firm specific factors might impact energy intensity of production and energy use. Thus, in equations 2a and 2b, the sector fixed effects and the vector of control variables \((X_i)\), isolate the effect of energy costs on output. Section 5.2 provides a broader discussion on the control variables included in the estimation of equations 2a and 2b.

Finally, equation 2c demonstrates that in the Cobb-Douglas production function, with indirect costs, total factor productivity \((TFP_i)\) can be calculated as the residual term of the production function specified in equation 2a. In turn, the coefficient of energy costs and other indirect costs represent the percentage change of output caused by increasing or decreasing energy and other costs respectively.
5.2 Data and definitions of key variables
To conduct the empirical estimation, this paper draws on the data of the World Bank’s Enterprise Survey (ES) of 2010. The ES is a “firm-level survey of a representative sample of the private sector at the country level that includes information on business environment topics including infrastructure, labor, and firm performance measures” (World Bank ES Methodology 2010). The 2010 ES, interviewed 12,855 enterprises in 30 Latin American and Caribbean countries, including registered firms in Colombia, Chile, Mexico and Peru. The ES provides a comparable measure of firm output and performance, because it relies on a standardized survey. Appendix A has a description of the number of firms that are included in the analysis for each country and the sectors that are identified for the firms.

Variables to measure TFP
Using the information available in the ES, the following variables are used as proxies for the output and inputs of the Cobb Douglas function described in Equation (1a) for each firm in the sample: (i) sales as a measure of output; (ii) the replacement value of machinery, vehicles and equipment as a of measure capital; (iii) the total compensation of workers including wages, salaries and bonuses as a measure of labor; and (iv) the cost of raw and intermediate materials as a measure of intermediate goods. Value added or net output is calculated as the difference between sales and the value of intermediate goods. All this variables are reported in annual nominal terms in the currency of the respondent’s country. For estimation purposes all variables are converted into a common currency (US dollars) using the average exchange rate of 2010 provided by the central bank of each of

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9 Information available in the Methodology page of the Enterprise Surveys website: http://www.enterprisesurveys.org/Methodology
the countries of the Pacific Alliance. Appendix B provides more detail on the effect using alternative conversion factors to estimate cross-country TFP. Also, in order to correct potential measure and reporting errors, only the observations between three standard deviations away from the mean for each individual country are included in the estimation.

**Indirect costs**

The ES provides information on the annual indirect costs reported by firms. These costs are desegregated into energy costs and other indirect costs, and are reported in annual nominal terms in the currency of the respondent’s country. Energy costs reported include all of the total annual costs of electric energy purchased from private or public providers. Other costs are measured as the difference between total indirect costs, and the costs of energy, telecommunications and fuel. Again, these variables are converted to a common currency (US dollars) for estimation purposes, and only observations between three standard deviations away from the mean for each individual country were included in the estimation to avoid reporting errors.

**Control variables**

Variables on firm characteristics are included to control for potential sources of endogeneity in the estimation of TFP. The ES provides information on multiple firm characteristics such as size, age, type of ownership and foreign trade. For the estimation, age is calculated as the difference between the year of the survey and the year in which the establishment was opened. Size, is measured according to the number of employees and is captured by two dummy variables: large firm and single worker. Large firm is a dummy that takes the value of 1 if the firm has 150 employees or more and zero otherwise, and single worker takes the value of 1 if the firm has only one employee and zero otherwise. For describing the type of ownership, the estimation includes a dummy
variable of foreign ownership that takes a value of one if the firm has at least 5% of foreign ownership and zero otherwise. Finally, there is a dummy variable to identify exporting firms that takes the value of one if more than 5% of a firm’s sales were direct exports in the year of the survey and zero otherwise.

It is expected that specific firm characteristics such as age, size, type of ownership and participation in foreign trade have a relation with firm productivity. For example, there is empirical evidence that indicates that larger firms are more productive because they have better access to finance and skilled labor (Pagés 2010). Furthermore, as shown in Section 2.2.1, for the countries of the PA, the sales margin of firms (a proxy of profitability and firm performance) varies with firm size, foreign trade and type of ownership. As a result, it is expected that those firm characteristics are also correlated with productivity, and thus it is relevant to include them as control variables.

6 Results
This section introduces the results of the estimation of a Cobb-Douglas production function for the PA, using equations 1a and 1b described above (Section 6.1). Then, it describes the results of the estimation of equations 2a and 2b, to identify the effect of energy costs on firm output (Section 6.2), and finally it presents a discussion and analysis of the results (Section 6.3), to identify if the results are robust to changes in variable specification.

6.1 Estimation of the Production Function for the Countries of the Pacific Alliance
Equations 1a and 1b were estimated using Ordinary Least Squares. The coefficients of the inputs (capital, labor and raw materials) in the estimation of the Cobb-Douglas production function can be interpreted as input factor elasticities of production. For the
specification in equation 1a, the estimation results indicate that the average input factor
elasticity to output for the countries of the PA are 0.03 for capital, 0.44 for labor, and
0.52 for intermediate materials. This indicates that for the countries of the PA, a 10
percent increase in capital is associated with an increase in output of only 0.3 percent;
while a 10 percent increase in labor, on average, increases output by 4.4 percent, and a 10
percent increase in the use of intermediate goods increases output by 5.2 percent. For the
specification in equation 1b, the coefficients on capital and labor are 0.07 and 0.83
respectively. This indicates that a 10 percent increase in capital is associated with 0.7
percent increase in value added, while the same increase in labor use raises by 8.3 percent
value added of output. These results are statistically significant, and further details on the
estimation results are presented in Table B.1 in Annex B.

**Country specific results**
In addition to cross-country estimation of input coefficients, this section provides country
level regressions of the production function using as a dependent variable output
(Equation 1a). Figure 6.1 presents the coefficients of each of the inputs (i.e. the input
factor elasticities of production) for each country. For all of the countries the coefficients
on capital, labor and raw materials are positive and statistically significant (See Appendix
C for details on estimation results). Also, Figure 6.1 shows that for each country and on
average for the region, the sum of the input coefficients is around one. This corresponds
to the assumption of the Cobb-Douglas production function.

The results indicate that the coefficient of capital is lowest in Mexico and Colombia with
an average value of 0.02, indicating that a 10 percent increase in capital is associated with
an increase in output of just 0.2 percent. Both Peru and Chile exhibit a share of capital
above that of the PA as a whole. This indicates that an additional use of capital in both countries has a larger impact on output than it does in Mexico and Colombia.

Regarding the effect of labor on productivity, the results indicate that Peru exhibits the lowest coefficient of labor in the production function estimate. This result indicates that additional increases in labor use in Peru yield less production units than would be the case in the other economies of the Pacific Alliance. On the contrary, Mexico has the largest coefficient for labor, and thus an increase in 10 percent of labor use yields a 4.7 percent increase in output. In the case of raw materials, Colombia exhibits the largest share of input elasticity for this factor of production.

**Figure 6.1: Input Factor Coefficients for the Countries of the Pacific Alliance**

![Input Factor Coefficients for the Countries of the Pacific Alliance](image)

Source: Authors own Calculations.

### 6.2 Estimation of Input Elasticity of Energy to Production

The estimation results of equations 2a and 2b are presented in Table 6.1. The results indicate that energy as an input of production has a positive and statistically significant effect on both output and value added for the countries of the Pacific Alliance. The input
elasticity of energy to production indicates that a 10 percent increase in energy use is associated with a 0.7 percent increase in output, and a 1.7 increase of value added or net output. It is important to note that the size of this effect is larger than that of capital. This indicates that output is more responsive to increases in energy use than it is to increases in capital, holding all other factors of production constant. In addition, the coefficient of energy is also large compared to that of other indirect costs. This indicates that energy is the indirect factor of production that has the largest impact on output production.

Regarding the control variables, the results indicate that for the countries of the PA, exporting firms and foreign owned firms are on average more productive. Also, large firms are on average more productive than small firms. Contrary with what the literature suggests, for the PA firm age is not correlated with firm performance.

Table 6.1: Results of Cobb-Douglas Production Function Estimation (Equations 2a and 2b)

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Output</th>
<th>Net Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital</td>
<td>0.015**</td>
<td>0.044*</td>
</tr>
<tr>
<td>Labor</td>
<td>0.407***</td>
<td>0.659***</td>
</tr>
<tr>
<td>Raw Materials</td>
<td>0.493***</td>
<td>-</td>
</tr>
<tr>
<td>Energy</td>
<td>0.076***</td>
<td>0.177***</td>
</tr>
<tr>
<td>Other Costs</td>
<td>0.004*</td>
<td>0.006*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Control Variables</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreign Owned</td>
<td>0080*</td>
<td>0.289**</td>
</tr>
<tr>
<td>Firm Age</td>
<td>-0.010</td>
<td>0.037</td>
</tr>
<tr>
<td>Large Firm</td>
<td>0.111**</td>
<td>0.250***</td>
</tr>
<tr>
<td>Single Worker</td>
<td>-0.144</td>
<td>-0.324</td>
</tr>
<tr>
<td>Exporter</td>
<td>0.075***</td>
<td>0.331***</td>
</tr>
</tbody>
</table>

Sector Fixed Effects | yes | yes |
Country specific results
In addition to cross-country estimation, this section provides country level regressions of the production function using as a dependent variable output (Equation 2a). Figure 6.2 presents the coefficients of each of the inputs including energy for each country. For all of the countries the coefficients on capital, labor, energy and raw materials are positive and statistically significant (See Appendix C for details on estimation results). The results indicate that in Mexico, labor has the highest effect on output (0.44) and energy the least (0.03). The opposite holds for Colombia, where a 10 percent increase in labor is associated with a 0.3 percent increase in output and a 10 percent increase in energy is associated with a 1.3 percent increase in output. This results are consistent with those of other authors, for the case of Colombia Eslava et al. (2004) find factor elasticities of 0.08, 0.24, 0.12 and 0.59 for capital, labor, energy and materials respectively, which are similar to those estimated in this study.
Figure 6.3 presents the country specific results of the coefficient of energy estimated in equations 2a and 2b for each country. These results are statistically significant and indicate that on average Colombian firms experience a higher responsiveness of output to changes in electric energy costs and use. On average an increase of 10 percent in energy is associated with a 1.3 percent increase in output and a 2.4 percent increase in net output for Colombian firms. In Mexico, output and net output have the smallest responsiveness to changes in energy from all the countries in this study. These results indicate that energy has the largest impact on production in Colombia, followed by Chile, Peru and finally Mexico. The ranking of production responsiveness to energy among the four countries (i.e. 1.Colombia, 2. Chile, 3. Peru, and 4. Mexico) holds for both estimation specifications (equations 2a and 2b)
6.3 Sensitivity Analysis and Discussion

This section evaluates the sensitivity of the estimation results when controlling for energy quality in the countries of the PA (Section 6.3.1). Then it presents a discussion of the results for specific manufacturing and services sectors (Section 6.3.2). Finally, it provides a detailed discussion of the results for Colombia taking into account that it is the country where energy has the largest impact on output (Section 6.3.3).

6.3.1 Energy Quality

As mentioned in Section 3, the empirical evidence has found a negative relation between the low quality and unreliability of energy infrastructure and firm productivity and performance. Therefore, in addition to the measure of energy costs, in this section the study explores the effect of energy quality on output for the countries of interest. For this,
the number of outages that a firm experiences in a typical month (Table 2.4) is used as a proxy for energy quality.

The estimation results including the logarithm of the number of output outages, indicates that a 10 percent increase in the number of outages results in a reduction of 0.9 percent in output, however this result is not statistically significant (Table 6.2). In the case of the specification using net output as a dependent variable, the effect of power outages is negative and statistically significant. The results presented in Table 6, show that the coefficients of the inputs of production including energy are similar to those that omit the variable for energy quality presented above. Thus, for the countries of the PA energy quality has a limited impact on input substitution, since the share of each input in explaining input does not change when controlling for energy quality in the Cobb-Douglas production function estimation. Also, the estimation results are robust to changes in the specification including energy quality.

This result contrasts with the findings for African firms (Moyo 2013), where in general the empirical evidence finds a negative and statistically significant effect of energy quality on firm level productivity. For the countries of the PA, energy costs are more relevant for firm productivity than the quality and reliability of energy supply. This is not an indication that energy quality is not relevant for the PA, but an indication that energy supply is reliable and as a result energy costs are more relevant than quality in explaining the responsiveness of output to energy use.

**Table 6.2: Results of Cobb-Douglas Production Function Estimation with Energy Quality (Equations 2a and 2b)**

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Output</th>
<th>Net Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital</td>
<td>0.019**</td>
<td>0.047**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>Labor</td>
<td>0.402***</td>
<td>0.613***</td>
</tr>
<tr>
<td>Raw Materials</td>
<td>0.469***</td>
<td>-</td>
</tr>
<tr>
<td>Energy</td>
<td>0.091***</td>
<td>0.157***</td>
</tr>
<tr>
<td>Other Costs</td>
<td>0.001*</td>
<td>0.007</td>
</tr>
<tr>
<td>Power Outages</td>
<td>-0.09</td>
<td>-0.103**</td>
</tr>
</tbody>
</table>

**Control Variables**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreign Owned</td>
<td>0.119*</td>
<td>0.477**</td>
</tr>
<tr>
<td>Large Firm</td>
<td>0.091*</td>
<td>0.321**</td>
</tr>
<tr>
<td>Exporter</td>
<td>0.104**</td>
<td>0.265**</td>
</tr>
<tr>
<td>Single Worker</td>
<td>-0.063</td>
<td>-0.403</td>
</tr>
</tbody>
</table>

**Sector Fixed Effects**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

**Observations**

|                         | 1,213   | 1,223   |

---

Note: *** Significant at 1% level , ** Significant at 5% level *, Significant at 10% level

In addition, Figure 6.4: 95% Confidence interval for coefficient of Energy Quality (Outages) presents the country level regression results on the coefficients of the power outage variable. These results indicate that power outages have a different effect on each of the Pacific Alliance countries, but only in the case of Mexico this effect is statistically significant. This result is consistent with the claim that energy quality is only relevant in countries where energy supply is less reliable. As mentioned in Section 2.3.1, firms in Mexico report on average the larger number of outages in a typical month, while firms in the other countries consider that on average energy supply is reliable and experience less and shorter outages than firms in Mexico.
6.3.2 Sector Specific Results

This section provides sector level regressions of the production function using as a dependent variable output (Equation 2a). Figure 6.5 presents the coefficients of energy (i.e. energy factor elasticity to production) for the most representative sectors among the surveyed firms in the PA. For all of the sectors the coefficients on energy are positive, but its magnitude changes across sectors. This result indicates that energy use and the effect of energy cost varies across sectors. As expected, in the metal and machinery sector that is highly energy intensive, the responsiveness of output to energy is the largest, thus a 10 percent increase in energy is associated with a 2.2 increase in output. On the contrary in the food sector, a 10 percent increase in energy use is only associated with a 0.8 percent increase in output, this result is statistically significant. In turn, energy prices and affordability for firms have differential effects across sectors.
6.3.3 Analysis for Colombia

Colombia is a case of interest among the countries of the Pacific Alliance, because of the following characteristics: the quality of the energy supply is above the PA average, and the responsiveness of output to changes in energy is the largest among the region. For Colombian firms, on average a 10 percent increase in energy results in a 1.3 percent in output, while the effect for the PA is of only 0.7 percent.

In comparative terms, it is possible to argue that the Colombian public sector has contributed to improving access to electricity and to reduce the cost of getting electricity. According to the World Bank Development indicators, 97% of the Colombian territory has access to electricity, and at the firm level; losses due to electrical outages are 0.5% of total sales while this is 3.7% for the world average. However, firms indicate that energy costs are a major constraint to increase internationalization and growth of industrial firms.
Furthermore, according to the 2013 Doing Business report, 38% of firms in Colombia identify electricity as a major constraint for their establishments. The results of this paper support this claims, taking into account that firm output and profitability is highly responsive to changes in electric energy use, even for regional standards.

Figure 6.6 presents the estimation results of the coefficients for labor and energy using Equation 2a for specific sectors in Colombia. The results indicate that Colombian firms on average have the lowest labor productivity among the countries of the PA. Only in the case of the metal and machinery sector labor productivity is above that of the average for the PA. Taking into account that the metal and machinery sector is highly energy intensive, this result could potentially indicate that firms in Colombia that have a higher share of energy as an input for production are more likely to have a better performance than the average firm of the PA.
7 Policy Implications and Conclusion

The main objective of this paper was to characterize the interaction between electric energy and productivity at the firm level in four Latin American countries. Electric energy is both an input of production and a component of physical infrastructure, directly influencing the costs of production. Thus, policies that improve the quality, efficiency and cost of energy will potentially have a positive impact on firm performance. In addition, electric energy quality and affordability improves the business-enabling environment, and thus facilitates private sector development, especially of firms in traded sectors in open market economies like Colombia, Chile, Mexico and Peru.

The results of this paper indicate that electric energy costs matter for firm level productivity in the countries of the Pacific Alliance. In fact, for all the countries of the PA, the responsiveness of firm output to energy costs is larger than that of other indirect costs of production, and also than that of capital. Also, the estimation results indicate that
input elasticity of energy to production explains cross-country differences in productivity among the countries of the PA. The results show that for Colombian firms the responsiveness of output to changes in energy use is four times that of firms in Mexico. Thus, while all the countries in the PA would benefit from policies that reduce electric energy costs or improve its efficiency, the effect in each country, and in different sectors across countries, is significantly different.

The interest in looking specifically at the role of energy as part of physical infrastructure derives from the increasing concern in the policy debate in the countries of the Pacific Alliance regarding the impact of electricity prices on firm productivity and competitiveness. In the particular case of Colombia, business associations and industrial interest groups (National Association of Industries ANDI 2013) constantly advocate and push for a reduction of energy prices paid by firms, in particular by manufacturing firms. For the other countries of interest, electricity prices and energy efficiency policies are also part of the policy debate regarding private sector development. The ongoing implementation of the energy reform in Mexico, and the discussion of the electricity market regulation in Chile and Peru acknowledge the need to address electric energy costs\textsuperscript{10}, taking into account that on average firms in the region have higher electric energy prices than those of firms in the US.

The results of this paper suggest that investments in energy efficiency and in reduction of energy costs are a cost effective way to improve the business enabling environment for firms in the Pacific Alliance. It is widely known that in Latin America is necessary to improve infrastructure quality in order for firms to raise their productivity (Pages 2010).

The results of this study point at the importance of investing in a specific feature of physical infrastructure: electric energy. The empirical evidence provided indicates that investment in energy infrastructure and policies that promote result in the reduction of electricity cost or the adoption of energy efficiency practices can have a large and significant effect on firm performance in the PA.

For the particular case of Colombia the results indicate that adopting policies that reduce energy costs and increase energy efficiency are a viable alternative to increase firm performance. Colombia exhibits the lowest labor and capital productivity of the countries of the PA, however firm output is highly responsive to changes in energy use. Therefore, both firm profitability and productivity can be improved if firms re-optimize among inputs of production by substituting less productive inputs for energy to avoid productivity losses (Fisher 2014). In consequence, the results of this study indicate that both the private sector and governments in Colombia should invest in strategies that reduce the cost of electricity for firms, or alternatively that improve the efficiency in energy use. Investments in energy availability and affordability offer a cost efficient alternative for Colombian firms to improve their competitiveness against firms in other countries of the Pacific Alliance.
Appendix A Data Description

The firm level data was obtained from the 2010 Enterprise Survey (ES) of the World Bank. According to the methodology of the ES, the survey collects firm-level data on the business environment from business owners and top managers. Also, the ES interviews only formal (registered) companies with 5 or more employees, in the cities/regions of major economic activity. The surveys cover a broad range of topics including the access and cost of infrastructure, labor, and performance measures such as sales. As a result, it offers comparable measures of inputs and outputs of firms.

The ES of 2010 includes data for all of the member countries of the Pacific Alliance and there are 4,455 observations. Each observation represents a firm registered in one of the countries (Table A.1).

<table>
<thead>
<tr>
<th>Country</th>
<th>2010</th>
<th>Participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colombia</td>
<td>942</td>
<td>21%</td>
</tr>
<tr>
<td>Mexico</td>
<td>1,480</td>
<td>33%</td>
</tr>
<tr>
<td>Peru</td>
<td>1,000</td>
<td>22%</td>
</tr>
<tr>
<td>Chile</td>
<td>1,033</td>
<td>23%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4,455</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Source: Authors calculations based on World Bank ES 2010

The ES identifies the sector of each of the firms included in the survey. For the case of the countries of the Pacific Alliance, the majority of the firms are in the manufacturing sector, with the subsectors of food, metal and machinery, and chemicals and pharmaceutics accounting for the larger share of firms (Table A.2).
Table A.2: Number of Observations per Sub-Sector

<table>
<thead>
<tr>
<th>Sector</th>
<th>Sub-Sector</th>
<th>Number</th>
<th>Participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing</td>
<td>Textiles</td>
<td>386</td>
<td>9%</td>
</tr>
<tr>
<td></td>
<td>Garments</td>
<td>526</td>
<td>13%</td>
</tr>
<tr>
<td></td>
<td>Food</td>
<td>592</td>
<td>14%</td>
</tr>
<tr>
<td></td>
<td>Metals and Machinery</td>
<td>269</td>
<td>7%</td>
</tr>
<tr>
<td></td>
<td>Electronics</td>
<td>77</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>Chemicals and Pharmaceuticals</td>
<td>486</td>
<td>12%</td>
</tr>
<tr>
<td></td>
<td>Non-metallic mineral products</td>
<td>170</td>
<td>4%</td>
</tr>
<tr>
<td></td>
<td>Other manufacturing</td>
<td>362</td>
<td>9%</td>
</tr>
<tr>
<td>Retail</td>
<td>Retail and Wholesale</td>
<td>486</td>
<td>12%</td>
</tr>
<tr>
<td>Services</td>
<td>Other Services</td>
<td>608</td>
<td>15%</td>
</tr>
<tr>
<td></td>
<td>Construction</td>
<td>167</td>
<td>4%</td>
</tr>
</tbody>
</table>

Source: Enterprise Survey WB 2010

Table A.3 presents a summary of the descriptive statistics of some of the relevant firm characteristics for the selected countries.

Table A.3: Summary of average values of selected firm characteristics by country

<table>
<thead>
<tr>
<th>Country</th>
<th>Age of the establishment (years)</th>
<th>Domestic ownership in a firm (%)</th>
<th>Average Number of Employees</th>
<th>Single worker (%)</th>
<th>Large Firms (%)</th>
<th>Percentage of Exporters (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chile</td>
<td>24.7</td>
<td>92.9</td>
<td>16.9475</td>
<td>2.6%</td>
<td>9.9%</td>
<td>19.7%</td>
</tr>
<tr>
<td>Colombia</td>
<td>16.5</td>
<td>91.5</td>
<td>38.05407</td>
<td>1.9%</td>
<td>9.3%</td>
<td>17.7%</td>
</tr>
<tr>
<td>Mexico</td>
<td>18.9</td>
<td>93.9</td>
<td>36.4775</td>
<td>1.5%</td>
<td>6.3%</td>
<td>19.6%</td>
</tr>
<tr>
<td>Peru</td>
<td>16.5</td>
<td>96.0</td>
<td>34.31425</td>
<td>2.2%</td>
<td>8.9%</td>
<td>16.8%</td>
</tr>
</tbody>
</table>

Source: Author’s calculations using World Bank Enterprise Survey 2010
Appendix B  Robustness of Empirical Results
This Appendix presents the results of the estimation of equations 1a and 1b using 3 different conversion factors of the variables used as proxies of inputs and outputs provided by the World Bank ES in nominal local currency. The objective of this is to test the robustness of the empirical result to changes in the units of measurement of the key variables. The results are presented in Table B.1.

Conversion factors
In addition to the estimation of variables in nominal dollar terms, two alternative conversion factors are introduced to estimate the production function in real terms: (1) PPP Conversion Factor and (2) GDP deflator.

1. PPP conversion factors—using the World Bank Development Indicators (WBDI) Database, this study converts the nominal variables in local currency using the ratio of a country’s GDP measured in market prices to its income measured in PPP prices. This conversion factor provides an estimate of the aggregate price level of a country relative to that of other countries. The ratio ranges from less than 0.2 in some poor countries to 1 or higher in Organization for Economic Cooperation and Development (OECD) countries. For Peru the ratio is 0.5, for Mexico and Colombia 0.6 and for Chile 0.7.

2. Also using the World Development Indicators Database, this study converts the nominal values in local currency using the GDP implicit deflator. According to the WBDI, the GDP implicit deflator is the ratio of GDP in current local currency to GDP in constant local currency. The base year varies by country. Furthermore, the WBDI indicates that the GDP Deflator is an economic metric that accounts for inflation by converting output measured at current prices into a constant dollar
GDP. The GDP deflator shows how much a change in the base year’s GDP relies upon changes in the price level.

Table B.1: Summary of TFP estimation results for countries of the PA (Equations 1a and 1b)

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Specification 1 Nominal Dollars</th>
<th>Specification 2 PPP Adjusted</th>
<th>Specification 3 GDP Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Output</td>
<td>Net Output</td>
<td>Output</td>
</tr>
<tr>
<td>Capital</td>
<td>0.0231**</td>
<td>* 0.073**</td>
<td>0.024***</td>
</tr>
<tr>
<td>Labor</td>
<td>0.432***</td>
<td>* 0.832**</td>
<td>* 0.448***</td>
</tr>
<tr>
<td>Raw Materials</td>
<td>0.533***</td>
<td>- 0.521***</td>
<td>- 0.531**</td>
</tr>
<tr>
<td>Sector Fixed Effects</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Observations</td>
<td>2,662</td>
<td>2,697</td>
<td>2,662</td>
</tr>
</tbody>
</table>

Note: *** Significant at 1% level , ** Significant at 5% level *, Significant at 10% level

The results provided in Table B.1 show that the results of the estimated coefficient do not vary significantly when changing the conversion factor.
Appendix C: Summary of Empirical Results

Table C.1: Summary of Country Level Results (Specification Equations 1a and 1b)

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Colombia</th>
<th>Mexico</th>
<th>Chile</th>
<th>Peru</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Output</td>
<td>Net Output</td>
<td>Output</td>
<td>Net Output</td>
</tr>
<tr>
<td>Capital</td>
<td>0.020**</td>
<td>0.046**</td>
<td>0.042*</td>
<td>0.051**</td>
</tr>
<tr>
<td></td>
<td>0.059**</td>
<td>0.092**</td>
<td>0.100***</td>
<td>0.199**</td>
</tr>
<tr>
<td>Labor</td>
<td>0.395***</td>
<td>0.939***</td>
<td>0.494***</td>
<td>0.593***</td>
</tr>
<tr>
<td></td>
<td>0.430***</td>
<td>0.850***</td>
<td>0.341***</td>
<td>0.792***</td>
</tr>
<tr>
<td>Raw Materials</td>
<td>0.566***</td>
<td>-</td>
<td>0.167***</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>0.476***</td>
<td>-</td>
<td>0.545***</td>
<td>-</td>
</tr>
<tr>
<td>Sector Fixed Effects</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Observations</td>
<td>749</td>
<td>549</td>
<td>1066</td>
<td>1057</td>
</tr>
<tr>
<td></td>
<td>589</td>
<td>589</td>
<td>517</td>
<td>517</td>
</tr>
<tr>
<td>Note: *** Significant at 1% level , ** Significant at 5% level *, Significant at 10% level</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table C.2 presents the results of the country specific regressions. The control variables of firm age and single worker were omitted because they are not statistically significant and do not affect the estimation results.

Table C.2: Summary of Country Level Results (Specification Equation 2a)

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Colombia</th>
<th>Mexico</th>
<th>Chile</th>
<th>Peru</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital</td>
<td>0.042*</td>
<td>0.0341**</td>
<td>0.0348***</td>
<td>0.091***</td>
</tr>
<tr>
<td>Labor</td>
<td>0.301***</td>
<td>0.341***</td>
<td>0.36***</td>
<td>0.325***</td>
</tr>
<tr>
<td>Raw Materials</td>
<td>0.517***</td>
<td>0.157***</td>
<td>0.448***</td>
<td>0.525***</td>
</tr>
<tr>
<td>Energy</td>
<td>0.134*</td>
<td>0.085**</td>
<td>0.103**</td>
<td>0.0466*</td>
</tr>
<tr>
<td>Other Costs</td>
<td>0.005</td>
<td>0.024**</td>
<td>0.0054**</td>
<td>-0.007</td>
</tr>
<tr>
<td>Control Variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign Owned</td>
<td>0.164**</td>
<td>0.622***</td>
<td>0.004*</td>
<td>-0.018</td>
</tr>
<tr>
<td>Exporter</td>
<td>0.093*</td>
<td>0.886***</td>
<td>0.157*</td>
<td>0.321***</td>
</tr>
<tr>
<td>Large Firm</td>
<td>0.068</td>
<td>0.706***</td>
<td>0.024*</td>
<td>0.276***</td>
</tr>
<tr>
<td>Sector Fixed</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>
Effects

| Observations | 491 | 1036 | 549 | 443 |

Note: *** Significant at 1% level , ** Significant at 5% level *, Significant at 10% level

References