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Associations between New Energy Vehicle Growth, Fossil Energy, and CO_2 Emissions in a Coal-Dependent Region: Evidence from Shaanxi, 2015–2021

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Abstract:

This paper studies the relationships among new energy vehicles (NEVs), fossil and coal consumption and CO_2 emissions in Shaanxi from 2015–2021. As a coal-dependent area, Shaanxi offers an important case for exploring the establishment of clean mobility of energy structure in a carbon-intensive region. The research develops descriptive presentations and regression analysis, based on the China Emission Accounts and Datasets (CEADs) and provincial statistics. The descriptive results indicate that accelerated NEV growth accompanied with a slight reduction in use of fossil and coal and a slow decrease in CO_2 emission. The results of the regression show however, that there is no statistically significant short-term association between NEV stock and fossil or coal use. The outcomes mentioned above suggest that the short-term impact of NEVs on emission mitigation is limited and arguably hidden by coal supremacy in coal-based regions (such as Shaanxi). Therefore, the NEV environmental benefits have a brighter future only when implemented within a system of low-carbon power production and structural energy changes.

Keywords: New Energy Vehicles (NEVs); Coal-Dependent Region; CO_2 Emissions; Energy Structure Transition

1. Introduction

Air pollution and climate change have become the major concern among policy makers around the world and the emission of CO_2 because of burning fossil fuel has been identified as the dominant causal agent of global warming. China has always been a producer of energy that is based on coal with the attendant consequence that the emissions of greenhouse gasses (GHG) were high and the air pollution locally was high and alarming [1]. The government, in the meantime, has promoted the development of NEVs as a major direction of the national energy replacement and environmental enhancement strategy. Shaanxi Province, located to the northwest of China, is a classic coal-heavy region and it has experienced the rampant, explosive expansion of NEVs in the past

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decade. Between 2015 and 2021, subsidies, industrial policies and construction of infrastructure aided the growth of the number of NEVs in Shaanxi. Meanwhile, coal use as fossil energy experienced marginal declines, and some sources registered a correspondingly wavering decline in CO_2 emissions, in part due to official reporting.

Despite these tendencies, it remains unclear to what extent the growth of NEV entering is congruent with the reduction of fossil energy usage or emissions. NEVs will help decrease direct tailpipe emissions, although the overall environmental effect will depend on the composition of power sources providing the energy, and how they contribute to structural decarbonization.

It is against this background that an empirical study of Shaanxi Province is undertaken to understand its pertinent test outcomes, i.e., to identify the statistical correlations between NEV development, fossil and coal consumption, and CO_2 emissions during the timeframe: 2015-2021. Compared to a search into causal assertions, explanatory analysis points to descriptive tendencies/correlations to contribute to the knowledge about the relations according to which the adoption of NEV as an energy category reacts to gradual change in an energy system dominated by coal. This provincial perception can help in understanding the dynamics of the energy transition in China, at the provincial level.

2. Literature Review

Researchers discussed the fact that fossil energy was the main contributor to greenhouse gas emissions and that coal consumption in China needed to be reduced [2]. A lot of research has shown that the emissions of carbon have a negative influence on the air power in the region the energy system of which relies heavily on coal, and such a situation influences negatively the lives of the human population and systematic development of the environment and the economy [3].

Simultaneously, the rapid emerging technologies of new-energy vehicles (NEVs) have been widely reported on as a requisite step in the perceived reduction of direct transportation emissions. With cleaner electricity production in combination with the use of NEVs, the researchers have concluded that NEV can contribute to decarbonization but not necessarily be as effective in areas with coal as a primary source of power [4, 5, 6]. The significance of the electricity mix in this research question is that NEVs do not add to the tailpipe emissions, but the total emission can vary considerably depending on how much the power grid depends on coal rather than renewable energy. All such studies point to the fact that the possible effect of NEV on emission reduction in a coal-heavy region could not be significant in general due to its short-term contribution but due to the power generation intensity.

Recent empirical evidence at the national level shows that the proliferation of NEVs is negatively associated with declining fossil fuel, and the strength of such an effect is different among provinces due to the diversity of industrial structure, energy function form and policy enforcement [7, 8]. Nonetheless, little empirical evidence from provincial level examining the issue, has to date emerged, and coal-intensive regions such as Shaanxi have been given especial scant attention. Filling this gap, the following study takes Shaanxi as a case to investigate whether the expansion of NEVs is synchronized with the fossil and coal consumption and the resultant CO_2 emissions.

3. Data and Methodology

3.1 Sources of Data

The analysis uses annual provincial-level data over 2015 to 2021. Four variables are included. First, the quantity of the new energy vehicles (NEVs) stock (it is the registered number in Shaanxi) accounts for the scale of clean vehicle adoption. It should be observed that the data of NEV in the year 2016 are not available, and in regression analysis, this year is screened out automatically [9]. Secondly, fossil energy consumption represents the integrated use of raw coal, crude oil and natural gas, reflecting the overall dependence on carbon-based energy. Third, the use of coal is analyzed individually as it is the dominant energy resource in Shaanxi and has a high carbon content. Third, CO_2 emissions were supposed to be extracted from the China Emission Accounts and Datasets (CEADs), however, provincial-level CEP values were lacking for all years. Such limitation explains that fossil and coal payments are a proxy to measure CO_2 emissions, which is a common practice in studies about coal dependent zones [10].

3.2 Data Processing

The dataset was reconciled for year and units. Individual fuel sectors values were summed to yield total fossil energy values. NEV gap aligned annually, if the 2016 gap was not filled up, no inclusion in the regression analyses. Since the CO_2 data weren't fully validated, the fossil and coal consumption are kept as the main source for emission trends[11]. This architecture is in line with the campaign's emphasis on observable trends rather than precise emission accounting.

3.3 Analytical Strategy

The empirical approach is a mix of descriptive and econometric methods. Descriptive analysis consists of NEV adoption time series plots, fossil consumption and coal consumption time series plots along with scatter plots to show pairwise correlations. For a more formal test of as-

sociations, three ordinary least squares (OLS) models are examined in the study.

Thus, Model 1 and 2 to examine if NEV stock has any statistical relation with fossil or coal use, Model 3 to examine if their year-on-year variation exhibits immediate co-movements. All regressions are estimated with robust standard errors.

3.4 Limitations

Several limitations must be acknowledged. A major limitation is the relatively short period of the (2015–2021), which limits the number of observations with a consequent decrease in statistical power. Second, NEV stock represents adoption scale but not usage intensity or electricity mix for charging which considerably affect net emissions. Third, the absence of NEV data for 2016 and incomplete CO_2 data bring limitations thus, fossil and coal consumption are thus used as proxy variables of the emission outcomes. Finally, the fact that it has a short time series and few variables means that the OLS regressions presented here should be thought of as a first-pass effort to examine statistical associations, and not as evidence of causally founded effects.

4. Results

4.1 Descriptive Trends

Clear cuts of the rise of NEV stocks in Shaanxi from 2015 to 2021, moderated by modest but fluctuating drops in the consumption of fossil energy and coal as well as a downward tendency of CO_2 emissions, are presented in Figure 1. This is descriptive evidence for a conjunct trend: Quick NEV adoption runs side by side with slowly relaxed fossil energy demand and emissions burden.

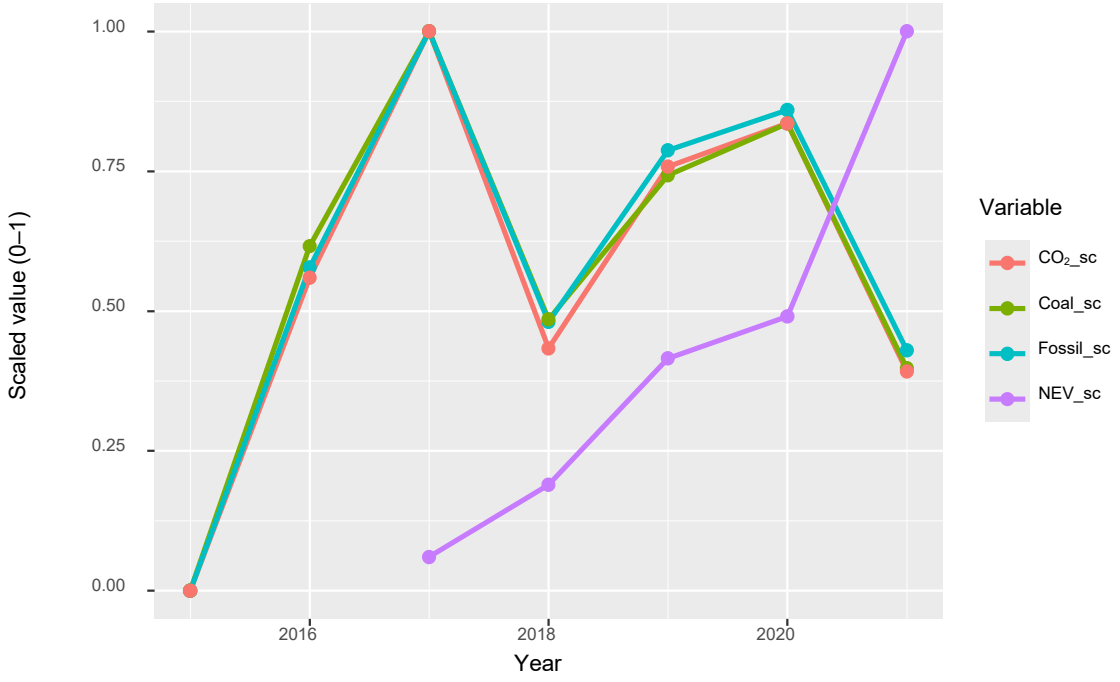

Fig. 1 2015–2021: NEV vs Fossil vs Coal vs CO_2 (scaled)
Picture credit: Original

4.2 NEVs and Energy Consumption of Fossil Energy

The scatter plots and regression results (Figure 2 and Figure 3, respectively) indicate that there is a negative bi-directional (two-way) association between NEV stock and fossil or coal consumption. Yet the estimated coefficients in both models are not statistically significant (Fossil: β = 3.72e–5, p = 0.885; Coal: β = 1.86e–5, p = 0.944), and the explanatory power of two models are quite low ($R^2 < 0.01$).

These findings suggest that there is little or no short-term correlation of NEV growth with reductions in the use of fossil fuels or coal. However, this does not mean that there is no connection; the short sample period, the low penetration rate of NEVs, and the still existing dominance of coal power supply in the non-hydro energy structure of Shaanxi might be the reasons.

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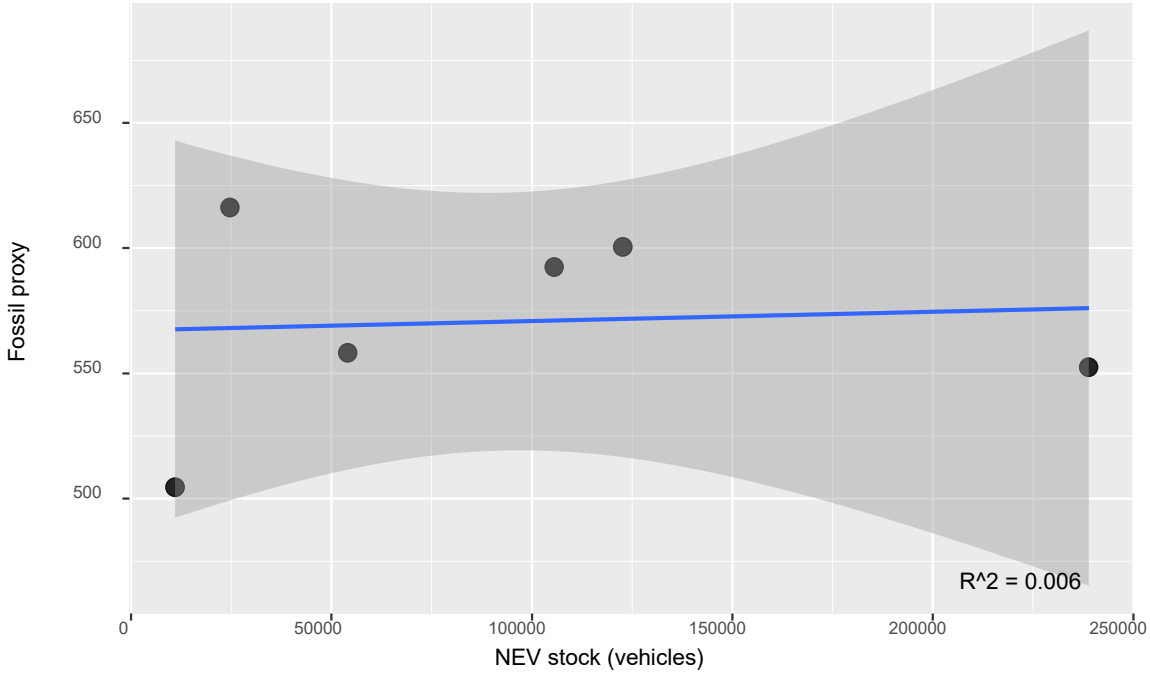

Fig.2 NEV stock vs Fossil energy (Shaanxi 2015–2021)
Picture credit: Original

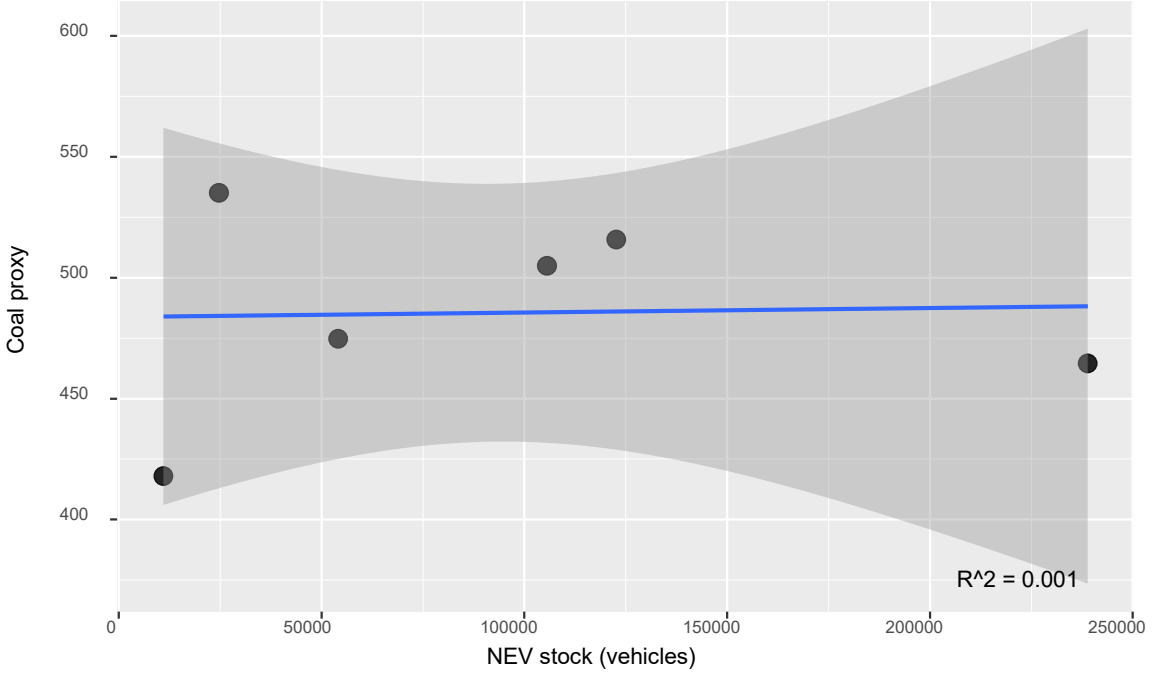

Fig.3 NEV stock vs Coal consumption (Shaanxi 2015–2021)
Picture credit: Original

4.3 Growth Rate Comparisons

Figure 4 shows the YoY growth rate, as a supplement to the level-based analysis. The findings demonstrate that NEV consumption growth rates are highly volatile in contrast to fossil and coal consumption growth rates which fluctuate generally steadily with policy subsidy and mar-

ket. There is no definite synchronous or inverse relation between the two. This deviation explains why regression models based on absolute levels showed little association: NEVs and fossil energy consumption have different short-term dynamics.

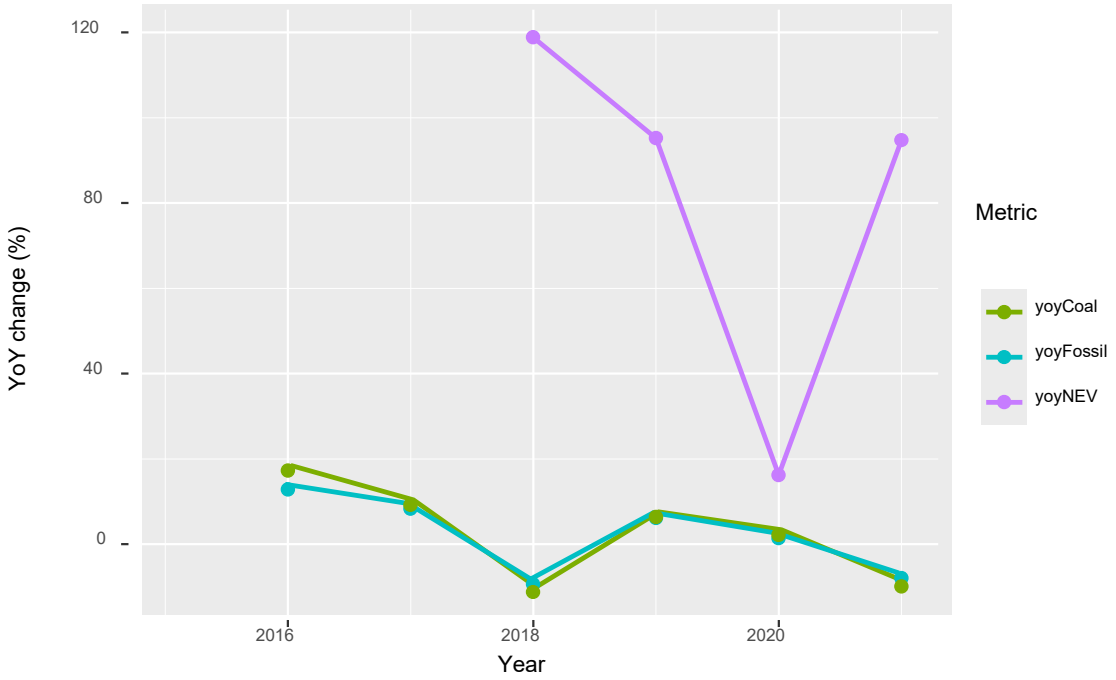

Fig. 4 YoY Growth Comparison: NEV vs Fossil vs Coal
Picture credit: Original

4.4 Summary of Findings

In all, descriptive evidence presents the image of similar trends: NEV exponentially expanded, fossil and coal contracted (humidifying) and the emission of CO_2 slowly declined. However, statistical tests indicate that these relationships are not significant in the short run. The results indicate that growing NEVs do increase quickly and NEVs have a weak direct association with the reduction in fossil energy and emissions in the short run. The evidence ought to be best interpreted as the early stages of trend associations rather than causal effects.

5. Data and Methodology

5.1 Interpretation of Results

The results of this study showed that the relationships between NEV stock and fossil, coal utilization were not statistically significant in Shaanxi (2015–2021). This result is closely associated with the province's energy structure. NEVs are the replacement for the oil mainly, but the energy system of Shaanxi is mainly coal dominated. Therefore, the possible impact of NEV increase on the total use of fossil energy may be already exceeded by the intensity as well as the variability of the coal consumption. Moreover, limited period and relatively low absolute NEVs numbers in comparison with conventional fleets limit the detectable magnitude of effects. Both factors combined to make the explanatory power of the regression models weak, despite the narrative trend that appear consistent with similar reductions in both energy use and emissions.

5.2 Data and Method Constraints

Multiple caveats should be kept in mind when interpreting the findings of these investigations. Firstly, the timeframe of the dataset is only seven years, which lacks to capture long-term structural change. Second, NEV stock is a measure of adoption but not of driving intensity, mileage, and the carbon intensity of charging electricity. Third, the lack of NEV data in 2016 and the incomplete CO_2 records, thus, the use of substitute indicators like fossil and coal consumption. Lastly, other drivers of emissions (e.g., industrial shifts, energy efficiency initiatives, and macroeconomic swings) are neglected. These limitations emphasize that one should not interpret the results as causal effects but as pointing to associations.

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5.3 Theoretical and Practical Integration

System coupling theory could help explain the findings better. NEVs belong to the transport sub-system while electricity generation is a part of the energy generation sub-system. The 'green' posture of NEVs is established according to the direction and strength of the coupling between these latter two subsystems. In Shaanxi as a major coal-fueled electricity area, weak coupling hinders the efficiency of NEVs in emission mitigation. This is likely the reason that the statistical relationships are weak despite NEV adoption growing quickly.

5.4 Policy and Practical Implications

The findings indicate that attention should be paid to promoting synergy of governance in policymaking. "Just pushing NEVs is not enough in coal-heavy areas as its potential can be unleashed only if the growth in vehicle stocks also leads to the rapid decarbonization of the power grid, including the proportion of wind, solar, and hydropower in it," he said. Meanwhile, other measures, including industrial energy efficiency gains and more robust coal reduction targets, are needed. Charging infrastructure investment and public awareness campaigns will drive local authority adoption, but the environmental payback will so far be modest – unless the power system is also decarbonized as EV adoption takes off. Therefore, to unleash the environmental potential of NEVs on the policy side, it is crucial to combine mobility and energy reforms.

6. Limitations and Future Research

Several limitations apply to this study. The first of which is the duration of the dataset which is only seven years (2015–2021), resulting into a reduced number of observations and statistical power. Second, 2016 NEV data are unavailable; one year had to be omitted from regression calculations, decreasing the number of observations. Third, related to data, the analysis could not calculate CO_2 emissions from all CEADs for all years, and in several cases, interpolation was needed, thereby introducing measurement error. Fourth, the study only covers Shaanxi Province, which is a coal-based province, and the results may not be transferable to provinces with more diversified energy sources. Fifth, the NEV stock is taken as a proxy for adoption and does not capture driving intensity, miles traveled, or carbon intensity of electricity for charging. Finally, the models do not capture any other drivers that are critical to energy consumption and CO_2 emissions, such as industrial activity, economic growth, or structural policy changes.

That may be a matter of investigation. The time series would require to be longer to pursue that and would also be interesting to have more frequent observations (2 or 4 times a year) to implement some more powerful statistical testing. Different provinces should have a large geographical coverage to make the energy structure of the individual states more comparable to each other. Additional comprehensive data of CO_2 gathering and electrical mix would help to elucidate the connection amid charge and power apparatus. They should conduct more studies which also control economic and industrial indicators with more complex econometric designs (such as STIRPAT) to break factors that contribute to emissions down further. Further, the addition of air pollution factors like PM2.5 would help improve understanding of other environmental as well as health impacts. The two listed improvements may work together to improve the comprehensive assessment of the impact of NEV penetration on energy consumption and emissions.

7. Summary

7.1 Summary of findings

This study analyzed the linkages between NEV taking rate, fossil and coal consumption, and CO_2 emissions in Shaanxi Province during 2015–2021. Descriptive statistics Average NEV growth became exponential, accompanied by a slight decrease in fossil and coal and a slow decrease in CO_2 emissions. Nevertheless, the static correlations were weak and non-significant according to the regression models, which was due to the short period, low NEV proportion of the conventional vehicle, and high contribution ratio of the coal in the energy of the region. The key conclusion is that, in the coal-based regions, short-term environmental benefits of NEVs are limited and difficult to observe in aggregated energy statistics.

7.2 Research Contributions

The study adds to the literature by pointing out that the abstraction process of technology adoption in a coal-based system is particularly challenging. Instead of giving a straightforward answer for the emission reduction, the discussion provides implications, in that NEV should be considered within the prospect of the whole energy transition. By introducing fossil and coal consumption as proxy variables of emissions, this paper shows that localized case studies can provide insight into the relative scale of the failure and success of clean mobility in contexts where energy structures continue to be carbon intensive.

7.3 Policy recommendations

The findings support the idea of using a joint action. In the region with coal, a simple implementation of NEV will not have a visible effect on emissions. Rather, this needs to be accomplished through policies that have a

system-wide perspective: transportation electrification can be undertaken at the same time as rapid decarbonization of the power system, through the construction of as much wind and solar and hydropower capacity as there exists. In such conditions only, the green potential of NEVs can be fulfilled. Mobility, energy and industrial policy reforms should therefore be integrated so that significant progress can be made.

7.4 Future Outlook

Further research must be carried out with not only short-term dataset studies but also with individual provinces as well. The analysis would be reinforced by longer time series of the data and higher frequency indicators. The dynamics on the system level (such as the integration of RE penetration, industrial processes and AQM) will become a more fragile reaction. Development of more complex models like STIRPAT and other composite models can also help de-couple the different drivers of emissions. Further research on this point might yield additional high-quality empirical data and practical recommendations on how to contribute to the general process of decarbonization and sustainable development.

8. Conclusion

This paper explored the links of NEV adoption and the consumption of fossil, coal, and emissions on CO_2 in Shaanxi Province during 2015–2021. Qualitative evidence bore this out: exponential growth in NEV went together with moderate decreases in fossil and coal consumption and steady decrease in CO_2 emissions. The results of the regression, however, showed that these were weak and not significant, possibly due to the reason of coal-based regional energy system and a short period of study. It means that the short-term environmental benefits of NEVs in coal-based regions of China are even scarcer and disguised in the context of a complete energy system.

The connotations are dual. First, even the NEVs alone cannot be anticipated to achieve large, short-run reductions to emissions as long as electricity generation remains carbon-intensive. They can be as efficient as the systemic impulse with which they are given by a steadily decreasing carbon power sector; a sector that in Shaanxi remains in development. Second, the study highlights the importance of combining strategies: We need to decarbonize the grid faster but also electrify transport in addition to making industrial activity more efficient and less dependent on coal.

In future research information will also be extended in time of series i.e. years and higher frequencies, the control variables will be added to the data with electricity mix and economic activity and a somewhat complex model such as STIRPAT is implemented to improve the interaction of the system. Comprehensively, this input suggests that NEV propagation is an obligatory, though not a direct progression in the environmental nexus and that its potential in the environmental nexus is conditional on integrative governance that synthesizes mobility/energy transitions.

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