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Electric power sector reform liberalization models and electric power prices in developing countries
An empirical analysis using international panel data

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ABSTRACT

This study aims to clarify whether the effects of electric power sector reforms should be different either across regions, or between developing and developed countries. An empirical model was analyzed to observe the impact of electric power prices on the selection of a liberalization model in the power sector. This was achieved by the use of an ordered response, fixed effect and a random effect model. An instrument variable technique was also used to estimate the impact of the liberalization model on the electric power price. This technique addressed the problems of simultaneity bias between the electric power price and the liberalization models selected. These econometric models were designed using panel data from 78 countries in four regions (developed countries, Asian developing countries, the former Soviet Union and Eastern Europe, and Latin America) for the period from 1985 to 2003. The research findings suggest that higher electricity prices are one of the driving forces for governments to adopt liberalization models. However, the development of liberalization models in the power sector does not necessarily reduce electricity prices. In fact, contrary to expectations, there was a tendency for the price to rise in every market modeled.

1. Introduction

This study empirically analyzes the impact of the electric power price on the selection of a liberalization model in the power sector and the impact of the liberalization model on the electric power price. Econometric models were designed using panel data from 78 countries in four regions (developed countries, Asian developing countries, the former Soviet Union, Eastern Europe and Latin America) for the period from 1985 to 2003.

The liberalization and privatization of the electric power sector began in Chile in 1982 which then, spread through various countries in the world subsequent to the 1990s. The electric power sector reforms first began in developed countries such as Europe, the United States, Australia, as well as, developing countries in Latin America. Reforms have taken hold gradually in the former Soviet Union, Eastern Europe and Asia, but have been slow to arrive in Africa and in the Middle East (Bacon and Besant-Jones, 2001). The major trend of the electric power reforms carried out in Europe and in the United States, is first to separate the four business activities of generation, transmission, distribution and retail supply of electrical power.

Electric power reforms then shifted electric power generation and retail supply business toward a free, competitive environment, allowing a local monopoly in the power transmission and distribution section promoting economic efficiency.

It is important to note, however, that the environments in which the electric power sector reforms occur in developing countries differ from those of developed countries.

First, while significant additional investments in electric power facilities, especially for generation, were not required in developed countries, the opposite is true for developing countries. Fig. 1 is a correlation diagram, which shows that demand for electricity is increasing rapidly due to economic development and a future need to significantly increase the number of electric power facilities is anticipated. This figure shows GDP per capita on the horizontal axis and installed capacity (kW) per capita on the vertical axis, from 1985 to 2003. Note, as the GDP per capita increases, the installation capacity per capita increases as well. It can be inferred that investment in electric power systems is necessary for sustainable economic growth in the future. This is especially true for developing countries.

Second, it will be necessary for incentives to be employed to sustain rural electrification once the power sector has been liberalized and privatized. Distribution companies, who have been involved in the rural electrification by extending distribution lines, would be reluctant to invest without incentives to realize profits. Therefore, the central government would need to be directly responsible for the rural electrification in the off-grid regions, currently utilizing the government subsidies.

Third, there still exists fuel subsidies for large groups of people with low incomes in the developing countries. The IEA (1999) emphasizes

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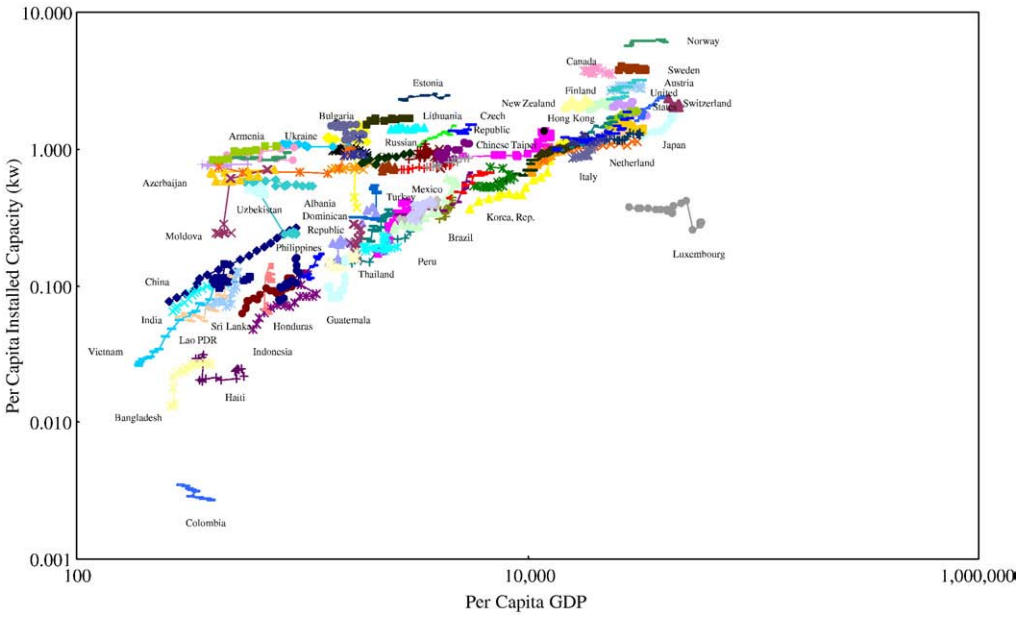


Fig. 1. Per capita GDP and per capita installed capacity. Note 1: GDP capita GDP is US dollar nominated fixed 1985 prices. Note 2: For vertical and horizontal axes, natural log are taken. Source: per capita GDP: World Development Indicators, the World Bank. Per capita installed capacity: Energy Information Administration, International Energy Annual 2004, June 1.

the importance of removing these subsidies. Artificially low energy prices, caused by heavy subsidies in the developing world, are at the root of the poor financial performance of many state-owned energy companies in developing and transitional economies. This poor performance seriously reduces the ability of those companies to meet increasing demand. This applies especially to those consumers who do not yet have access to commercial energy. It also prohibits private and foreign investment in the energy sectors of these countries.

As discussed, developing countries have problems such as limited electricity supply, high demand, unstable power transmission systems, delayed development of power distribution networks and public enterprises in a financially fragile situation. In designing institutional arrangements for the power sectors in developing countries, improvement in the economic efficiency of the sector is not the main target as it is in developed countries. Instead, the three pillars of developing a stable supply of electric power are 1 – through inviting private investments; 2 – to adjust power prices to reflect the true cost of generation and distribution and 3 – the eradication of poverty. The subsequent increase in the rate of electrification should be achieved at the same time. To attain these pillars, the government has to clarify the respective roles of government and the market, playing an important role in certain fields where market principles cannot be applied (such as investment in transmission, rural electrification, etc.) and establishing institutions which promote competition in the private sector.

This paper is organized as follows: Section 2 – reviews earlier studies. Section 3 – discusses the outline of liberalization models for power sector reforms. In Section 4, we provide an empirical analysis based on an econometric model. Finally in Section 5, we discuss the conclusion and tasks to be considered for future study.

2. Review of earlier studies

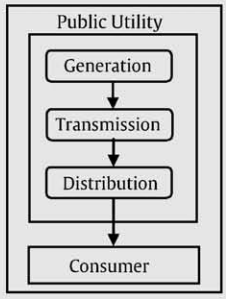
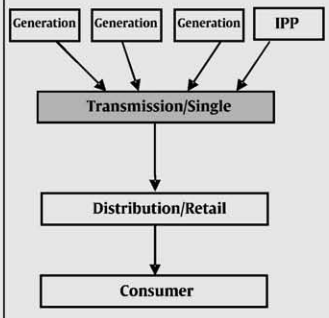
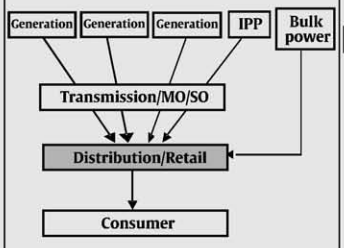
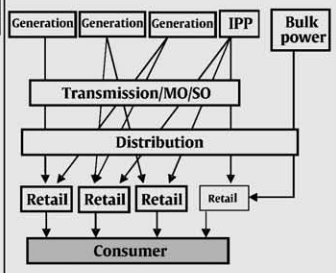
Weinmann and Bunn (2004) compared the power industries of 26 Latin American countries. They analyzed how the structure and resource possession level of the power supply industry of the countries impacted the possibility of introducing the electric power sector structural reform in each country. They point out that not being able to divide a capital-intensive property, such as nuclear plants and hydroelectric power plants, becomes problematic when wholesale market competition is introduced in the electric power sector. Further, countries with rich oil reserves and lower dependence on hydro generation tend to delay the execution of the electric power sector structural reform after a general market liberalization reform.

Joskow (1998) points out that in the United States, the states with the highest electricity prices have a high possibility of executing reforms. Additionally, Ando and Palmer (1998) measured how the existence of interest groups influences the shift to retail liberalization by utilizing cross section data from each state in an ordered probit model. Legislative and regulatory statutes were used as dependent variables. The dependent variable takes the value of two if decision, one if consideration, and zero if no action. The level and standard deviation of the average electricity prices, "Import" price gaps, "Export" price gaps, and stranded costs, Republican party controls, and other variables act as independent variables.

Using the cross section data, Bacon and Besant-Jones (2001) assume the progress of the reforms to be a dependent variable, and construct a model by which the macroeconomic policy, political economic risk GDP, and regional dummies are assumed independent variables. They find that macroeconomic management of the country and the consistency of the policy work positively in electric power sector reforms, while the risk index works negatively.

Steiner (2001) performed an empirical analysis using a panel dataset of 19 OECD countries for the period of 1987–1996. Hattori and Tsutsui (2004) reproduced Steiner's model for the same 19 OECD countries and extended it through 1999. Steiner (2001) tests the regulatory environment, the degree of vertical integration and the degree of private ownership to see if they have an impact on efficiency and on prices. Efficiency is determined by the capacity utilization rate and the electricity generation reserve margin. Improved efficiency, lower industrial electricity prices and lower industrial/residential price ratios are expected to arise from the liberalization of regulations, restructuring and private ownership. Steiner (2001) found that with respect to the impact on prices there were no significant estimated coefficients on unbundling of generation and transmission or, on a third party access. On the other hand, the coefficient for private ownership was unexpectedly positive and significant. This suggests that increased competition is not necessarily correlated with private

Table 1
Outline of electric power liberalization model.

	Monopoly model	Single buyer	Wholesale competition	Wholesale/retail competition
Sector Structure Illustration Generation	 Vertical integration monopoly model		 *MO = Market Operator.	
Definition	Each IPP contract PPAs (Power Purchase Arrangement) with Public Utility or with Government.	Single Buyer/market: Competition is introduced only to the electricity wholesale sector. The market where the independent Single Buyer procures wholesale electric power based on fixed contracts with the power producer through competitive bidding.	Wholesale competition market: Competition is introduced only to the electricity wholesale sector. A market where wholesale electric power is dealt with in a form required by market participants, irrespective of the presence of electric power pool market.	Wholesale/retail competition market: A market where competition is introduced to both electricity wholesale and retail electric power sector.Consumer can select power providers other than conventional power company (power distribution company).

Note 1: In countries where the development of liberalization varies by state, such as India, the United States, Canada, and Australia, we adopted the liberalization models of the most advanced state. Note 2: Japan is categorized in wholesale/retail competition, however regionally monopolized utilities are vertically integrated with limited retail competition. Some states of United States are also regionally vertically integrated. Note 3: "Privatization" is defined as the passage of primary legislation commonly known as 'Electric Privatization' law, and the establishment of the regulatory framework; this includes partial and full equitization of state-owned companies. Source: Governmental sources of each country, created by author from various government sources and Nagayama (2007).

ownership. The creation of a spot market did bring about lower prices. There are several contrasts between Steiner (2001) and Hattori and Tsutsui (2004). While Steiner (2001) provided results for random effect models only, Hattori and Tsutsui (2004) provided results for both random and fixed effect estimation. Steiner (2001) did not find that the existence of a wholesale market is a statistically significant positive for prices, while Hattori and Tsutsui (2004) found the opposite. In addition, while Hattori and Tsutsui (2004) found that third party access is a statistically significant negative, Steiner (2001) says it is statistically insignificant. Finally, Hattori and Tsutsui (2004) state that the private ownership coefficient is significantly negative for prices, which is in contrast to Steiner's results.

Zhang et al. (2002) measured the effects of dummy variables, such as the existence of an independent regulatory agency, a wholesale electric power pool market, private electric businesses, electricity generation per capita, installed capacity per capita, electricity generation per employee, and residential/industrial electricity prices, using data from 51 developing countries in the time period ranging from 1985–2000. They found that neither privatization on its own nor regulation on its own leads to obvious gains in economic performance. This is because the effect either of privatization or of having an autonomous regulator is statistically insignificant. The study also concluded that the coexistence of privatization and an autonomous regulator is correlated with greater electricity availability, more generation capacity and higher labor productivity. As a result of these findings, they determined that an effective regulatory framework should be a priority when privatizing electricity supply under monopolistic conditions. Finally, the study showed that introducing competition is effective in improving performance irrespective of changes in ownership or regulation, since competition appears to bring about favorable results for service penetration, capacity expansion, labor efficiency and prices for industrial users. They obtained statistically significant results that competition both raises the productivity of electricity generation and lowers industrial electricity prices.

Previous work on the relationship between reforms in the electric power sector and the transition to liberalization has demonstrated that the relationship is both complicated and reciprocal. Clearly, there is still much that we do not understand about the relationship between reforms and liberalization, as well as the relationship differences between developing and developed countries. We begin examining these questions with more detail in the following section.

3. Liberalization models of power factor reform

The adoption of a liberalization model affects electric power prices and electric power prices affect the selection of liberalization models. To correctly evaluate this relationship, which represents an endogeneity issue, we introduced a scorecard approach.[1] This approach integrates policy variables related to electricity sector reforms such as unbundling, the introduction of a wholesale electric power spot / exchange market, the introduction of a retail market, the establishment of a regulatory institution, privatization, and the introduction of IPPs into one variable. This represents the liberalization status of the electric power sector. Table 1 is a outline of a electric power liberalization model.

To be more precise, there are four steps in the liberalization model:

1) Monopoly model –
   - if the stage holds the status of 'before competition' or 'no competition'
2) Single Buyer model –
   - if a mid- or long-term competitive bid is introduced to the generation business only and/or unbundling between generation and transmission is implemented
3) Wholesale market model –
   - when the wholesale market is liberalized
4) Retail market model –
   - If the wholesale and retail markets are liberalized.

[1] There is some argument that proceeding stepwise in the implementation of reform models does not fully represent reality. For example, some Latin American countries have successfully implemented complex competitive models, while some industrialized countries remain with the old model equally successfully.

Table 2
Model transition pattern.

	Model transition	Number	Share (%)	
			By area	By total
Asian developing countries	01	9	81.82%	11.54%
	012	1	9.09%	1.28%
	03	1	9.09%	1.28%
	Total	11	100.00%	14.10%
Former Soviet Union and Eastern Europe	0	8	38.10%	10.26%
	01	5	23.81%	6.41%
	013	3	14.29%	3.85%
	012	1	4.76%	1.28%
	010	1	4.76%	1.28%
	02	2	9.52%	2.56%
	03	1	4.76%	1.28%
	Total	21	100.00%	26.92%
Developed countries	0	4	15.38%	5.13%
	013	8	30.77%	10.26%
	023	2	7.69%	2.56%
	03	12	46.15%	15.38%
	Total	26	100.00%	33.33%
Latin America	0	3	15.00%	3.85%
	01	9	45.00%	11.54%
	012	3	15.00%	3.85%
	02	4	20.00%	5.13%
	03	1	5.00%	1.28%
	Total	20	100.00%	25.64%
Total		78		100.00%

Note: 0: Monopoly Model; 1: Single Buyer Model; 2: Wholesale Competition Model; 3: Wholesale / Retail Competition Model.
Source: Created by the author.

The purpose of SB (Single Buyer – referred here-after as "SB") is to legally divide power generation, transmission and distribution, allowing fair, "equal" treatment for IPP and power plants of national electric power companies, thus promoting competition. This allows the reduction of the wholesale charge over several years in the beginning stages of development. Creation of the market for centralized transactions will serve as the foundation of subsequent market developments. Once the SB stage has been passed, it will then become difficult for power producers to increase prices unreasonably. This is achieved once the retail market becomes liberalized, as the charge under the SB model becomes the base and centralization of transactions through the SB market system enable the reliable price index in connection with electric power transactions to be established. On the other hand, Lovei (2000) assumes the SB model to be an artificial monopoly and cautions any country that selects this model. He points out that the SB model in developing countries ushers in corruption, insufficient electricity collection and results in contingent liability on the government. The SB model can be thought of as a market transition measure toward the competitive market. He suggests that in the case of weak government with corruption and low cash collection cases, a SB model should be carefully introduced. He also suggests moving on to Multiple-seller–multiple-buyer models and skipping the SB process.

The unbundled years and/or the introduction of foreign IPP with a competitive environment were selected for transition conditions from the monopoly model to the SB model. The conditions for the transition to wholesale competition and retail/wholesale competition were set as the establishment of the Wholesale Market and the

Table 3
Liberalization models and regulatory functions to be prepared.

	Regulatory functions to be prepared	Vertical integration	Single buyer	Wholesale competition	Wholesale/retail competition
1) Regulations for businesses	Issuance of licenses to new entrants	○	○	○	○
	Transmission wheeling rate guidelines			○	○
	Approval of expansion/improvement plans for transmission facilities	○	○	○	○
	Publication of guidelines on the Open Access Transmission Service (OATS) and generation prices before the introduction of retail competition			○	○
	Determination of charges and fees related to Ancillary Services		○	○	○
	Duty to secure capacity to suppliers			○	○
	Promulgation of rules, guidelines and procedures related to the licensing of suppliers			○	○
	Promulgation of rules, guidelines and procedures related to the licensing of power sales companies	○	○	○	○
	Publication of other guidelines related to the enforcement of grid codes and distribution codes, and the assessment of technical and business plans			○	○
2) Price regulation	Calculation of transmission costs		○	○	○
	Industry price regulations	○	○	○	○
	Commercial price regulations	○	○	○	○
	Residential price regulations	○	○	○	○
	Price control method for transmission (PC, RC or ROR)	○	○	○	○
	Price control method for distribution (PC, RC or ROR)	○	○	○	○
3) Metering	Establishing approval guidelines for MSPs (Meter Service Providers)				○
	Establishing guidelines related to electric power meters and inspection				○
4) Rural electrification	Evaluation of electrification methods			○	○
	Evaluation of universal charges for rural electrification			○	○
	Evaluation of new participants			○	○
	Determination of areas within the franchised territories of the distribution company which are deemed unviable and approval of new participants performing distribution in the area			○	○
5) Saving of energy and new energy	Energy saving regulations such as DSM	○	○	○	○
	Duty to use renewable energy	○	○	○	○
6) Consumer Protection	Providing necessary data	○	○	○	○
	Holding public hearings and handling complaints	○	○	○	○
7) Evaluation of assets related to unbundling of sectors	Review and approval of Transition Supply Contracts				○
	Establishment of evaluation methods and evaluation of unrecoverable investment costs			○	○
	Establishment and promulgation of guidelines on the delineation of voltage transmission assets and sub-transmission assets			○	○

Note 1: Operations related to metering include setting performance criteria for meters, inspecting meters and measuring inspection data. Note 2: PC = Price Cap, RC = Revenue Cap, ROR = Rate of Return regulations, DSM = Demand Side Management. Note 3: Since the general definition of Open Access is "opening of lines to third parties," it is necessary at the stage of wholesale competition. Note 4: Sub-transmission Assets: Electricity transport facilities below transmission voltage. Assets of the public utilities which are linked with generation and transmission but are not included in generation assets or transmission assets (The transmission company separately owns transmission facilities). Note 5: Demand Side Management: load centralized control. To control the load of customers in a concentrated manner in order to level the annual load factor (average power ÷ maximum power) due to increasing maximum power. Note 6: Only grid codes are necessary under the single-buyer model. Note 7: Transition Supply Contracts are power purchase contracts associated with privatized assets. Source: Created by the author.

Table 4
Elements that influence electric power price.

	Elements where electric power price increases	Elements where electric power price decreases
Associated with liberalizations models	• Exercise of market power entailed by the liberalization • High PPA price with IPP • Profit guarantee to distribution companies (There are a lot of newly created companies upon privatization, especially in East Europe and in Latin America. • Cost for rural electrification • Cost to promote new entry to retail market • Introduction of cost reflective tariffs	• Free market competition functions and competitive pressures become strong (new entries and productivity enhancement).
Not associated with liberalizations models	• Rise of price of fossil fuels	• Rise of democratic movement • Price decreases through political pressure • Introduction of hydro-power and coal thermal power generation • Decrease of capital costs • Decrease in price of fossil fuels • Price caps

Source: Created by the author.

Retail Market, respectively. Many countries introduced retail competition gradually. However, we select the year when the liberalization law is enacted, not when it is fully realized. We choose a year when a country begins to open the market, not a year when the market has completed the process.[2]

For the timing of the changing value of the dependent variable for respective countries, please refer to Appendix A.

Table 2 reveals the descriptive statistics of the transitional pattern of liberalization reform. In Asian developing countries, few countries adopted wholesale or retail competition models. In the former Soviet Union, in Eastern Europe and Latin America, transition patterns and the current status of liberalization models in each region vary widely. Some countries still preserve a monopoly model while others introduced competition in generation and in distribution level models. Most of the countries categorized as developed countries introduced retail competition.

Table 3 – Exemplifies liberalization models and regulatory functions to be prepared. Generally, when a vertically integrated public electric power enterprise is unbundled into four parts – generation, transmission, distribution and retail – the liberalization model evolves, the number of stakeholders and procedures necessary at various places increase and, as a result, regulatory functions will increase. This additional cost for regulation could be one of the factors responsible for raising the electric power price.

Table 4 details factors that influence the electric power prices. The electricity price will decrease due to political pressure both in the industrial and residential prices and/or by an effect of the price decrease promoted by free market competition. Decreases in electricity prices are induced by market competition. Increase in regulatory costs are associated with the unbundling and/or exercise of market power, or the introduction of cost-reflective tariffs in each region, entailed by the liberalization of power sectors. As the selected liberalization model develops, prices will be expected to decrease due to the development of liberalization and competition in developed countries. However, for some markets in developed countries with higher liberalization models, costs for the regulation are one of the factors responsible for raising the electric power price. In developing countries, there are also controversial questions that arise with liberalization. For example, to what extent should cost reflective tariffs for accelerating private investment be adopted? Price increases are more likely to be associated with the restructuring of the electric industry and the removal of subsidies. IPPs also often pre-date liberalization and can be conflicting with liberalization due to structure of long-term contracts. As pointed out in Nagayama (2007), the increase on electric power prices in Asian countries often resulted due to introduction of IPPs, since payments for IPPs (Independent Power Producers) are guaranteed for foreign investor under structure of long-term PPA(Power Purchasing Agreements) contracts.

4. Empirical analysis based on econometric models

In this section, we formulate three econometric models. Fig. 2 shows the structure we will follow. We can quantify the models by region to show which causes are ultimately dominant in the determination of the electricity price level. By using this model structure, we can capture the underlying synergetic, offsetting effects. Model – 1 measures the impact of electric power prices on liberalization. Model – 2 and 3 measure the impact of liberalization models on electric power prices. (Model structure is shown in Fig. 2.)

As previously indicated, these models were estimated using panel data from 78 countries in four regions (developed countries, Asian developing countries, the former Soviet Union, Eastern Europe and Latin America) for the period from 1985 to 2003. With cross section data, we can only examine the selection of a liberalization model at a certain point in time. However, with panel, data we can take into consideration not only which liberalization model was selected, but also the timing of the shift between different liberalization models.

Original electric power price data is taken from OLADE (Organización Latinoamericana de Energía: Latin American Energy Organization), Energy Prices and Taxes, published by the IEA (International Energy Agency), Transition reports by the European Bank for Reconstruction and Development (EBRD), government information sources such as National Statistics Bureau (China), and public utilities such as MERALCO (Philippines), CEB (Sri Lanka), EVN (Vietnam), PLN (Indonesia). Macroeconomic data was constructed using WDI (World Development Indicators) by the World Bank.

We undertook the analysis with the US dollar-denominated PPPs (Purchasing Power Parities) prices, since the OECD recommends using constant PPPs for time-series analysis.[3] We used this method to obtain a common base for electricity prices. Electric power prices are deflated by the CPI (Consumer Price Index) of each country and thus, we obtained electricity prices in real terms. We then converted the currency of various countries into US dollars by PPPs.

[2] For instance, the U.K. started to open its retail market from 1990 onward, while it was completely opened from 1998 forward. We take 1990 as the starting year of retail competition.

[3] Paul Schreyer 'Purchasing Power Parities and their Uses' OECD BfS Neuchatel, April 2004 (http://www.stat.ch/tpl/ssso/frsem04/Schreyer.pdf (accessed 1 December 2008)).

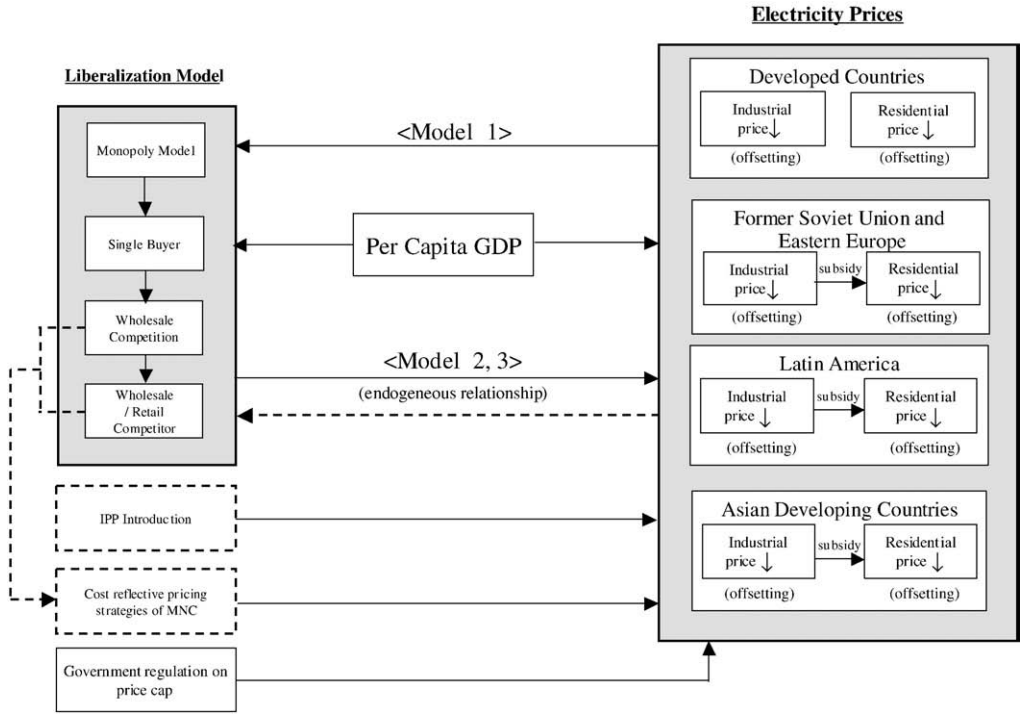


Fig. 2. Model structure.

Data on liberalization models in our study was collected by sorting the models of different market structures. Liberalization models were coded 0–3 in order of each step of electric sector liberalization: the country is coded zero if it holds the status of "before liberalization", "monopoly" or "no competition"; one if an SB model; two if the wholesale market is liberalized; three if the wholesale and retail markets are liberalized.

4.1. Analysis of the impact of electricity prices on the selection of liberalization models

4.1.1. The model

To observe the effect of electricity prices on the selection of electric power liberalization models for each region, we used an ordered probit model.[4] This is one of the models for discrete choice. Denoting the liberalization model as y, the equation is written as follows:

Model 1[5] (Ordered probit model)

$$\gamma_{it}^{*} = \alpha + \beta' X_{it-2} + \gamma_i + \varepsilon_{it-2}$$

γ_{it}^{*} is a latent variable which will not be observed as a continuous numerical data and the true measure of liberalization models adopted. β is the vector of parameters to be estimated. X_{it} is the variable described above, γ_i is an unobserved time-invariant country specific effect and ε_{it-2} is an error term. γ_{it}^{*} takes vales from minus infinity to plus infinity. To correspond γ_{it}^{*} to discrete selections, let us divide γ_{it}^{*} into 4 selections. The observed rating is determined by the cut-off point of the unknown threshold parameter μ_j $(j=1,2)$ which holds sequence restrictions. Categories 1, 2, and 3 are differentiated by μ_j.

To be observed are

$$\gamma_{it} = \begin{cases} 0(\gamma_{it}^{*} \le 0) \\ 1(0 < \gamma_{it}^{*} \le \mu_1) \\ 2(\mu_1 < \gamma_{it}^{*} \le \mu_2) \\ 3(\mu_2 < \gamma_{it}^{*}) \end{cases}$$

Subscript ί indicates the country and t indicates the time period. Independent variables are electric prices and GDP per capita with two years lag. The method of maximum likelihood is used to estimate the probit model. The likelihood is maximized by determining the joint distribution function of the explained variable. Since it is technically difficult to assume the fixed effect in the panel probit model, we take use of the random effects.

Endogeneity is not a significant issue in model 1 as long as reform responds to price with the lagged term. In this paper, we took a two-year lag for all independent variables since there is thought to be some time lag for the selection of models. It is often the case that countries commence restructuring and raising prices well before reforms take effect, firstly, to act as a new energy policy and secondly, to attract foreign investors by signaling that secure returns can be obtained.

Missing data are treated as missing values and are analyzed using unbalanced panel data. We choose the first year of action taken to shift from one model to another.

[4] It is appropriate to use the probit model to estimate the random effect of panel data for discrete type data, as Hsiao (2003) literature suggests that there is no consistent estimator of β for fixed-effects probit models. As for the example, in which the probit model was used with panel. Cheung (1996) had analyzed the ratings of the local government units of Canada by the ordered probit model. Although they have dealt with the panel data, they did not expand their model into the panel model by use of sequence categorical analysis. Blume et al. (1998) analyzed the industrial bond rating of the United States, by using the panel data of the United States of 23 years. They pointed out that, in the U.S., the rating references have become economically acerbic. This was accomplished through the assumption of the periodic effects using fixed model effects, which take into account the dummy variables.

[5] LIMDEP version 8 was used for model 1 estimation.

Table 5
Estimation results of the ordered probit (random effect) model (Model 1).

Variables	Expected Sign	Total	Asian developing Countries	Latin America	Former Soviet Union and Eastern Europe	Developed Countries
Industrial prices						
(1) Electricity prices	+	0.00078228***	0.00064687***	0.3032956	0.00106781***	0.00010113
		(11.625)	(3.864)	(0.884)	(11.103)	(0.614)
(2) GDP per Capita (%)	+	0.0000152445***	0.00020521***	0.0000050793	0.0000586226**	0.0000181856***
		(6.883)	(3.778)	(0.229)	(2.090)	(7.452)
μ (1)		0.63388377***	1.40543487***	0.81428672***	0.65601919***	0.19157673***
		(17.083)	(11.097)	(11.788)	(8.148)	(6.034)
μ (2)		0.95781683***	1.58793682***	1.94249562***	1.18255838***	0.24551819***
		(22.972)	(11.353)	(14.127)	(9.508)	(6.868)
Log likelihood		−1403.520	−174.3765	−378.9503	−255.9733	−465.3292
Number of observations		1326	187	340	357	442
Residential prices						
(1) Electricity prices	+	0.00087861***	0.00068838***	0.00426032	0.00116709***	− 0.0000432774
		(11.760)	(4.161)	(0.126)	(11.027)	(−0.2)
(2) GDP per Capita (%)	+	0.0000124402***	0.00021224***	0.0000135054	0.0000392415	0.0000174346***
		(5.713)	(3.904)	(0.692)	(1.424)	(7.614)
μ (1)		0.63176010***	1.40722826***	0.80098849***	0.67339108***	0.19157673***
		(19.079)	(11.096)	(11.815)	(8.273)	(6.034)
μ (2)		0.95413805***	1.59004129***	1.91573911***	1.18620263***	0.24551819***
		(22.960)	(11.353)	(14.140)	(9.653)	(6.868)
Log likelihood		−1398.007	−175.4951	−378.5174	−248.0789	−459.0952
Number of observations		1326	187	340	357	442

Note 1: The value in parentheses is *t*-value. Note 2: *** Statistically significant at a significance level of 1%. ** Statistically significant at a significance level of 5%. * Statistically significant at a significance level of 10%. Note 3: Categorized into 4 regions: Developed Countries: Korea Rep., Japan, Australia, New Zealand, United States, Canada, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, South Africa, Hong Kong, Singapore. Former Soviet Union and Eastern Europe: Romania, Hungary, Poland, Slovakia, Czech Republic, Kazakhstan, Russia, Ukraine, Kirghiz Republic, Albania, Armenia, Azerbaijan, Belarus, Bulgaria, Croatia, Georgia, Latvia, Lithuania, Macedonia, Republic of Moldova, Slovenia. Asian developing countries: China, India, Indonesia, Sri Lanka, Thailand, the Philippines, Vietnam, Turkey, Malaysia, Laos, and Cambodia. Latin America: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Venezuela, Uruguay.

4.1.2. Independent variables and expected signs

As the electric power price level increases, it is expected that the electricity sector will be more liberalized and the political movements that encourage lower electric power prices will increase. Particularly in developing countries, industrial users are more likely to demand liberalization because they are less subsidized than residential users. Higher GDP per capita (1995 prices) may lead to accelerated liberalization.

4.1.3. Results of Model 1

Table 5 demonstrates that, although there are some differences between the areas, the estimated results are generally in line with expectations. The higher the electric price, the stronger the impetus is to perform electric sector reforms. Electric power prices, for both industrial and residential prices, take a statistically significant positive value in Asian developing countries, the former Soviet Union and Eastern Europe. In developed countries and in Latin America, however, while the direction of the coefficients is as expected, statistically significant results are not evident.

In terms of the control variable for the industrial and residential prices, GDP per capita is statistically significant and positive, except for Latin America. Thus, a higher absolute level of GDP per capita is associated with liberalization models.

4.1.4. Examination of the result of Model 1

As can be seen in Table 6, the results of Model 1 can be summarized as follows: the industrial/ residential prices of both Asian developing countries along with the former Soviet Union and Eastern Europe had an impact on the transition of the liberalization model (from monopoly model → SB model → Wholesale model → Wholesale/Retail competition model) as a result of the increase in the level of electricity prices, with statistically significant results as expected. Further, statistically significant positive results for the transition of liberalization models indured by high levels of GDP per capita in residential prices were observed in Asian developing countries, and in developed countries. Statistically significant results were not obtained for Latin American and developed countries. However, statistically significant results for industrial electricity prices obtained in all areas except for Latin American countries. This result may arise from heterogeneity in liberalization patterns in Latin America.

Table 6
Overall summary of the results of Model 1.

	Expected sign	World total		Asian developing countries		Latin America		Former Soviet Union and Eastern Europe		Developed countries	
		Ind.	Res.	Ind.	Res.	Ind.	Res.	Ind.	Res.	Ind.	Res.
(1) Electricity Prices (X_1)	+	↑	↑	↑	↑			↑	↑		
(2) GDP per Capita (X_2)	+	↑	↑	↑	↑			↑		↑	↑

Note 1: The arrow shows direction of coefficients ↑ (plus) ↓ (minus).
Note 2: The coefficients with statistically significant at a significance level of 10% are shown. Note 3: "Ind" represents "Industrial electricity price", and "Res." represents "Residential electricity price".

4.2. The impact of liberalization models on electricity prices

4.2.1. The model

We next estimated the impact of the policy variable of the electric sector reform on electricity prices in order to examine the effect of the sector reforms.[6]

Model 2: (Fixed-effect/random-effect model)

$$\gamma_{it} = \alpha + \beta X_{it} + Z_{it} + \gamma_i + \varepsilon_{it}$$

y_{it}: electricity power prices, X_{it}: selected liberalization model, Z_{it} is GDP per capita, γ_i: country specific effect and ε_{it} is the normal disturbance term.

It is important to note that endogeneity is not a considerable issue in Model 1 since reform responds to price with a lag but in Model 2, price responds immediately to market structure.

It is expected that the liberalization model affects electric power prices, and that electric power prices affect the selection of liberalization models. To correctly evaluate the relationship between these two variables, we must resolve the endogeneity issue. It takes time for the effect of liberalization to appear and it is possible that the effect is cumulative. During the period contained in the data, the effect of liberalization tends to appear more in countries that were liberalized earlier than in countries that were liberalized at a later stage. Thus, we used instrument variables in Model 3 to deal with this simultaneity bias problem between electric power prices and the selected liberalization model.

Model 3 (Instrument variables model)[7]

We assume X_{it} (the selected liberalization model) as endogenous and use instrument variables with M_{it}. M_{it} is an identifying instrument.

$$\gamma_{it} = \alpha + \beta X_{it} + Z_{it} + \gamma_i + \varepsilon_{it}$$

$$X_{it} = \theta_1 + \theta_2 M_{it} + \nu_{it}$$

y_{it}: electric power prices, X_{it}: selected liberalization model, Z_{it} is GDP per capita, t, γ_i: country specific effect and ε_{it} is the normal disturbance term.

Since the political democratic degree index[8] can be seen as exogenous to the equation of interest and is deeply related to the selected liberalization model, we employed the political democratic degree index, M_{it}. Other factors such as market power or regulatory costs are difficult to obtain for 78 countries with the same standards. Fuel prices have different impacts on the electricity prices for each country, due to taxes exercised by each country or by natural endowment. (as discussed in Nagayama (2007)). This factor was not considered in the model.

Table 7
Estimation results of the impact of selected liberalization models on electricity prices (Model 3).

	Expected sign		World total		Asian developing countries		Latin America		Former Soviet Union and Eastern Europe		Developed countries	
			F	®	F	®	©	R	F	®	F	®
Industrial IV												
Constant			−0.0096306	0.1222555***	0.2037163***	0.2225598	0.2142676*	0.2366365***	−0.1080179	0.1361625***	0.3957035***	0.1629197***
			(−0.14)	(3.76)	(3.15)	(0.91)	(1.85)	(3.67)	(−0.38)	(3.68)	(3.71)	(4.70)
(1) Selected liberalization model (X_1)	+	−	−0.0765018***	−0.099534***	−0.1268065*	−0.122625**	−0.00192	0.0017881	−0.1315384*	−0.0999731	0.0473134**	0.0355113*
			(−2.84)	(−2.25)	(−1.92)	(−2.00)	(−0.03)	(0.04)	(−1.64)	(−1.61)	(2.48)	(1.77)
(2) GDP per capita (X_2)		−	0.0000194**	0.0000102	0.0001127	0.0001039	−0.0000132	−0.0000217	0.0001025	0.0000205	−0.0000163***	−5.76e−06**
			(2.37)	(1.57)	(1.32)	(1.33)	(−0.23)	(−0.67)	(1.00)	(0.88)	(−3.00)	(−2.48)
Number of observations			999	999	135	135	356	356	104	104	404	404
Hausman test (*P*-value)				3.42		6.15		−0.09		0.41		3.61
				(0.1807)		(0.9295)		(-)		(08135)		(0.1644)
Residential IV												
Constant			0.0876974	0.1653556***	0.1926505***	0.2251685***	0.0378306	0.1893335***	0.3737498	0.2447901***	0.4212791***	0.3334879***
			(1.52)	(8.80)	(4.34)	(3.03)	(0.18)	(2.95)	(2.95)	(3.39)	(4.45)	(4.66)
(1) Selected liberalization model (X_1)	+	−	−0.0445563****	−0.0527512	−0.0468096	−0.0392388	−0.1067358	−0.06972	0.0409065	0.0429009	0.040684**	0.0342821**
			(−1.91)	(−1.55)	(−1.06)	(−1.05)	(−0.87)	(−1.07)	(0.74)	(1.02)	(2.44)	(2.15)
(2) GDP per capita (X_2)		−	9.82e−06	3.75e−06	0.0000417	0.0000257	0.0000792	0.0000161	−0.0000928	−0.0000524	−0.0000147***	−0.0000108**
			(1.38)	(0.83)	(0.72)	(0.57)	(0.74)	(0.46)	(−1.66)	(−1.62)	(−3.08)	(−2.90)
Number of observations			1050	1050	132	132	356	356	144	144	418	418
Hausman test (*P*-value)				1.04		3.40		−0.98		−0.43		1.45
				(0.5947)		(0.1828)		(-)		(-)		(0.4850)

Note 1: F: Fixed Effects Models. R: Random Effects Models. ○ shows the employed model. Note 2: Fixed effects are tested with t-value; random effects are tested with z-value. Note 3: *** statistically significant at a significance level of 1%. ** statistically significant at a significance level of 5%. * statistically significant at a significance level of 10%. Note 4: The categories of the four regions are same as in Table 5.

[6] There were systematic differences in the coefficients between the fixed-effect/random-effect models and the instrument variables models. This suggests that an endogeneity issue existed, but was resolved by the use of the IV technique. We will focus on the results of the instrument variables (Model 3).

[7] STATA version 8.0 was used for Models 2 and 3 estimation.

[8] We used Polity IV as the political democratic degree index. The Polity IV Project was created by the Center for International Development and Conflict Management at the University of Maryland. The democratic degree of each country from 1800–2003 are arranged in a database as Political Regime Characteristics and Transitions at http://www.cidcm.umd.edu/inscr/polity/. Under the Polity IV Project, since many polities have the characteristic of both democracy and autocracy, the characteristic of a government at a certain period is measured as Polity Index by representing both democracy (DEMOC) and autocracy (AUTOC) of each year with indicators and subtracting the AUTOC score from the DEMOC score. The range of numerical value is -10 (Full Autocracy) to 10 (Full Democracy). This means the polity of each country can be represented by a score of −10 to 10.

Table 8
Overall summary of the results of Model 3.

	Expected sign	World total		Asian developing countries		Latin America		Former Soviet Union and Eastern Europe		Developed countries	
		Ind.(R)	Res.(R)	Ind.(R)	Res.(R)	Ind.(F)	Res.(F)	Ind.(R)	Res.(R)	Ind.(R)	Res.(R)
(1) Selected liberalization model (X_1)	+−	↓		↓						↑	↑
(2) GDP per Capita (X_2)	−									↓	↓

Note1: The arrow shows direction of coefficients ↑ (plus) ↓ (minus) for models adopted.
Note2: (F) denotes fixed effects model and (R) denotes Random effects model.
Note3: The coefficients with statistically significant at a significance level of 10% are shown.
Note 4: "Ind." represents "Industrial electricity price" and "Res." represents "Residential electricity price".

4.2.2. Results of Model 3

4.2.2.1. Selected liberalization models. Table 7 displays the estimation results of Model 3. Table 8 summarizes Table 7. We have chosen to focus on these results because they provide better results concerning our objective variable- "the Selected Liberalization Model". (Model 2 results are in the Appendix B) The endogeneity problem present in Model 2 is resolved by the inclusion of the independent variables in Model 3. Tables 7 and 8 reveal that the progress of electric power sector reforms lowers the industrial electric power prices in the world total and in Asian developing countries. Conversely, it raises the industrial and residential electric power prices in the developed countries.

Our interpretation of these results can be summarized as follow; First, in developed countries, the regulatory costs and the exercise of market power associated with shifting to higher liberalization models, are stronger than the downward pressure to decrease electricity prices. Hence, it is more likely that prices will remain high in these countries.

Second, in the former Soviet Union and in Eastern Europe, the pressure of decreasing residential prices as the result of liberalization can be explained by governmental pressure to keep the electricity tariffs low. In Hungary, for example, the government applied pressure to suppress the electricity price to levels below cost in 2000. The MVMRt Co., a single buyer, consequently put out massive losses. The government compensated them through the budget in fiscal year 2001. As Krishnaswamy and Stuggins (2003) points out, Union Fenosa in Moldova was confronted with a variety of difficulties, such as the new administration pressuring the regulatory institution not to raise prices in order to fulfill its election promise. A variety of political pressures existed; for example, the mayor of the capital city lead a backlash against the increase in electricity prices by refusing to fund the increased payment. Henisz and Zelner (2001) pointed out that in the Czech Republic, the MOF (Ministry of Finance) has the jurisdiction to make final decisions for electricity prices as well. In the former Soviet Union and in Eastern European countries, the electricity tariff–setting method is the problem. A price cap has been adopted in such countries as Armenia, the Republic of Georgia, Hungary, Moldova, Slovakia and the Ukraine where private capital participates. However, in almost all of the former Soviet Union and Eastern European countries, a cost-plus system has been adopted. Disputes have taken place in Hungary and Moldova regarding the extent to which costs can be included in electricity prices.

Third, in Asian developing countries, cross-subsidies exist from industrial users to residential users as industrial users are less subsidized. We determined that cross-subsidies are removed as the liberalization models progressed.

Fourth, in Latin American countries, the impact of liberalization on electricity prices is mixed as liberalization models progress. This is probably due to the fact that wholesale and retail prices tend to rise under the process of unbundling and privatization in order to assure profit to private investors, which are comprised mostly of multinational corporations.

Remembering also from Table 1, as the liberalization model develops, the number of stakeholders in the sector increases along with the maintenance cost. Developing countries need to be particularly careful regarding which models of liberalization they choose to employ.

4.2.2.2. Control variables. In terms of control variables, we find that the industrial and the residential electric power prices decrease in the developed countries while GDP per capita increases. We could not obtain statistically significant data for other areas.

5. Conclusion

This paper, uses panel data from 78 countries, including developing nations. We estimated the effect of electric power prices on electric sector liberalization models and the effect of the selected liberalization models on electric power prices of each country for a period ranging from 1985 to 2003. The endogeneity of electricity prices and power liberalization models has also been examined. The research findings suggest that higher electricity prices are one of the driving forces of adopting liberalization models. However, the development of liberalization models in the power sector does not necessarily reduce electricity prices. In fact, contrary to expectations prices had a tendency to rise. Therefore, when the selection of a liberalization model is discussed in developing countries, careful consideration should be given to the types of reforms that would best suit the economic development stage of each country.

It is necessary to take into account the fact that the change in prices, influenced by power sector reforms, has a dynamic impact on other factors as well. In developing countries for example, the increase in electricity prices decreases electricity accessibility to the poor segments of the population. Alternatively in developed countries, the decrease in electricity prices mitigates the effort put forth toward saving energy. The decrease in electricity prices is clearly a negative factor for investors in terms of profit performance This will almost certainly inhibit investment promotion in electricity fields. Our future research will consider dynamic aspects resulting from power sector reforms.

There is still much room for improvement within the models and data presented in this paper. There is a need to further scrutinize the models against further data in the future. Furthermore, we treated large countries United States, Australia, Canada and India, in which the development of liberalization varies from state to state in the same way as developing countries that came late to liberalization. Thus, in the future, we need to contrive ways to reflect the impact of the size and scale of each of these countries.

There will be some other factors that need to be mentioned. In developed countries within the EU, the directives of the European Commission also had an impact on the adoption of the reforms, irrespective of prices. We need to evaluate this impact in argument of prices and reforms.

The policy which was intended to promote competition and efficiency ended up with compromising efforts to secure the additional power supply necessary for developing countries, to achieve

rural electrification and the support of the poorest segment of the population. We need to understand that the number one root cause of the massive problems in a developing country's power sector is the high cost of electricity production which governments are unwilling to pass on to consumers for political reasons. Splitting public utilities into private companies in the name of power sector reform will not purely solve this problem. This problem can only be solved by pushing hard to implement low cost power generation projects.

The preceding results indicate there is a definite need for continued analyses of the effect of reforms in the electricity supply industry. There is also an indication that it is too early to reach any concrete judgment for future policy recommendations based on the results of this paper. An accurate calculation of the long-term effects of reforms on prices will require much additional study over longer periods of time. In many countries, regulatory reform in electricity supply is still an on-going process, a fact that also highlights the need for continued study.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.eneco.2008.12.004.

Appendix B

The results of Model 2

	Expected Sign	Total		Asian developing countries		Latin America		Former Soviet Union and Eastern Europe		Developed countries	
		F	R	F	R	F	R	F	R	F	R
Industrial											
Constant		0.1623282***	0.1719344***	0.2879025***	0.316282***	0.2327885***	0.2514032***	0.2442737***	0.147619***	0.1266179***	0.1173156***
		(15.47)	(12.07)	(12.63)	(5.13)	(9.16)	(9.02)	(4.85)	(6.57)	(16.80)	(13.70)
(1) Selected liberalization model (X_1)	+ −	−0.0055397***	−0.004032**	−0.0237063***	−0.0214516***	0.0088172*	0.0104568**	−0.026667***	−0.0319674***	−0.0014433*	−0.0021016***
		(−2.77)	(−2.20)	(−3.23)	(−2.97)	(1.71)	(2.13)	(−3.40)	(−4.99)	(−1.70)	(−2.65)
(2) GDP per capita (X_2)	−	−1.90e-06*	−3.18e-06***	−0.0000137	−0.0000237	−0.0000226**	−0.0000292***	−0.0000285*	−2.04e-06	−2.51e-06***	−2.09e-06***
		(−1.85)	(−4.26)	(−0.71)	(−1.34)	(−2.33)	(−3.95)	(−1.78)	(−0.33)	(−7.25)	(−7.04)
Number of observations		1006	1006	135	135	357	357	104	104	410	410
Hausman test (*P*-value)			3.83		0.90		1.10		6.52		3.20
			(0.1472)		(0.6365)		(0.5780)		(0.0384)		(0.2017)
Residential											
Constant		0.1918183***	0.1827713***	0.2503015***	0.2694163***	0.2621957***	0.2577334***	0.2500036***	0.1476131***	0.1658634***	0.1625281***
		(20.33)	(15.17)	(16.79)	(6.01)	(8.24)	(7.85)	(6.04)	(6.78)	(24.31)	(15.11)
(1) Selected liberalization model (X_1)	+ −	0.0040344*	0.0037335*	0.0216203***	0.0217194***	0.0241341***	0.0226773***	−0.0040039	−0.0099561	−0.0017349*	−0.0018047**
		(1.94)	(1.94)	(4.61)	(4.71)	(3.73)	(3.72)	(−0.56)	(−1.62)	(−1.95)	(−2.08)
(2) GDP per capita (X_2)	−	−3.48e-06*	−3.11e-06***	−0.0000413	−0.0000424***	−0.0000334***	−0.0000305***	−0.000037**	−2.43e-06	−1.91e-06***	−1.86e-06***
		(−3.97)	(−4.98)	(−3.48)	(−3.65)	(−2.75)	(−3.43)	(−2.37)	(−0.39)	(−6.35)	(−6.59)
Number of observations		1083	1083	132	132	357	357	144	144	450	450
Hausman test (*P*-value)			0.94		1.38		1.72		22.33		0.25
			(0.6252)		(0.5008)		(0.4232)		(0.0000)		(0.8825)

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