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The Impact of Energy Efficiency Programs in South Korea: An Empirical Analysis

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This research rigorously explores the intricate dynamics underlying household energy demand within the unique context of the South Korean economy. Employing empirical data, our study utilizes a robust structural time series model to conduct a thorough analysis of the factors influencing energy consumption patterns. Our findings illuminate a compelling positive correlation between household income and the demand for energy resources. This insight underscores the significance of economic factors in shaping the energy landscape within South Korean households. Additionally, our study delves into the nuanced relationship between energy prices and demand, revealing a discernible mitigating effect. This discovery suggests that fluctuations in energy prices play a crucial role in influencing and modulating household energy consumption. The implications derived from our research extend beyond mere academic discourse. The identified positive correlation between household income and energy demand serves as a pivotal point for policymakers. It prompts a reevaluation of existing strategies and calls for the development of a comprehensive approach to managing and controlling household energy demand in South Korea. As policymakers consider the multifaceted nature of these findings, they gain valuable insights to inform the design of effective strategies. Our research thus not only contributes to the academic understanding of household energy dynamics but also offers a practical roadmap for policymakers to craft informed and adaptive policies. This new direction holds the potential to shape the future of energy management in South Korea, fostering sustainability and resilience in the face of evolving economic and environmental challenges.
Kerwords: household, energy demand, energy efficiency programs
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1. INTRODUCTION

Since the emergence of the global energy crisis in 1973 and 1979, policymakers and planners, both in developed and developing countries, have ardently championed policies and programs aimed at fostering energy conservation and enhancing efficiency across all sectors, including residential areas. South Korea, as a developing nation, has actively participated in this global endeavor. Despite the extensive research conducted on the effects of technical efficiency and structural changes in residential energy demand in developed OECD countries by authors such as Khazzoom (1987), Dunstan and Schmidt (1988), Chern and Bouis (1988), and Haas and Schipper (1998), there has been a noticeable gap in the literature concerning similar studies in non-OECD developing countries. This study stands out as one of the pioneering attempts to conduct an econometric analysis of the effects of technical energy efficiency in a non-OECD developing country. Focusing on South Korea, we utilize annual time series data spanning from 1973 to 2003, employing a structural time series model to unravel the intricacies of technical energy efficiency in the residential sector. The significance of our research lies not only in its contribution to the academic understanding of energy dynamics but also in its contextual relevance to the unique challenges faced by developing nations. By bridging this gap in the literature, our study aims to provide valuable insights that can inform policy decisions and strategies tailored specifically to non-OECD developing countries.

In 1973, the per capita energy consumption in South Korea's residential sector stood at approximately 182 Ktoe. Over the subsequent decades, a dynamic pattern unfolded. By 1983, the consumption had ascended to about 261 Ktoe, marking an average annual growth of 3.64% from 1973 to 1983. However, a significant shift occurred in the following decade, with a deceleration in consumption to approximately 200 Ktoe by 1993, showcasing an average annual decline of -2.61% from 1983 to 1993. The trend then reversed, depicting a robust average annual increase of 6.69% from 1993 to 2003, culminating in a consumption of about 379 Ktoe. Concurrently, the observed trend implies a notable enhancement in energy efficiency within the residential sector. This is evident in the declining energy intensity, which experienced an average annual decrease of -1.76% from 1973 to 1983, followed by a more substantial annual decline of -9.25% from 1983 to 1993. Subsequently, there was a reversal in the trend, with an average annual increase of 1.93% from 1993 to 2003. The evolution of energy

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efficiency is further highlighted by the Energy Efficiency Index, which exhibited a consistent decline from 0.53 in 1973 to 0.45 in 1983. A more substantial decrease occurred by 1993, reaching a minimum of 0.15 in 1996, before stabilizing and maintaining a flat trajectory up to 2003, with an average of 0.20. A pivotal factor influencing South Korea's escalating residential energy demand has been the growing market share of household appliances. This surge can be attributed to the increased demand for housing, particularly in and around Seoul, where the development of new satellite cities has been substantial (IEA, 2005). Illustrating this trend, ownership of refrigerators surged by 156% between 1981 and 1991, while air conditioners and televisions saw staggering increases of 900% and 747%, respectively, during the same period (Sun-Keun, 2001). This intricate interplay of consumption patterns, energy efficiency trends, and the impact of evolving lifestyle preferences offers valuable insights for policymakers seeking to formulate strategies for sustainable energy management in South Korea's residential sector.

Within the residential sector of South Korea, climate emerges as a pivotal factor influencing household energy consumption patterns. An illuminating snapshot of this influence is evident in the data from 1986, where space heating claimed a substantial portion, constituting nearly 70% of the total household energy demand. In contrast, cooking accounted for a modest 14% of the total energy demand, while water heating played a negligible role in household energy consumption at that time. The significant decline observed in residential sector energy intensity over the years can be attributed, in part, to the adoption of district heating as a remarkably efficient method for warming both homes and industries. District heating has played a transformative role, contributing to a reduction in energy intensity. Notably, South Korea has earned the distinction of being a global leader in district heating technology, a status recognized by the International Energy Agency (IEA) in 2006. The establishment of district heating corporations by the South Korean government in 1985 marked a pivotal moment, sparking a rapid expansion in the demand for this energy-efficient heating method. In addition to the advancements in district heating, the South Korean government has actively pursued energy efficiency measures, particularly since 1992. A significant stride in this direction involves the promotion of energy efficiency for household appliances through the implementation of standards and labeling. The IEA report of 2006 emphasizes South Korea's commitment to enhancing energy efficiency in household appliances. This concerted effort aligns with the observed decline in residential energy intensity, suggesting that the response of household appliance users to the government's energy efficiency policies has played a crucial role in this positive trend. The intricate interplay between climate, technological advancements in heating methods, and proactive government policies towards energy efficiency underscores South Korea's multifaceted approach to address and mitigate residential energy consumption challenges. The collaborative efforts of citizens and policymakers in embracing energy-efficient practices and technologies present a promising trajectory for sustainable energy management in the residential sector.

2. ENERGY CONSERVATION & EFFICIENCY PROGRAMS

The efficacy of national energy efficiency and conservation policies and programs remains pivotal in fostering the judicious use of energy within the residential sector of South Korea. The foundation of these efforts lies in the Rational Use of Energy Act (RUEA) enacted in 1979, which serves as the guiding framework for formulating and implementing conservation and efficiency measures. Broadly categorized into market-based voluntary and command and control approaches, South Korea's energy efficiency and conservation programs primarily emphasize the market-based strategy. Under this approach, incentives are extended to building owners to enhance insulation, a move aimed at curbing energy consumption. Simultaneously, the promotion of appliance efficiency through initiatives such as efficiency labeling and the establishment of minimum efficiency performance standards for appliances takes center stage. A noteworthy example of South Korea's commitment to market-based efficiency and conservation is evident in the incentivization of building owners. In particular, the government actively encourages improvements in building insulation to curtail energy use. Additionally, the efficiency of appliances is addressed through a meticulous system involving efficiency labeling and the imposition of minimum efficiency performance standards. This strategic focus underscores a commitment to fostering a culture of energy-conscious choices within the residential sector. An exemplary case of government intervention is the monitoring of energy consumption in buildings exceeding four million kilowatts of electricity per annum since 1992. This initiative reflects a proactive stance in assessing and regulating energy use. Furthermore, the approval of five-year energy conservation plans for 629 buildings consuming more than six million kilowatts of electricity per annum showcases a comprehensive and forward-thinking approach (IEA, 2006). The emphasis on the market-based approach in South Korea's energy efficiency and conservation policies signifies a recognition of the importance of incentivizing and empowering individuals and businesses to make energy-efficient choices. This concerted effort not only aligns with global sustainability goals but also positions South Korea at the forefront of nations actively addressing the challenges of residential energy consumption

Moreover, the residential sector policies in South Korea extend their purview to encompass both buildings and household appliances. Since 1979, a stringent approach has been adopted for new buildings under construction, mandating inspections to ensure the utilization of standard insulation products and prescribed thickness. This commitment to quality and efficiency in construction practices represents a foundational step toward sustainable residential energy management. Building on this foundation, regulatory measures were further strengthened in 1985 with the introduction of a mandatory requirement for any building permit application for large structures to include an accompanying energy savings plan. Notably, this requirement extends to new buildings with a surface area exceeding 10,000 square meters. The proactive stance of the South Korean

government in this regard underscores a commitment to integrating energy conservation considerations into the very fabric of urban development. A targeted initiative focuses on existing large buildings that surpass an annual electricity consumption of 4 million kWh. These buildings are designated for audits and ongoing supervision to ensure adherence to energy efficiency standards. While these energy audits incur a fee for large residential and commercial buildings, the government extends the service of free energy audits to government and public buildings. This distinction reflects a strategic emphasis on promoting energy efficiency in public infrastructure, aligning with broader sustainability goals. Following these audits, the government provides technical assistance, addressing specific needs identified during the assessment process. This may include interventions such as the installation of thermal insulation and double-glazed windows, tailored to optimize energy efficiency. The provision of such targeted support not only fosters compliance with energy conservation standards but also serves as a proactive measure to enhance the overall energy performance of buildings. The comprehensive approach outlined in these policies exemplifies South Korea's commitment to embedding energy efficiency principles into the construction and maintenance of residential structures. By actively engaging with both new and existing buildings, the government seeks to create a built environment that aligns with sustainable energy goals, fostering a resilient and energy-conscious residential sector.

In addition to policies targeting buildings, South Korea has also implemented comprehensive measures directed at household appliances. This initiative, known as Minimum Efficiency Performance Standards (MEPS) and the labeling program, has been in place since 1981 and has undergone periodic legislative reviews. The program represents a systematic approach to assessing and categorizing electrical appliances, employing a five-grade ranking system. Appliances are graded from Grade 1, denoting the most energy-efficient models, to Grade 5, representing the least efficient. Significantly, Grade 1 products demonstrate a substantial energy savings potential of 30 to 40% when compared with Grade 5 products. The impact of this program has been transformative, as highlighted by Sun-Keun (2001). Over the years, the market has witnessed a notable shift, with the proportion of energy-efficient appliances (Grade 1 or Grade 2) escalating from 55.4% in 1993 to an impressive 66% in 2000. This success can be attributed to the concerted efforts of both the government and non-governmental organizations (NGOs) in actively raising public awareness about the benefits of energy-efficient appliances. The collaboration between these entities and manufacturers has played a crucial role in fostering a market environment that prioritizes and promotes energy-efficient choices. Furthermore, energy conservation policies within the public sector extend to public procurements. These policies mandate the acquisition of certified high-energy-efficiency equipment. Additionally, in the construction and extension of public buildings, there is a legal obligation to use certified high-energy-efficiency equipment. This strategic integration of energy conservation measures into public sector practices not only sets a precedent for responsible resource management but also serves as a demonstration of the government's commitment to leading by example in sustainable energy practices. In summary, South Korea's multifaceted approach to energy conservation, encompassing both household appliances and public sector practices, showcases a commitment to fostering a culture of energy-conscious choices. The collaborative efforts of government, NGOs, and manufacturers have not only transformed the market landscape but also positioned South Korea as a global leader in sustainable and efficient energy management.

3. MODEL SPECIFICATION

Recognizing the paramount importance of technical energy efficiency, the selection of an appropriate modeling approach becomes a critical step when estimating price and income elasticities of demand, as well as assessing the effects of technical energy efficiency. The ideal model should possess the flexibility to isolate the impacts of economic factors, such as overall economic activity and real energy prices, from the effects of technical progress, influenced by both endogenous and exogenous factors. The rationale behind choosing a model that can adeptly capture the multifaceted influences on residential sector energy consumption aligns seamlessly with the principles of the Structural Time Series Model (STSM). This modeling framework provides a robust foundation for disentangling the intricate web of factors that contribute to energy consumption patterns. The STSM's capacity to discern the effects of economic variables and a range of other factors, including technical progress, makes it an optimal choice for empirical analysis in this context. This methodological preference aligns with the perspective put forth by Harvey et al. in 1986, who emphasized the importance of flexibility in models to account for diverse influences on energy consumption. By leveraging the capabilities of the STSM, the empirical analysis aims to provide a nuanced understanding of the interplay between economic factors, technical progress, and their collective impact on residential sector energy consumption in South Korea. In essence, the adoption of the STSM as the chosen methodology signifies a commitment to precision and comprehensiveness in capturing the dynamics of energy consumption. This strategic approach acknowledges the complex interdependencies within the residential sector and positions the analysis to yield insights that transcend traditional modeling constraints. As a result, the empirical findings derived from this methodological choice are poised to contribute substantively to the discourse on energy economics and inform more targeted and effective policy interventions.

4. RESULTS & DISCUSSION

The standard diagnostic tests conducted for the model outlined in Table-1 affirm its overall robustness, revealing no indications of autocorrelation or non-normality issues. It is noteworthy that while an initial challenge of non-normality in the levels residuals was identified, a proactive intervention in the form of introducing a level dummy in 1999 successfully

addressed this concern. Subsequent to this adjustment, the model exhibits a clean bill of health with no discernible diagnostics problems or structural breaks observed. The preferred specification, as evidenced by the diagnostic results, aligns with the local trend model. This model, characterized by its adaptability to local variations, emerges as the most suitable choice for capturing the nuances of the residential sector's energy demand in South Korea. Importantly, the local trend model introduces a dynamic element, implying that the energy demand in the residential sector does not adjust instantaneously to its long-run position. This nuanced characteristic of the local trend model signifies a recognition of the temporal dynamics inherent in the residential energy landscape. The acknowledgment that adjustments in energy demand may unfold over time rather than occurring instantaneously underscores a commitment to capturing the realistic complexities of the system under examination. This dynamic feature enhances the model's capacity to reflect the evolving nature of factors influencing residential energy consumption, contributing to a more accurate and insightful representation of the dynamics at play. All the estimated elasticities from the model exhibit statistical significance and demonstrate the expected signs, affirming the reliability of the analytical framework. In the long run, the income elasticity registers at 0.97, while its price counterpart stands at -0.63. A comparative analysis with existing literature reveals interesting insights. Notably, the long-run income elasticity of 0.97 is notably lower than the 1.27 reported by Dahl (1998) but surpasses the 0.62 figure obtained by Pesaran et al. (1994). In contrast, the long-run price elasticity from the present study is notably higher at -0.63 compared to the -0.33 reported by Dahl (1998) and the -0.20 obtained by Pesaran et al. (1994). It is imperative to note that these divergent findings can be attributed to the inclusion of a trend variable in the current model. The absence of this variable in previous studies, coupled with the temporal gap—over a decade—since their completion, underscores the evolution in the understanding and modeling of residential sector energy demand. The observed differences in long-run elasticities highlight the importance of accounting for temporal dynamics and incorporating trend variables in the model. The current study's more nuanced approach, bolstered by these considerations, contributes to a refined understanding of how income and price impact residential energy consumption in South Korea. The consistent statistical significance and expected signs in the estimated elasticities, coupled with the nuanced comparison to previous studies, underscore the methodological advancements incorporated in the present analysis. The inclusion of a trend variable and the temporal relevance of the study collectively enhance the robustness and applicability of the findings to the current energy landscape.

Table-1: Structural Time Series Results for South Korean Residential Sector

Variables	Coefficients (T-statistics)
Y	0.53 (4.7667)
P	-0.35 (- 2.196)
E_{t-1}	0.44 (3.4195)
Level_1999	0.24 (4.556)
Long-run estimates	
Income(Y)	0.96
Price(P)	-0.63
Nature of trend	*Local trend model*
Estimated Components	
Level	0.32
Slope	-0.026

The estimated elasticities offer insightful implications, suggesting that the relatively low income elasticity may be attributed in part to the influence of embedded technological progress. As incomes rise, there appears to be an acceleration in the replacement of household appliances and equipment. This phenomenon contributes to an enhanced efficiency of the overall stock of appliances and equipment. The implication is that the evolving economic landscape, marked by income increases, acts as a catalyst for the adoption of more technologically advanced and energy-efficient household items. Conversely, the relatively high value of the long-run price elasticity could be indicative of a scenario where technical energy efficiency is induced by persistent increases in energy prices. As energy prices experience a sustained upward trajectory, this trend encourages the introduction of more energy-efficient stocks of appliances and equipment into the market. Consequently, this dynamic also contributes to an improvement in the overall efficiency of the existing stock of appliances and equipment. When considering the joint effects of long-run price and income, the results suggest a noteworthy shift in the long-run energy demand curve. Specifically, the inward shift observed during the estimation period implies a fundamental change in the underlying dynamics of residential energy demand in South Korea. This shift reflects the combined impact of technological progress, income changes, and the interplay with energy prices.

5. CONCLUSIONS

Structural Time Series models were employed to scrutinize the impacts of enhanced technical efficiency on residential energy demand in South Korea from 1973 to 2003, utilizing time series data. The obtained statistical properties not only align strikingly with underlying economic theory but also adhere to key econometric assumptions. Notably, the estimated coefficient of long-run price elasticity stands at -0.63, while the long-run income elasticity registers at 0.97. The observed shape of the trend in the model is characterized as generally stochastic, demonstrating a consistent negative slope throughout the entire estimation period. This temporal pattern reflects the dynamic and unpredictable nature of the residential energy demand trend over the years. The convergence of these results reinforces the robustness of the employed Structural Time Series models in capturing the nuanced dynamics of South Korea's residential energy demand. Importantly, the derived outcomes provide compelling evidence suggesting a substantial improvement in the autonomous efficiency of residential energy demand during the estimation period. The observed negative slope in the trend, coupled with the estimated elasticities, indicates a notable responsiveness of energy consumption patterns to changes in both price and income. This responsiveness is a key indicator of the positive impact of enhanced technical efficiency on the residential demand for energy. In short, the comprehensive analysis utilizing Structural Time Series models offers valuable insights into the evolving dynamics of South Korea's residential energy demand. The consistency with economic theory, adherence to econometric assumptions, and the documented improvement in efficiency collectively contribute to a nuanced understanding of the complex interplay between technical progress and residential energy consumption over the studied period.

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