How vulnerable are small firms to energy price increases?
Evidence from Mexico

Hannes Greve[1,2*], Jann Lay[1,2] and Ana Negrete[1,3,4]

[1] German Institute for Global and Area Studies (GIGA), Hamburg, Germany, [2] University of Göttingen, Göttingen, Germany, [3] Southern Oregon University, Oregon, USA, and [4] Universidad de Guanajuato, División de Ciencias Económico Administrativas, Guanajuato, México.

Corresponding author. E-mail: hannes.greve@giga-hamburg.de

ONLINE APPENDIX

A. Energy price development in Mexico City

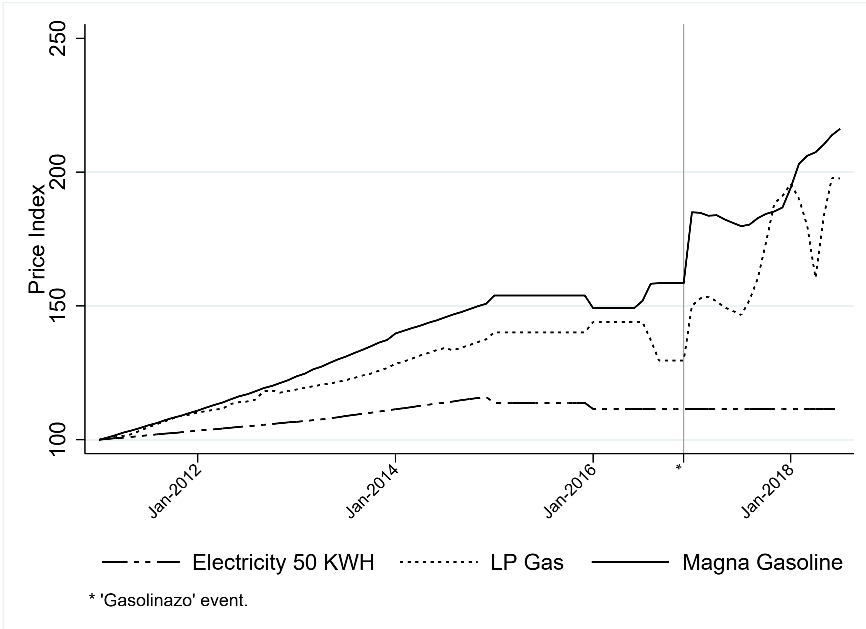

Figure A1. Energy price indexes for Mexico City, 2011–2018, base in January 2011.

Source: Self-elaboration based on data from CFE (2017); Gobierno de México (2017); PEMEX (2017)

B. Price data

Fuels The ENAMIN survey aggregates all LPG, natural gas, gasoline, coal, and "others" into a single category. Given that it is not possible to observe fuel-inputs at a more disaggregated level, we cannot assign the exact price to the "Fuels" category. As the largest share within that category is expected to be gasoline, we approximate the real price with gasoline prices. The price of gasoline corresponds to the simple average between high- and low-octane gasolines. We additionally estimate the cost-function for LPG prices as well as an unweighted average of gasoline and LPG prices, yielding almost identical elasticity estimates (results not reported).

Electricity Total electricity consumption in kWh is estimated by matching electricity prices with the survey data on firms' expenditure. As most firms are not officially registered with tax authorities, we assume that informal and self-employed entrepreneurs receive bills for residential rather than commercial customers. For formal firms that hire labor, we assign the PBDT (Pequeña Demanda en Baja Tensión) tariff, denoting small demand at low voltage (up to 25 kW). We consider the fact that the electricity cost structure follows an increasing block tariff. The available data provides us with monthly average prices at different levels of consumption for 46 cities for the residential tariff. Therefore, regional and seasonal fluctuations are captured. In warmer climate regions, for example, tariffs are separated into summer and non-summer rates, mainly due to air-conditioning costs. To estimate quantities of electricity consumption, we follow several steps. First, the official price levels are assigned to all firms operating in the cities under consideration. MSEs based in small cities or in rural areas are assigned the average price that is prevalent in their respective federal state. Second, the block-price structure is considered by assigning the average electricity price that corresponds to expenditure. This procedure makes it possible to convert the values into prices per kWh and estimate the amount of electricity that the firm consumes each month. It is possible that MSEs receive electricity from households or other firms near the places they typically operate. In this case it could be that they pay a premium for electricity, which would introduce an upward bias to the kWh estimate. For larger, formal firms, we assign the national average of the PBDT tariff, as regional data is not available. We are able to assign each firm the respective tariff of the PDBT block structure, and thus the respective block price accordingly. For those firms that clearly do not contract the PBDT tariff (as indicated by negative kWh consumption values when computing real consumption with the expenditure and price data), we assign the residential tariff instead.

Labor Based on the workers' information reported in ENAMIN, we construct a price measure by computing the median wage for 10 industries (construction, manufacturing, miscellaneous services, personal services, professional services, repair services, restaurants and hotels, retail and wholesale trade, transportation services, other) and 75 municipalities. The 46 main cities are considered independently, while the remaining geographical locations correspond to the surrounding rural areas of each federal state.

C. Input-demand elasticity estimation

The translog function as developed by Christensen *et al.* (1973) provides enough flexibility to approximate any function to the second degree and imposes restrictions on substitution elasticities. The empirical approach is similar to the recent studies of Haller and Hyland (2014) as well as Bardazzi *et al.* (2015). The cost function is defined as follows:

$$\begin{aligned} ln(C_f) =& \beta_0 + \sum_{i=1}^{n} \alpha_i ln(p_{if}) + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij} ln(p_{if}) ln(p_{jf}) \\ &+ \sum_{i=1}^{n} c_i ln(p_{if}) ln(y_f) + \gamma ln(y_f) + \beta_Z Z_f + \beta_D D_f + \mu_f \end{aligned} \tag{A1}$$

where f is the firm index, i and j are production inputs, C is cost, p are prices, y is output, Z are additional explanatory variables, and D_f dummies – including region, industry, and time dummies – as well as μ_f (firm specific error terms). By differentiating equation (A1) logarithmically with respect to price, we obtain the factor-share equations:

$$S_{if} = \alpha_0 + \sum_{j=1}^{n} \beta_{ij} ln(p_{if}) ln(p_{jf}) + c_i ln(p_{if}) ln(y_f) + \mu_f \tag{A2}$$

We estimate equations (A1) and (A2) simultaneously using the two-step seemingly unrelated regression (SUR) method developed by Zellner (1962) using generalized least squares (see parameter estimates in table A2). SUR allows errors u_f to be correlated across equations for each observation. Thus, we account for the interdependence of the use of different inputs and total costs. Motivated by production theory, we impose symmetry and linear parametric constraints across both equations. Hence, parameter estimates of the same α, β, and c_i in equations (A1) and (A2) are forced to be equal.

Own-price elasticities (equation (A3)) measure the average percentage change in demand for input i given a 1 per cent price increase. Cross-price elasticities (equation (A4)) are absolute measures of substitutability, giving the percentage change in demand for input i when the price of another input j rises by 1 per cent.

$$\eta_{ii} = \frac{\gamma_{ii} + S_i^2}{S_i} - 1 \tag{A3}$$

$$\eta_{ii}j = \frac{\gamma_{ij} + S_i S_j}{S_i} \tag{A4}$$

Before computing elasticity estimates, we undertake several tests to evaluate whether the cost function produces reliable results. Following Haller and Hyland (2014), we first compare predicted with actual cost shares. The sample means of the two variables are nearly identical. Second, the cost function should satisfy monotonicity, resulting in nonnegative predicted cost shares. For instance, for the sample containing only firms employing labor, 4.7 per cent of observations exhibit negative predicted electricity cost-shares. These observations are dropped before estimating elasticities. Finally, the cost function should satisfy quasi-concavity, which means that the Hessian matrix is negative semi-definite: that is, own-price elasticities should be negative at the mean of the sample. For our case, some electricity elasticity estimates do not satisfy quasi-concavity (26 per cent of observations), possibly due to incorrectly modeling of the cost structure of the block tariff. To produce more reliable estimates, we iterate the estimation in the following way: after each estimation, observations violating monotonicity and quasi-concavity are dropped and SUR is estimated again. This procedure is repeated until none of the observations violate monotonicity or quasi-concavity. Although the sample size decreases substantially, elasticity estimates do not differ to the extent that the qualitative findings change, particularly with respect to the labor-energy substitution relationship. This indicates that we do not systematically bias the estimation by reducing the sample.

Table A1. Parameter estimates of the translog cost function estimation

Dependent: Log costs	All industries, hired labor		All industries, self-employed	
Log electricity price	0.35	(0.02)	0.18	(0.06)
Log fuels price	0.23	(0.04)	0.31	(0.09)
Log wage rate	0.42	(0.04)	0.50	(0.11)
Interaction of log prices (electricity)	0.05	(0.00)	0.03	(0.00)
Interaction of log prices (fuels)	-0.02	(0.01)	-0.03	(0.00)
Interaction of log prices (wages)	-0.02	(0.01)	0.06	(0.01)
Interaction of log prices (elec. and fuels)	-0.03	(0.01)	0.00	(0.00)
Interaction of log prices (elec. and wages)	-0.01	(0.00)	-0.03	(0.00)
Interaction of log prices (fuels and wages)	0.03	(0.01)	-0.03	(0.01)
Interaction of log elec. prices and log output	0.00	(0.00)	0.01	(0.01)
Interaction of log fuel prices and log output	0.02	(0.01)	0.02	(0.01)
Interaction of log wage rates and log output	-0.02	(0.00)	-0.02	(0.01)
Log output value	0.25	(0.02)	0.11	(0.03)
Age of owner	0.02	(0.01)	0.00	(0.01)
Age of owner squared	-0.00	(0.00)	0.00	(0.00)
Female entrepreneur (dummy)	-0.08	(0.03)	-0.06	(0.03)
Age of the enterprise	0.00	(0.00)	0.00	(0.00)
Log years of schooling	0.01	(0.00)	0.00	(0.00)
Firm has premises (dummy)	0.10	(0.04)	0.16	(0.03)
Entrepreneur is self-employed (dummy)	-0.24	(0.08)	-0.02	(0.02)
Capital stock	0.00	(0.00)	0.00	(0.00)
Dummy unpaid labor	0.03	(0.03)		
Intercept	4.04	(0.20)	5.60	(0.45)
Ratio of variable fuels costs				
Log electricity price	-0.03	(0.01)	0.00	(0.00)
Log fuels price	-0.02	(0.01)	-0.03	(0.00)
Log wage rate	0.03	(0.01)	-0.03	(0.01)
Log of output value	0.00	(0.00)	0.01	(0.00)
Ratio of variable electricity costs				
Log electricity price	0.00	(0.00)	0.01	(0.00)
Log fuels price	-0.03	(0.01)	0.00	(0.00)
Log wage rate	-0.01	(0.00)	-0.03	(0.00)
Log of output value	-0.01	(0.00)	-0.00	(0.00)
Ratio of variable wage costs				
Log electricity price	-0.01	(0.00)	-0.03	(0.00)
Log fuels price	0.03	(0.01)	-0.03	(0.01)
Log wage rate	-0.02	(0.01)	0.06	(0.01)
Log of output value	0.02	(0.00)	-0.01	(0.00)
Dummy unpaid labor	-0.01	(0.00)		
N	1758		1363	

Notes: Standard errors in parentheses. Year, region, industry, and block-tariff dummy variables are included in all equations, but parameter estimates are not reported.

D. Elasticity estimates by sector

Table A2. Own- and cross-price input-demand elasticities, retail and wholesale trade

	Price of fuel	Price of electr.	Price of labor
Firms with hired labor			
Fuels	-0.97	0.04	0.88
	(0.07)	(0.08)	(0.06)
Electricity	0.06	-0.39	0.35
	(0.12)	(0.10)	(0.10)
Hired labor	0.32	0.08	-0.40
	(0.02)	(0.02)	(0.03)
Self-employed			
Fuels	-1.09	-0.04	1.02
	(0.09)	(0.09)	(0.07)
Electricity	-0.06	-0.63	0.70
	(0.14)	(0.10)	(0.11)
Own labor	0.08	0.04	-0.11
	(0.01)	(0.01)	(0.01)

Notes: Standard errors in parentheses, computed using the delta method. Elasticity estimates are obtained after the fourth iteration for hired labor and after the seventh for one-person firms. This reduced the sample size from 438 to 279 and from 727 to 446 respectively.

Table A3. Own- and cross-price input-demand elasticities, services

	Price of fuel	Price of electr.	Price of labor
Firms with hired labor			
Fuels	-0.84	-0.10	0.77
	(0.05)	(0.04)	(0.03)
Electricity	-0.24	-0.42	0.76
	(0.10)	(0.09)	(0.05)
Hired labor	0.22	0.09	-0.31
	(0.01)	(0.01)	(0.01)
Self-employed			
Fuels	-1.02	0.06	0.84
	(0.03)	(0.04)	(0.03)
Electricity	0.29	-0.75	0.58
	(0.17)	(0.11)	(0.07)
Own labor	0.09	0.01	-0.10
	(0.00)	(0.00)	(0.00)

Notes: Standard errors in parentheses, computed using the delta method. Elasticity estimates are obtained after the seventh iteration for hired labor and after the second for one-person firms. This reduced the sample size from 1,032 to 636 and from 1,403 to 1,369 respectively.

Table A4. Own- and cross-price input-demand elasticities, manufacturing

	Price of fuel	Price of electr.	Price of labor
Firms with hired labor			
Fuels	-0.80	0.01	0.72
	(0.05)	(0.04)	(0.04)
Electricity	0.04	-0.44	0.59
	(0.13)	(0.09)	(0.07)
Hired labor	0.31	0.08	-0.40
	(0.02)	(0.01)	(0.02)
Self-employed			
Fuels	-1.06	-0.06	0.49
	(0.07)	(0.06)	(0.08)
Electricity	-0.20	-0.47	0.24
	(0.17)	(0.17)	(0.12)
Own labor	0.07	0.01	-0.08
	(0.01)	(0.01)	(0.01)

Notes: Standard errors in parentheses, computed using the delta method. Elasticity estimates are obtained after the sixth iteration for hired labor and after the tenth for one-person firms. This reduced the sample size from 787 to 600, and from 1,074 to 862 respectively.

Table A5. Own- and cross-price input-demand elasticities, restaurants and hotels

	Price of fuel	Price of electr.	Price of labor
Firms with hired labor			
Fuels	-0.82	-0.05	0.81
	(0.04)	(0.05)	(0.04)
Electricity	-0.11	-0.46	0.60
	(0.11)	(0.08)	(0.07)
Hired labor	0.29	0.09	-0.38
	(0.01)	(0.01)	(0.02)
Self-employed			
Fuels	-1.17	-0.09	0.61
	(0.12)	(0.11)	(0.12)
Electricity	-0.18	-0.19	0.43
	(0.22)	(0.16)	(0.15)
Own labor	0.05	0.02	-0.07
	(0.01)	(0.01)	(0.01)

Notes: Standard errors in parentheses, computed using the delta method. Elasticity estimates are obtained after the fourth iteration for hired labor and after the seventh for one-person firms. This reduced the sample size from 589 to 451 and from 1,054 to 404 respectively.

E: Output price transmission versus first-order profit loss

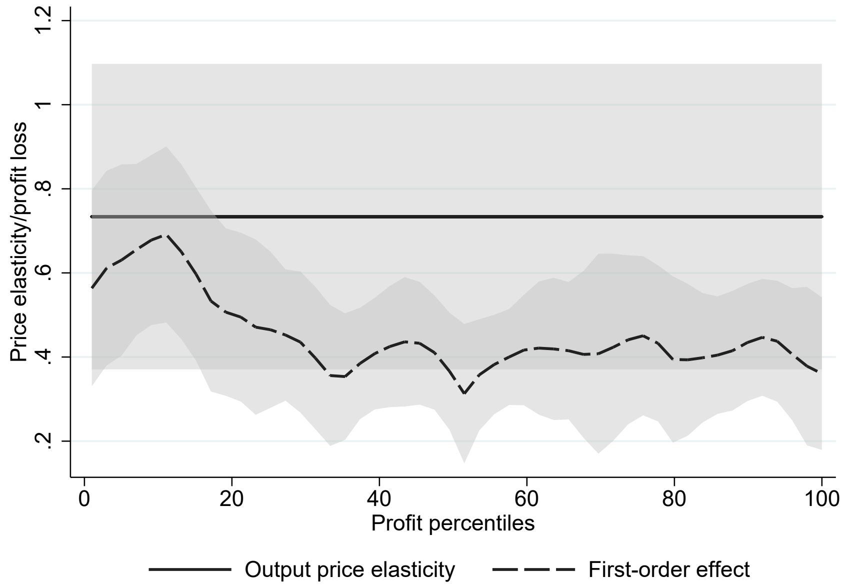

Figure A2. Profit loss estimates and output price elasticity for taco, tamales, and tortilla producers.
Notes: Output price elasticity from specification (3) in table 5 of the main text, with 95% confidence interval.

References

Bardazzi R, Oropallo F and Pazienza MG (2015) Do manufacturing firms react to energy prices? Evidence from Italy. *Energy Economics* **49**, 168–181.

CFE (2017) Consulta tu tarifa. Mexico: Comisión Federal de Electricidad (in Spanish).

Christensen LR, Jorgenson DW and Lau LJ (1973) Transcendental logarithmic production frontiers. *The Review of Economics and Statistics* **55**, 28–45.

Gobierno de México (2017) Catálogo de Datos Abiertos del Gobierno de la República. Mexico D.F. (in Spanish).

Haller SA and Hyland M (2014) Capital-energy substitution: evidence from a panel of Irish manufacturing firms. *Energy Economics* **45**, 501–510.

PEMEX (2017) Productos. Mexico: Petróleos Mexicanos (in Spanish).

Zellner A (1962) An efficient method of estimating seemingly unrelated regressions and tests for aggregation bias. *Journal of the American Statistical Association* **57**, 348–368.