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厦门大学

博士学位论文

巴基斯坦能源需求、经济增长和碳减排分析

**Analysis of energy demand, economic growth and emission
mitigation in Pakistan**

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Dedicated

To my

Parents, siblings, wife and daughter

厦门大学博硕士学位论文摘要库

Abstract (Chinese version)

摘要

巴基斯坦是一个缺乏能源的国家，但对能源的需求却快速增长。从历史上看，石油和天然气是能源和财政收入的主要来源。石油和天然气主要用于交通运输业和制造业。石油主要是进口商品，而天然气是本地生产的。电力主要来自水力资源。然而，由于工业化、城市化进程的进行和经济规模的扩张，对电力的需求开始增加，政府开始建设火电项目。现在火电项目已经超过了水电项目，这严重损害了能源安全和环境可持续性。目前，巴基斯坦正面临严重的能源危机，严重影响经济。巴基斯坦政府已经出版了一份官方文件《巴基斯坦 2025 年，一个国家一个愿景》，其目标是到 2025 年巴基斯坦争取成为世界上在经济增长方面最快的 25 个经济体。该文件还旨在增加能获得能源的人口比例，争取从 67% 增长 90%，并控制气候变化。由于需要平衡这些经常相互矛盾的目标，所以在制定国家能源政策时要达到微妙的平衡。因此，本文从节能，替代和减排的角度出发，分析巴基斯坦的能源需求。

第一步，我们使用 Johanson 协整方法分析巴基斯坦能源需求的长期决定因素。结果表明，经济增长是影响能源需求的主要因素。能源价格，劳动生产率和资本强度是长期减少能源需求的因素。我们进一步利用这些因素预测巴基斯坦未来的能源需求。除此之外，我们利用情景分析方法估计巴基斯坦的节能潜力。我们的结果表明，能源价格改革，提高劳动生产率和技术进步以及研发投入对于实现节能潜力至关重要，特别是在到 2025 年实现高经济增长的背景下。

巴基斯坦为了满足不断增长的能源需求，采用火电项目而不是水电项目，这有财政成本和环境损害。因此，为了分析这种技术变化，我们使用超越对数生产函数，用能源和非能源投入来估计替代弹性。结果表明，资本与能源，劳动力与能源是替代品，从而说明需要更加关注技术进步和技能创造就业，以节约能源和减少排放。改革能源价格使价格能够反映真实成本是防止能源消耗增加和促进资本密集型生产方法所必需的。基于资本与能源，石油和天然气的情景分析进一步鼓励节能减排。结果进一步表明以可再生能源和天然气为特

征的能源供应组合的重要性。我们还对交通运输部门进行了替代性分析，因为它是在产出，能源和环境方面的新兴部门。这也是《2025年愿景》目标的一部分。结果表明，通过不断提高运输资本，可以实现劳动力和资本之间的替代，从而实现巴基斯坦经济从劳动密集型转向资本密集型转型。

我们还对能源相关的二氧化碳和减排潜力进行了单独的分析，因为巴基斯坦是受气候变化影响最严重的国家之一。基于 Kaya 恒等式，我们使用 LMDI 分解方法把 CO₂ 排放变化分解成若干因子。研究表明，人均 GDP 和人口增长是增加排放的主要因素，而能源强度和燃料替代具有混合和不稳定的影响。基于设计的情景分析，我们模拟了未来的排放和减排潜力。我们认为碳税，能源价格改革，能源供应组合多元化有利于清洁能源和节能并且也是实现减排潜力的关键。

根据以上这些研究的结果，我们提出的政策建议包括能源节约，能源替代或能源供应组合的多样化，以及促进可再生能源和能源价格改革。虽然我们在上述研究中进行了节能和替代的分析，但是未来需要在巴基斯坦经济中进行一些关于可再生能源和能源改革的综合研究，以填补空白。

Abstract (English Version)

Pakistan is an energy deficient country and has a rapidly growing demand for energy. Historically, oil and gas was the main source of energy and fiscal revenue. Oil and gas was mainly used for transportation and manufacturing. Oil was mainly an imported commodity while the gas was produced indigenously. Electricity was produced mainly from hydro resources. However, due to the increase in industrialization, urbanization, and economic expansion the demand for electricity increased and the government starts thermal power projects. Now the thermal power projects have overtaken the hydro power projects, which is a serious compromise on energy security and environmental sustainability. Currently, Pakistan is facing a severe energy crisis which is badly affecting the economy. The Government of Pakistan has published an official document ‘Pakistan 2025, One nation One vision’ which has the objective to elevate Pakistan in the world top 25 economies in respect of economic growth by 2025. This document also have the objective to increase peoples access to energy from 67 % to 90 % of the population and to mitigate the climate change. Since these often conflicting objectives need a delicate balance in the formulation of national energy policy. Therefore, this dissertation has been carried out to analyze energy demand and economic growth with reference to energy conservation, substitution and emission mitigation.

As a first step we analyze the long run determinants of energy demand in Pakistan using the Johanson Co-integration approach. The results showed that economic growth is major factor positively affecting the energy demand. The energy price, labor productivity and capital intensity are the factors reducing the energy demand in the long run. We further utilized these factors in predicting the future energy demand for Pakistan. Besides this, utilizing some specially designed scenarios, we estimate the energy conservation potential for Pakistan. Our results employ that the energy price reforms, increasing the labor productivity and the technological advancement & investment in research and development (R&D) are critical to exploit the high energy conservation potential, especially in the context of achieving high economic growth by 2025.

Since Pakistan, in order to meet the growing energy demand, adopted the thermal power projects instead of hydro power projects, which have fiscal cost and environmental damages. Therefore, to analyze this technical change, we used trans-log production function by employing energy and non-energy inputs to estimate elasticity of substitution. The results reveals that capital & energy

and labor & energy are substitutes, thereby suggesting the need for an increased focus on technological advancement and skilled employment generation to conserve energy and mitigate emissions. The energy price reforms making the price reflecting the true cost is required to discourage the increased energy consumption and promote capital intensive production methods. Scenario analysis based on substitution of capital & energy and oil & gas further encourages the energy saving and emission mitigation. Results further suggest the importance of energy supply mix characterized by renewable energy alongside natural gas. We also did the substitution analysis for transport sector as it is the most emerging sector in respect of output, energy and environment. Also it is part of the objective of the Vision 2025. The results suggest that by continuous upgrading of transport capital, substitution between labor and capital can be achieved and the transition of Pakistan transport from labor intensive to capital intensive can be realized.

While doing a little analysis of emission mitigation in the above mentioned studies, we also did separate analysis for energy related CO₂ and the reduction potential as Pakistan is one of the highly vulnerable country to the effects of climate change. We used LMDI approach of decomposition to decompose the change in CO₂ emissions into pre-determined factors based on Kaya identity. The study shows that GDP per capita and population growth are the major factors to increase the emission, while the energy intensity and fuel substitution have mixed and unstable effects. Based on the designed scenario analysis, we simulate the future emission and the reduction potential. We believe that carbon tax, energy price reforms, diversification of energy supply mix in favor of clean energy and energy conservation are critical to materialize emissions reduction potential.

While we did few studies, mentioned above, to suggest for achieving high economic growth vis-à-vis energy security and environmental sustainability, there are few policy recommendations which are common among these studies. These include energy conservation, energy substitution or diversification of energy supply mix, promotion of renewable energy and energy price reform. While we analyzed the energy conservation and substitution in the above studies, some comprehensive studies on renewable energy and energy price reforms in Pakistan economy are needed for further policy implications.

Key words: Economic growth, energy consumption, fuel substitution, emissions, Pakistan

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Author's published work

The entire dissertation includes the published and under reviewed works of the author and therefore for the sake of reference the source are mentioned here:

1. Energy substitution effect on transport sector of Pakistan based on trans-log production function. *Renewable and Sustainable Energy Reviews*. 2016, 56: 1182-1193. With Lin Boqiang
2. Technical change, inter-factor and inter-fuel substitution possibilities in Pakistan: A trans-log production approach. *Journal of Cleaner Production*. 2016, 126: 537-549 With Lin Boqiang
3. Analysis of Energy related CO₂ emission and reduction potential in Pakistan. *Journal of Cleaner Production*. 2017, 143: 278-287 With Lin Boqiang
4. How increased energy access impact on energy consumption and conservation potential of Pakistan. Under review in the *Energy Journal*

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