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The Impact of International Trade on Electric Loads in Mexico

Marc H. Vatter[a,*]

Daniel F. Suurkask[a]

[a]*Birch Energy Economics, 13670 West Prairie Avenue, Post Falls, Idaho 83854*
www.birchenergy.com

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* Corresponding author at: 9 Underhill Street, Nashua, NH 03060-4060, USA; marc@appliedecon.net; 603.402.3433 (land); 503.227.1994 (cell); www.appliedecon.net.

Abstract

We estimate effects relevant to a possible shift in U.S. trade policy on electric loads in Mexico. We find exports to be a highly significant predictor of energy loads and a significant predictor of peak loads in models that do and do not include GDP and a trend toward greater efficiency in the use of electricity. These results are consistent with trade impacting load through high load factor, industrial customers. We conclude that, if a shift in trade policy toward Mexico is seen as a realistic possibility, it would be worthwhile to analyze its impact on loads, especially energy loads, in scenarios.

Keywords: Trade; Electricity; Mexico

1 Introduction

The North American Free Trade Agreement liberalized trade among Canada, Mexico, and the United States and went into force in January of 1994. From 1990 to 1994, Mexico ran trade deficits with the United States, but it ran trade surpluses with the United States every year from 1997 to 2014, and those surpluses grew at 8.6% p.a.[1] Trade across the Rio Grande was an issue in the 2016 U.S. presidential campaign, and a shift toward a more protectionist stance in U.S. trade policy appears to be a possibility.

The wholesale electric market in Mexico is restructuring along lines established in other countries. The state-owned utility, Comisión Federal de Electridad (CFE), is in the process of creating transmission, distribution, supply, and six generation subsidiaries, each of which will be managed separately. The different generation subsidiaries will compete with one another and other entrants in spot and forward markets operated by the system operator, Centro Nacional de Control de Energía (CENACE). The restructuring has prompted a flourish of planning and analysis on the part of existing and new market participants, and the possible shift in U.S. trade policy adds an element of uncertainty to those efforts.

In particular, in modeling the restructured electric power market in Mexico, would forecasts of energy and peak loads be substantially affected? Should scenarios be "run" in which Mexico experiences lower exports? How should load forecasts be adapted to account for a possible decline in Mexican exports? How should overall Mexican GDP be adjusted in forecast models in relation to exports?

[1] Source: World Bank; http://data.worldbank.org/data-catalog/wits, accessed December 30, 2016.

To help answer these questions, we estimate the effects of Mexico's overall exports on energy and peak loads by Mexican electrical region (simplified to "region" hereafter), controlling for GDP and a trend toward energy efficiency. In Section 2, we provide a brief overview of electric loads in Mexico, including key drivers. In Section 3, we present the sample data used in our analysis. Section 4 describes our econometric methods and models. Section 5 presents and discusses results, and we conclude in Section 6. We clarify some econometric issues in the appendix.

2 Economic Development and Loads in Mexico

If one were to look back over the past 20 or 30 years, one might be tempted to conclude that Mexico is stuck in a "slow growth" trend, and its aspirations to realize developed country status have in large part not been realized. But the same observer would likely acknowledge a fundamental economic transformation over the same time frame. Gone is the day of only low end manufacturing – clothing, textiles, and simple assembly. In its place is a diversified industrial base, led by high-end manufacturing. Mexico now ranks as the seventh largest producer of cars in the world, with many of the major car manufacturers having or soon to have operations in the country.[2] Like the automotive industry, the aerospace, plastics, and medical device industries have seen tremendous growth.

[2] "Despite fears, Mexico's manufacturing boom is lifting U.S. workers," Aug 21, 2016. Available at http://www.latimes.com/projects/la-fi-manufacturing-boom-mexico/, accessed Jan 19, 2017.

In fact, Mexico has been able to establish itself as a manufacturing powerhouse, using to its advantage its proximity to the world's largest consumer market and its low wages relative to the U.S. Manufacturing now represents approximately 18 percent of GDP.[3]

Much of the export-oriented, high-end manufacturing is in the north of the country, along the U.S. border. Monterrey, in the Northeast region, has a very large manufacturing base, and is a major steel producing area. Electronics manufacturing is also important in the northern states of Chihuahua and Baja California.

However, owing to several factors, including the continuation of infrastructure development, high- and medium-end manufacturing in Mexico is now also increasingly prevalent away from the U.S. border, in states such as Guanajuato, Aguascalientes, San Luis Potosi, and Queretaro, collectively called the "Bajio".[4] Stratfor elaborates: [5]

> Unlike the border states, the central lowland region is a part of Mexico's economic and political heartland. It hosts a large, educated population, and its climate is the most temperate in the country. It is centrally located, with relatively easy access to ports on both coasts, the United States to the north, and Mexico City in the south.
>
> Geography has benefited the Bajio, as have improved transportation infrastructure, comparatively better security, and efforts to attract investment. More manufacturing investment and output will bring Mexico's industrial core closer to Mexico City and populations in need of jobs. Bajio manufacturing will not replace manufacturing

[3] "Mexico's Manufacturing Sector Continues to Grow", Apr 6, 2015. Available at https://www.stratfor.com/analysis/mexicos-manufacturing-sector-continues-grow, accessed Jan 19, 2017.
[4] The corresponding electric region is Occidental.
[5] "Mexico's Manufacturing Sector Continues to Grow", Apr 6, 2015. Available at https://www.stratfor.com/analysis/mexicos-manufacturing-sector-continues-grow, accessed Jan 19, 2017.

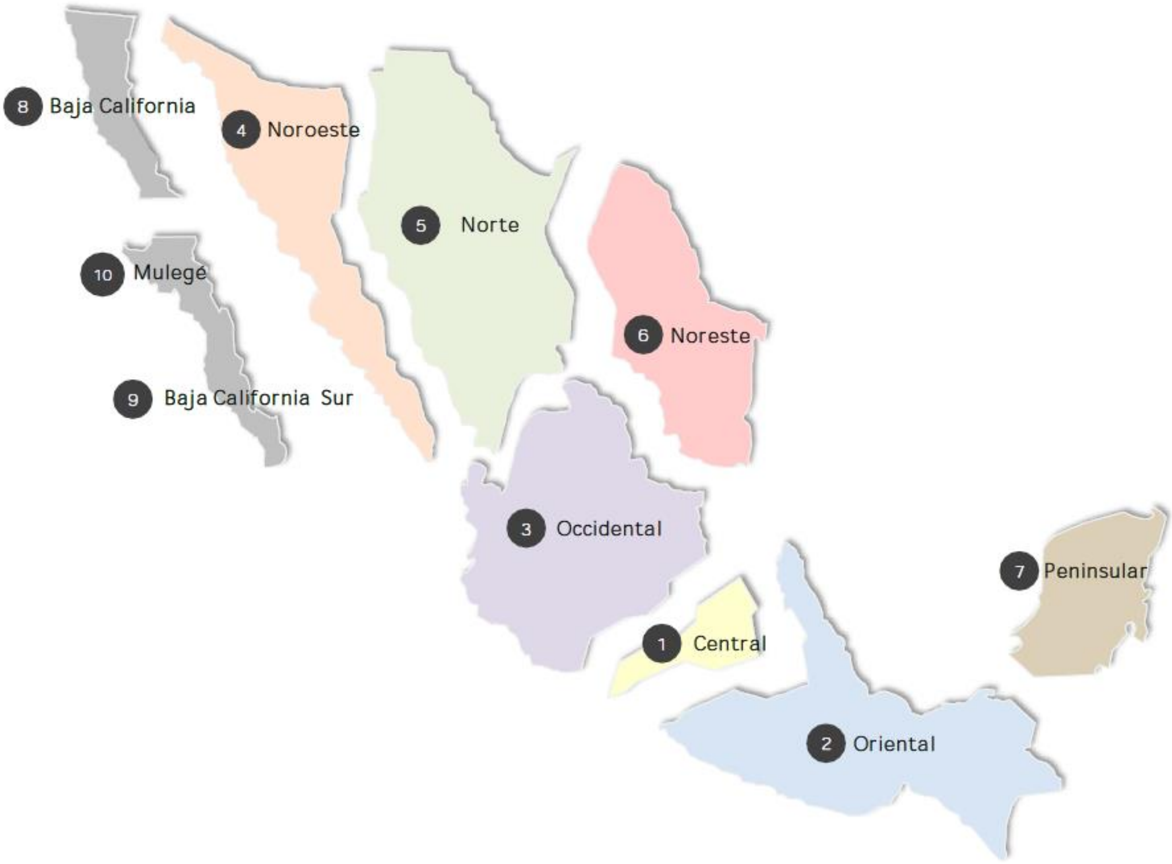
activity along the border, but it gives Mexico an opportunity to develop more evenly and sustainably.

In the south of the country, in the Oriental and Yucatan Peninsula (hereafter “Peninsular”) regions, in addition to the petroleum industry, low-end manufacturing of goods like clothing and textiles continue to make an important – and growing – contribution to the economy. Low-end manufacturing in these regions of Mexico has benefited, in part, from strong wage and transportation inflation in China.

We also mention the importance of the tourism and hospitality industry in the economic development – and load growth – of different areas of the country, but especially around Cancun, a popular tourist destination, in the Peninsular region.

Figure 1, below, shows the regions on a map of Mexico. (The Bajio is situated in the Occidental region.)

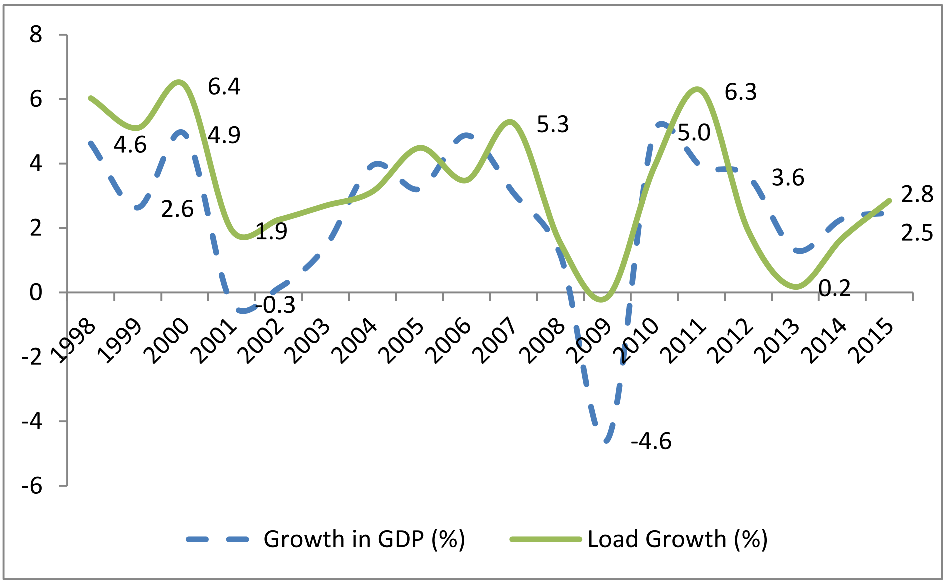
Figure 1: Mexican Regions[6]



Electric load growth and load shapes, as one might expect, reflect this economic transformation. Over the 1997-2015 period, load growth has averaged 3.0 percent. Over the same period, GDP growth has averaged 2.4 percent. As with the change in growth in GDP, load growth has been quite variable over this period. GDP growth and load growth, for the period 1997-2015, are shown in Figure 2, below.

[6] Source: PRODESEN 2016

Figure 2: GDP & Load Growth, 1997-2015[7]

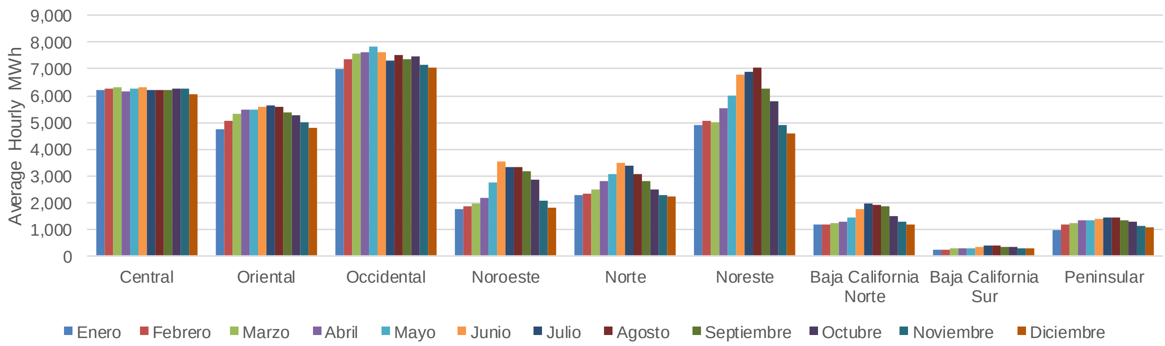


On the whole, Mexico has high load factors, with the electric grid covering most of Mexico maintaining an average 78% load factor between 2010 and 2015.[8] This, of course, reflects the large manufacturing base, as well as the relatively low penetration of air conditioners and a large body of population in the relatively temperate Mexico City and surrounding areas. In the North of the country, where temperatures are more extreme, load factors are lower than elsewhere, notwithstanding the manufacturing base. The primary driver of peak loads in the North of the country, then, is the use of air conditioning. In contrast, in the Central region, including Mexico City, the annual peak is typically in the winter around the Christmas festivities, owing to decorative lighting on homes and businesses, electric space heating, and additional lighting requirements owing to the shorter days.

[7] Sources: Secretaría de Energía (SENER) and Organization for Economic Cooperation and Development (OECD).
[8] Load factor is a measure of the load shape, namely average load divided by peak load. The higher the load factor, the less capacity is required to meet the energy requirements.

Figure 3, below, shows the distribution of load across the regions, and over the months. Estimated 2016 loads are shown in average hourly MW, by region and by month.

Figure 3: Monthly Load by Region[9]



As can be observed from the above chart, the two regions with the most load, Central and Occidental, have a relatively flat monthly load profile, owing largely to temperate weather year-round. The Noreste, Norte, Noroeste, and Baja California Norte loads exhibit more seasonal variation because of more extreme summer temperatures.

3 Data

We use historical load data from CFE and the Secretaría de Energía (SENER). Historical data on Mexican trade and GDP come from the Organization for Economic Cooperation and Development (OECD).[10] Table 2 shows the basic data used in our analysis. While Mexico

[9] Source: SENER, with modifications by authors.
[10] Source: OECD; http://stats.oecd.org/OECDStat_Metadata/ShowMetadata.ashx?Dataset=EO95_LTB&ShowOnWeb=true&Lang=en, accessed December 30, 2016.

has run a trade surplus with the United States, imports have exceeded exports overall. Because our focus is on Mexico, and because of the complex interactions between bilateral and multilateral trade, we analyze data on overall trade, rather than trade with the United States, implicitly assuming that a tightening of U.S. trade policy would lower Mexican exports overall. Using overall exports also broadens the applicability of our analysis beyond Mexico-U.S. trade.

Table 2: Basic Data

										Mexico		
	Baja Norte	Baja Sur	Central	Noreste	Noroeste	Norte	Occidental	Oriental	Peninsular	Exports	Trade Surplus	GDP
	Gigawatt Hours									$Million	$Million	$Billion
1997	6,739	1,039	37,059	26,208	11,900	12,006	33,947	26,524	4,523	121,603	-819	1,287
1998	6,954	1,063	38,859	28,571	12,100	12,970	36,178	28,260	4,923	129,187	-9,194	1,348
1999	7,674	1,130	40,711	30,293	12,519	13,624	38,385	29,231	5,201	148,083	-8,363	1,384
2000	8,641	1,200	43,080	32,464	13,046	14,698	40,955	30,835	5,711	179,863	-11,955	1,453
2001	8,927	1,231	44,515	32,958	13,463	15,404	40,682	31,040	6,123	171,465	-14,125	1,448
2002	8,827	1,231	45,335	34,040	13,120	15,856	41,774	32,259	6,331	173,803	-12,919	1,450
2003	9,334	1,282	46,313	34,406	13,649	16,178	43,262	33,021	6,746	177,375	-11,701	1,471
2004	9,723	1,380	47,573	35,660	14,259	16,742	44,633	33,556	7,156	201,949	-15,736	1,530
2005	9,926	1,505	49,459	36,952	15,134	17,768	47,159	35,081	7,359	230,369	-14,731	1,580
2006	10,516	1,662	50,863	38,459	15,583	18,253	48,646	36,286	7,872	266,227	-14,045	1,659
2007	11,272	1,841	51,953	41,068	16,616	19,416	51,603	38,322	8,353	289,537	-17,972	1,711
2008	11,418	2,068	52,430	41,824	16,690	19,347	52,405	39,107	8,854	309,559	-25,591	1,731
2009	11,100	2,121	52,158	41,470	16,997	19,437	52,179	39,096	9,216	244,799	-15,144	1,654
2010	10,991	2,152	54,227	43,442	17,339	20,403	55,602	40,098	9,206	314,094	-13,500	1,738
2011	11,426	2,302	55,108	47,379	19,251	22,116	60,066	42,447	9,735	365,586	-15,998	1,807
2012	12,020	2,353	54,866	47,776	20,097	22,484	61,665	43,835	9,938	387,587	-13,713	1,874
2013	11,996	2,386	53,891	47,581	20,466	22,679	61,974	44,224	10,300	400,923	-11,893	1,898
2014	12,598	2,460	53,228	48,559	21,089	23,150	63,540	44,901	10,635	418,952	-15,025	1,942
2015	13,122	2,546	53,649	50,114	21,642	23,734	65,220	46,587	11,617	403,808	-23,823	1,991
	Megawatts											
1997	1,329	170	6,447	4,307	2,182	1,937	5,209	4,528	737			
1998	1,393	181	6,884	4,662	2,195	2,163	5,472	4,797	805			
1999	1,491	186	7,181	4,759	2,217	2,231	5,702	4,954	839			
2000	1,695	204	7,439	5,245	2,365	2,421	6,062	5,058	908			
2001	1,698	224	7,700	5,558	2,496	2,516	6,157	5,291	971			
2002	1,699	215	7,737	5,676	2,457	2,660	6,345	5,373	985			
2003	1,823	214	7,874	5,688	2,491	2,720	6,632	5,434	1,043			
2004	1,856	234	8,047	6,148	2,606	2,853	6,523	5,425	1,087			
2005	1,961	264	8,287	6,068	2,872	2,997	7,047	5,684	1,175			
2006	2,095	284	8,419	6,319	2,916	3,113	7,106	5,882	1,284			
2007	2,208	307	8,606	6,586	3,059	3,130	7,437	5,786	1,290			
2008	2,092	341	8,435	6,780	3,072	3,328	8,069	6,181	1,404			
2009	2,129	360	8,702	6,886	3,285	3,248	7,763	6,071	1,441			
2010	2,229	368	9,004	7,070	3,617	3,385	8,175	6,375	1,534			
2011	2,237	385	8,844	7,587	3,772	3,682	8,669	6,633	1,562			
2012	2,302	389	8,651	7,798	3,870	3,725	8,975	6,656	1,583			
2013	2,225	428	8,411	7,781	4,087	3,841	9,207	6,709	1,628			
2014	2,350	454	8,192	7,876	4,034	3,955	9,104	6,767	1,664			
2015	2,479	457	8,151	8,248	4,154	3,986	9,374	6,960	1,789			

4 Method and Model

We regress annual percent changes in regional energy and peak loads on regional indicator variables and, depending on which of the four models estimated we are referring to, percent changes in exports and GDP, and a deterministic trend toward energy efficiency. An issue is controlling for variation in GDP when both exports and GDP are included in the model. Including both would normally give an estimate of the effect of variation in exports on load, holding GDP constant, effectively modeling the effects on loads of changes in the composition of GDP. However, we consider it preferable to allow GDP to vary, but only to the extent that it depends on exports. Therefore, as a preliminary, we remove variation that depends on exports from the GDP variable before including it in a regression.

To do so, we must identify variation in GDP that depends on that in exports. Exports may be endogenous to GDP because, for example, a rise in consumer confidence may increase demand for and production of all consumption goods, including those that would otherwise be exported, diverting them from foreign to domestic consumption. To find exogenous variation in exports, we regress annual percent changes in exports on their lag, two lags of percent changes in the trade deficit, and two lags of percent changes in GDP.

$$
\begin{aligned}
x_t - x_{t-1} &= \alpha_0 + \alpha_x\left(x_{t-1} - x_{t-2}\right) + \alpha_d^1\left(\ln\left[M_{t-1} - X_{t-1}\right] - \ln\left[M_{t-2} - X_{t-2}\right]\right) \\
&\quad + \alpha_d^2\left(\ln\left[M_{t-2} - X_{t-2}\right] - \ln\left[M_{t-3} - X_{t-3}\right]\right) \\
&\quad + \alpha_g^1\left(g_{t-1} - g_{t-2}\right) + \alpha_g^2\left(g_{t-2} - g_{t-3}\right) + \varepsilon_t^x
\end{aligned} \tag{1}
$$

where x_t is log exports in Year t, M_t is imports, X_t is exports, g_t is log GDP, and ε_t^x is assumed to be spherical. Let $\Delta\hat{x}_t$ be the predicted value of $x_t - x_{t-1}$ from estimation of (1). We regress the annual percent change in Mexican GDP on $\Delta\hat{x}_t$.

$$
\begin{aligned}
g_t - g_{t-1} &= \gamma_0 + \gamma_a \Delta\hat{x}_t + \varepsilon_t^g \\
&= \hat{\gamma}_0 + \hat{\gamma}_a \Delta\hat{x}_t + e_t^g
\end{aligned} \tag{2}
$$

where e_t^g, the residual shown on the second line, is statistically independent of exports. We then add the average percent change in GDP to this residual to form a variable that represents GDP and the variation therein that is independent of exports.

$$
g_t^d - g_{t-1}^d = \overline{\Delta g} + e_t^g \tag{3}
$$

$g_t^d - g_{t-1}^d$ can be included in a regression with $\Delta\hat{x}_t$ so as to allow GDP to vary to the extent to that it depends on exports, but to be otherwise held fixed as exports vary. Again, including both GDP and exports as regressors would hold GDP fixed as exports vary; (2) and (3) are necessary so that GDP may vary to the extent that it depends on exports. When the ordinary GDP variable is included as a regressor, GDP is held entirely fixed as exports vary, changes in exports imply a change in merely the composition of GDP, and, therefore, exports have no apparent effect on electric loads. We show that that is hardly the case when exports are allowed to affect GDP.

In considering models that predict electric loads, we begin with a simple model, Model I, in which energy and peak loads are interdependent, but follow constant rates of growth that are specific to each Mexican region.

$$\begin{aligned} q_{it}^{GWH} - q_{it-1}^{GWH} &= \beta_0 + \beta_i + \varepsilon_{it} \\ q_{it}^{MW} - q_{it-1}^{MW} &= \delta_0 + \delta_i + \mu_{it} \end{aligned} \quad (4)$$

ε_{it} and u_{it} may be heteroskedastic, auto-, and inter-correlated. We estimate the equations in (4) simultaneously using seemingly unrelated regression, a consistent, asymptotically efficient, iterated maximum likelihood estimator, implemented using Stata's® "sureg" command with the "isure" option. (These assumptions and techniques are not needed simply to calculate average rates of growth, as is done in (4), but they become useful as we add regressors.) The lower case variables represent natural logs. A model in differences in logs is a model of percentage rates of growth, and this differencing helps to minimize the possibility of spurious estimates of coefficients caused by non-stationarity in variables. q_{it}^{GWH} is energy load in Region i in Year t, and $\hat{q}_{it}^{GWH}$ is its predicted value using fixed effect estimators $\hat{\beta}_X$ of each corresponding β_X. β_0 is growth in energy load common to all regions, and the fixed[11], regional, effect on annual percent growth is captured in the term β_i for Region i. q_{it}^{MW} is annual peak load in Region i in Year t, and $\hat{q}_{it}^{MW}$ is its fixed effects

[11] This is termed a "fixed" effect if β_i is correlated with the regressors; only if not could it be modeled as a "random" effect.

estimator. δ_0 is growth in peak load common to all regions, and the fixed, regional, effect in this equation is captured in the term δ_i for Region i. In general, $\beta_i \neq \delta_i$, so trends in growth may differ not only by region, but trend growth in consumption of energy may differ from that in peak load within a region.

$i =$ (Baja California Sur, Central, Noreste, Noroeste, Norte, Occidental, Oriental, Peninsular). Baja California (Norte) is omitted to avoid the "dummy variable trap", and Mulegé, which is very small, is not included in our analysis. We expect β_i and δ_i to be relatively high in fast-growing areas, such as Peninsular, where growth has been driven by tourism in Cancun. We also expect $\beta_i - \delta_i$ to be relatively high in areas that have seen rapid industrialization because industrial loads tend to exhibit high load factors.

A random effects model could have improved on the fixed effects model if there had been many individuals in the panel, or time-invariant regressors specific to each region.[12] However, there are only nine regions, and no regressors specific to those demarcations. Seemingly unrelated regression is thought to improve fixed effects models when "In practice, [the number of time-periods is] much larger than [the number of individuals]…"[13] The sample of annual data covers nine regions over eighteen years, 1997-2015.

In Model II, we introduce percent changes in exports

$$\begin{aligned} q_{it}^{GWH} - q_{it-1}^{GWH} &= \beta_0^x + \beta_i^x + \beta_x^x \Delta\hat{x}_t + \varepsilon_{it}^x \\ q_{it}^{MW} - q_{it-1}^{MW} &= \delta_0^x + \delta_0^x + \delta_x^x \Delta\hat{x}_t + \mu_{it}^x \end{aligned} \tag{5}$$

[12] See Kennedy, P., 2008. *A Guide to Econometrics*, 6th ed., pp. 283-4.
[13] See Baum, C.F., 2006. *An Introduction to Modern Econometrics Using Stata*, p. 237.

where $\Delta\hat{x}_t$ is the predicted value from the first stage regression, (1). Since international trade includes manufactured goods, we might expect that $\beta_x^x > \delta_x^x$ due to the aforementioned tendency toward high load factors in industrial loads.

In Model III, we introduce percent changes in GDP that are independent of exports. We discuss properties of this model in the appendix.

$$\begin{aligned} q_{it}^{GWH} - q_{it-1}^{GWH} &= \beta_0^g + \beta_i^g + \beta_x^g \Delta\hat{x}_t + \beta_g^g \left(g_t^d - g_{t-1}^d \right) + \varepsilon_{it}^g \\ q_{it}^{MW} - q_{it-1}^{MW} &= \delta_0^g + \delta_0^g + \delta_x^g \Delta\hat{x}_t + \delta_g^g \left(g_t^d - g_{t-1}^d \right) + \mu_{it}^g \end{aligned} \tag{6}$$

Again, there is no variation in g_t^d that depends on x_t, log exports, so, as x_t varies, GDP can vary to the extent that it depends on x_t; recall that $\Delta\hat{x}_t$ is the exogenous percent change in x_t. It may also be that $\beta_g^g \neq \delta_g^g$, so that growth in Mexican GDP may affect growth in peak load differently from how it affects growth in energy load.

In Model IV, we introduce a deterministic trend toward energy efficiency.[14]

$$\begin{aligned} q_{it}^{GWH} - q_{it-1}^{GWH} &= \beta_0^t + \beta_i^t + \beta_x^t \Delta\hat{x}_t + \beta_g^t \left(g_t^d - g_{t-1}^d \right) + \beta t + \varepsilon_{it}^t \\ q_{it}^{MW} - q_{it-1}^{MW} &= \delta_0^t + \delta_0^t + \delta_x^t \Delta\hat{x}_t + \delta_g^t \left(g_t^d - g_{t-1}^d \right) + \delta t + \mu_{it}^g \end{aligned} \tag{7}$$

[14] See SENER, 2014, *Estrategia Nacional de Transición Energética y Aprovechamiento Sustentable de la Energía*, for descriptions of energy efficiency programs.

If the Mexican economy is becoming more energy efficient, we expect the coefficients on t to be negative. Wing (2008, p. 24) attributes improving energy efficiency in the U.S. to technical progress within industries.[15]

5 Results

Estimation of (1) gives.

$$\begin{aligned}\Delta\hat{x}_t = \alpha_0 &- \underset{0.2425}{0.3436}\left(x_{t-1} - x_{t-2}\right) - \underset{0.0361}{0.3435}\left(\ln\left[M_{t-1} - X_{t-1}\right] - \ln\left[M_{t-2} - X_{t-2}\right]\right) \\ &+ \underset{0.0140}{0.0430}\left(\ln\left[M_{t-2} - X_{t-2}\right] - \ln\left[M_{t-3} - X_{t-3}\right]\right) \\ &+ \underset{1.0645}{2.7152}\left(g_{t-1} - g_{t-2}\right) - \underset{0.3724}{0.5897}\left(g_{t-2} - g_{t-3}\right) + \varepsilon_t^x\end{aligned} \tag{8}$$

The adjusted R^2 is 0.5330, and the overall *F*-statistic is highly significant.

Estimation of (2) gives

$$\hat{g}_t - \hat{g}_{t-1} = \underset{0.0018}{0.0098} + \underset{0.0175}{0.2061}\Delta\hat{x}_t \tag{9}$$

Both the constant and the coefficient are highly significant. The adjusted $R^2 = 0.4892$.

Exports are an important component and driver of Mexican GDP.

[15] Wing, I.S., 2008. Explaining the Declining Energy Intensity of the U.S. Economy. Resource and Energy Economics 30, 21-49.

Table 3 shows results from estimation of Models I-IV. The constant terms in Model I represent the annual rate of growth in Baja California (Norte), and the coefficients on the indicator variables represent adjustments by region. Energy loads in Baja California grew at 3.7% during the sample period, and peak loads there grew at 3.5%. Loads in Peninsular grew considerably faster, and loads in Central grew considerably more slowly. The adjusted $R^2 = 0.0666$ in the energy equation and 0.0833 in the peak load equation.

Table 3: Effects of National Exports on Electric Loads in Mexican Regions

	Variable	Model I Coeff.	Model I Std. Err.	Model II Coeff.	Model II Std. Err.	Model III Coeff.	Model III Std. Err.	Model IV Coeff.	Model IV Std. Err.
	GWH								
Percent Change	Exports			0.107	0.026	0.107	0.024	0.111	0.023
Percent Change	GDPd					0.531	0.114	0.524	0.110
	Year							-0.001	0.000
Indicator	Baja Sur	0.013	0.009	0.017	0.009	0.017	0.008	0.017	0.008
Indicator	Central	-0.016	0.009	-0.016	0.009	-0.016	0.008	-0.016	0.008
Indicator	Noreste	-0.001	0.009	-0.002	0.009	-0.002	0.008	-0.002	0.008
Indicator	Noroeste	-0.004	0.009	0.001	0.009	0.001	0.008	0.001	0.008
Indicator	Norte	0.001	0.009	0.001	0.009	0.001	0.008	0.001	0.008
Indicator	Occidental	-0.001	0.009	0.000	0.009	0.000	0.008	0.000	0.008
Indicator	Oriental	-0.006	0.009	-0.004	0.009	-0.004	0.008	-0.004	0.008
Indicator	Peninsular	0.015	0.009	0.017	0.009	0.017	0.008	0.017	0.008
	Constant[a]	0.037	0.006	0.027	0.006	0.014	0.007	2.697	0.818
	MW	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Percent Change	Exports			0.071	0.033	0.071	0.032	0.077	0.031
Percent Change	GDPd					0.397	0.152	0.387	0.147
	Year							-0.002	0.001
Indicator	Baja Sur	0.020	0.011	0.024	0.011	0.024	0.011	0.024	0.011
Indicator	Central	-0.022	0.011	-0.024	0.011	-0.024	0.011	-0.024	0.011
Indicator	Noreste	0.001	0.011	0.003	0.011	0.003	0.011	0.003	0.011
Indicator	Noroeste	0.001	0.011	0.007	0.011	0.007	0.011	0.007	0.011
Indicator	Norte	0.005	0.011	0.004	0.011	0.004	0.011	0.004	0.011
Indicator	Occidental	-0.002	0.011	-0.001	0.011	-0.001	0.011	-0.001	0.011
Indicator	Oriental	-0.011	0.011	-0.011	0.011	-0.011	0.011	-0.011	0.011
Indicator	Peninsular	0.015	0.011	0.016	0.011	0.016	0.011	0.016	0.011
	Constant[a]	0.035	0.008	0.027	0.008	0.018	0.009	3.520	1.092

[a] Applies to Baja California (Norte).

Model II introduces exports. In the absence of GDP and a trend toward energy efficiency, exports are highly statistically significant in the energy equation, and significant, at the 95% level, in the equation predicting peak load. The adjusted $R^2 = 0.1812$ in the energy equation and 0.1350 in the peak load equation. In the absence of exports, regional effects explain peak load better than energy load, but, with exports included, the regressors in the energy equation have greater explanatory power. These results are consistent with exports driving loads disproportionately through their impact on high load-factor, manufacturing customers.

However, the domestic economy is an important driver of electric loads. Model III introduces the GDP variable from which variation dependent on exports has been removed. Variation in exports may still cause variation in GDP, but variation in GDP that is independent of exports is now included in the regression. The GDP variable is statistically significant at the 99% level in both the energy and peak load equations. Exports continue to be highly significant in the energy equation and significant at the 95% level in the equation predicting peak load.[16] Results are still consistent with international trade substantially involving manufactured goods produced by industrial customers with high load factors. The adjusted $R^2 = 0.2851$ in the energy equation and 0.1705 in the peak load equation. Domestic economic activity also appears to be a stronger driver of energy than of peak load.

Model IV adds a deterministic trend to reflect improving efficiency in the use of electricity. Consistent with expectations, its coefficients are negative and significant at the 99% level in both the energy and peak load equations. Exports continue to be highly significant in the energy equation and significant at the 95% level in the equation predicting peak load. The

[16] If we use a GDP variable from which variation dependent on exports has not been removed, the GDP variable has the same coefficients and standard errors, but exports, a component of GDP, lose all statistical significance. See the appendix for further discussion.

GDP variable is highly significant in the energy equation and significant at the 99% level in the equation predicting peak load. The adjusted $R^2 = 0.3320$ in the energy equation and 0.2226 in the peak load equation. The trend adds explanatory power.

If we add the residuals from the energy equations in Models III and IV across regions, a Robinson test estimates the degree of fractional differencing required to render the sum of residuals from Model III level stationary to be $d = \underset{0.2021}{0.0492}$, and a Bartlett test assigns a *p*-value of 0.9962 to a null hypothesis that these residuals were generated by a white noise process, indicating that the model is well specified. A Robinson test estimates the degree of fractional differencing required to render the sum of residuals from Model IV level stationary to be $d = \underset{0.2021}{-0.3108}$, and a Bartlett test assigns a *p*-value of 0.7420 to a null hypothesis that these residuals were generated by a white noise process. Though the trend toward efficiency appears to have explanatory power, and Model IV is also well specified, it is likely somewhat less well specified than Model III.

Across all four models, the largest difference in regional effects between the energy and peak load equations, $\beta_i - \delta_i$, are in Central and Oriental. The differences in Central can be attributed to a program designed to shave peak load during the sample period, and to a temperate climate and relatively flat load, as shown in Figure 3. The differences in Oriental, which is near Central America and west of Peninsular, are attributable to industrial growth. At the turn of the century, low wages in China made it difficult for Mexico to compete in markets for light manufactured goods, but rising wages in China have since changed that, and we forecast that load factors will rise in the Oriental region and hold steady in Peninsular, despite falling somewhat nationwide.

> …the area in central-southern Mexico is large, populous and still relatively underdeveloped. It is in this area, which includes the states of Campeche, Veracruz, Chiapas and Yucatan, where we see the type of low-end development that fits our criteria. Mexico's ability to develop its low-wage regions does not face the multitude of challenges China faces in doing the same with its interior.
>
> …rising wages in China have once again shifted the equation in global manufacturing. Average manufacturing labor costs in Mexico are now almost 20 percent lower than in China, whereas in 2000, Mexico's labor costs were 58 percent more expensive than China's.
>
> …low-end manufacturing of goods like clothing and textiles is continuing to expand in southern Mexico, in cities like Campeche and Veracruz…[17]

6 Conclusion and Implications for Load Forecasting

In the introduction, we asked whether, in modeling the restructured electric power market in Mexico, forecasts of energy and peak loads would be substantially affected by exports. Exports are a highly significant driver of energy loads and a significant driver of peak loads in Mexico, with or without accounting for effects of GDP and a trend toward efficiency in the use of electricity. Both the model that includes GDP and the model that includes GDP and

[17] "Mexico's Manufacturing Sector Continues to Grow," April 6, 2015. Available at http://www.forbes.com/sites/stratfor/2015/04/08/mexicos-manufacturing-sector-continues-to-grow/#71e061373c9e, accessed May 2, 2016.

the trend are well specified, but the former is better specified, while the latter appears to have greater explanatory power.

We also asked whether scenarios should be "run" in which Mexico experiences lower exports. If a change in U.S. or other countries' trade policies toward Mexico is seen as possibility, it would be worthwhile to examine scenarios in which the effects of trade on electric loads, especially energy loads, are taken into account.

Finally, we asked how load forecasts should be adapted to account for a possible decline in Mexican exports, and how overall Mexican GDP should be adjusted in forecast models in relation to exports. A practical problem is that load forecasting models may not include exports separately as a predictor of loads, though they typically do include GDP. Even the gold standard of Mexican load forecasting models, that used by SENER in its annual PRODESEN publication, uses GDP but not exports to predict load.[18]

A relatively simple way to examine scenarios regarding exports, then, is to make the appropriate corresponding adjustment in GDP growth. In (10), 0.0238 is annual GDP growth during the sample period, 1997-2015, which included the Great Recession, and the other numeric values are from (9). To use this approach, one need not have an assumed forecast of export growth, but an assumed ratio of export growth to GDP growth; $\Delta x^s / \Delta g^s$. While GDP grew at 2.38% annually during the sample period, exports grew at 5.01%, so this ratio was 2.10.

[18] See SENER (2016), pp. 57-60.

$$\Delta g^s = \Delta g^b - \left(0.0238 - \frac{0.0098}{1 - 0.2061 \dfrac{\Delta x^s}{\Delta g^s}} \right) \tag{10}$$

$\Delta g^s \equiv$ scenario GDP growth rate

$\Delta g^b \equiv$ base case GDP growth rate

$\Delta x^s \equiv$ scenario export growth rate

About 80% of Mexican exports go to the United States[19], so it is not too extreme to assume that a more protectionist U.S. policy would imply that exports no longer led economic growth in Mexico, so that exports and GDP grew at the same rate: $0.0098/(1-0.2061) = 1.23\%$ p.a., so one would lower expected GDP growth by $2.38\% - 1.23\% = 1.15\%$ from what one would assume with no change in trade policy.

[19] See http://www.worldstopexports.com/mexicos-top-import-partners/, accessed May 8, 2017.

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Appendix: Clarification of Regression Model

It has been suggested that our regressions using the GDP variable calculated in (2) and (3) are equivalent to ordinary least squares (OLS). The coefficient on that GDP variable is, in fact, the same as in OLS, but the coefficient on (exogenously determined) exports is not. This is as intended: We do not wish to hold GDP entirely fixed as we allow variation in exports to cause variation in loads, as would be done in an OLS regression. Using matrix notation, an OLS regression would take the form

$$L = X\beta_X + G\beta_G + u$$

where L is the first difference in log load, G is the first difference in log GDP, X is the first difference in log exogenous exports and a constant term (a vector of 1's), and u is an error term. (We set aside the simultaneity of estimation of energy and capacity loads and regional effects because they only complicate the issue raised here.) By a corollary to the Frisch-Waugh Theorem[20], estimated coefficients on GDP, exports and the constant, respectively, are

$$\hat{\beta}_G = \left(G'M_X G\right)^{-1} G'M_X L \qquad M_X \equiv I - X\left(X'X\right)^{-1} X'$$
$$\hat{\beta}_X = \left(X'M_G X\right)^{-1} X'M_G L \qquad M_G \equiv I - G\left(G'G\right)^{-1} G'$$

where $\hat{\beta}_X$ includes both the coefficient on the export term and the constant.

[20] See Greene, p. 27.

Using (2) and (3), our GDP variable is $M_X G+\bar{G}$, where $\bar{G}$ is the sample mean of G, so our model differs from the OLS model:

$$L = X\beta_X^{VS} + \left(M_X G+\bar{G}\right)\beta_G^{VS} + u$$

Again by the Frisch-Waugh Theorem, the estimated coefficient on the GDP variable is

$$\begin{aligned}\hat{\beta}_G^{VS} &= \left(G'M_X G\right)^{-1} G'M_X \left(L-\bar{G}\hat{\beta}_G^{VS}\right)\\ &= \left(G'M_X G\right)^{-1} G'M_X L - \left(G'M_X G\right)^{-1} G'M_X \bar{G}\hat{\beta}_G^{VS}\\ &= \hat{\beta}_G - \left(G'M_X G\right)^{-1} G'M_X \bar{G}\hat{\beta}_G^{VS}\end{aligned}$$

Therefore,

$$\hat{\beta}_G^{VS} = \frac{\hat{\beta}_G}{1+\left(G'M_X G\right)^{-1} G'M_X \bar{G}}$$

The (1x1) term $\left(G'M_X G\right)^{-1} G'M_X \bar{G}$ is the estimated coefficient on G in a regression of $\bar{G}$, a constant across observations, on G and X. X includes a vector of 1's, the estimated constant term will equal $\bar{G}$, and the estimated coefficient on G will be zero. Therefore, $\hat{\beta}_G^{VS} = \hat{\beta}_G$.

However, a similar result does not obtain for $\hat{\beta}_X^{VS}$.

$$
\begin{aligned}
\hat{\beta}_X^{VS} &= \left(X'M_G X\right)^{-1} X'M_G \left(L - \bar{G}\hat{\beta}_G\right) \\
&= \left(X'M_G X\right)^{-1} X'M_G L - \left(X'M_G X\right)^{-1} X'M_G \bar{G}\hat{\beta}_G \\
&= \hat{\beta}_X - \left(X'M_G X\right)^{-1} X'M_G \bar{G}\hat{\beta}_G
\end{aligned}
$$

The term $\left(X'M_G X\right)^{-1} X'M_G \bar{G}\hat{\beta}_G$ is the coefficient on X in a regression of $\bar{G}\hat{\beta}_G$, a constant across observations, on G and X. X includes a vector of 1's, and the coefficient on X will not, in general, be zero, so, generally, $\hat{\beta}_X^{VS} \neq \hat{\beta}_X$. Our model is not equivalent to OLS. The inclusion of regional indicator variables, as in (6) and (7), and a trend line, as in (7), does not change this result, nor does the simultaneity of estimation of energy and peak loads.