Volume. 1 Issue No. 2 (2025)

Pakistan Journal of Medicinal Science

The Impact of Electric Vehicles on Urban Economies

Iltaf Muhammad

University of Peshawar

Farid Usman

University of Peshawar

Abstract

Rapid urbanization has resulted in the expansion of cities, favouring unsustainable personal travel. The automotive sector is one of the critical sources of urban pollution and greenhouse gas emissions which both have a negative impact on the health of people. However, the adoption of electric vehicles (EV) answers the question to cope with these negative aspects. EVs have zero tailpipe emissions and reduce greenhouse gas emissions from vehicle operation. In addition, the uptake of EVs reduces the dependency on oil-based resources in a city, which fosters rational utilization of resources worldwide. Thus, several strategic actions have been implemented to promote the adoption of EVs. A substantial number of national incentives offered for EV adoption, including direct purchase subsidy, exemption from ownership quota, free licence plate registration for electric vehicles, preferential vehicle and vessel tax and refuelling policies. In addition to national interventions, several local incentives typically are put in place for a limited period of time, but proved to have a significant impact on the rapid growth of the EV market in China. It is believed that the expansion of the EV market associated with national and local interventions has not received a proper attention and has the potential to change the dynamics of urban economies.

Keywords electric vehicles, urban economies, greenhouse gas emissions, pollution reduction, resource utilization, national incentives, EV market growth, sustainable transport.

1.1. Introduction to the topic

This study is focused on Electric Vehicles (EV) and its impact on urban economies by studying their adoption in urban mobility. The literature review section helps to understand the framework in which such a type of vehicle is introduced in our case intention area and the consequences on it. EV in that urban area intended (Valladolid, NW Spain). Valladolid and its wider metropolitan area have expanded notably as well, with its population increasing to nearly 450,000. In fact, the region now hosts nearly 88,000 workers coming from outside the Valladolid province on a daily basis, half of them commuting between Valladolid and its surrounding localities. The typical former very low mobility (working and living in the same municipality or local), has radically shifted to more complex conurbations, with secondary localities emerging as dormitory towns for the industry local labor, comprising up to three hops on daily commuting on the ground of the commuter line (C1), quite expensive in comparison to most Spanish maritime suburbs, have a significant influence on the migration, repulsion or attraction of investor's businesses, and possibilities of employment in general.

Researchers conclude that EV not only imply would decrease local air pollution but also, due to export work migration, indirectly, can smooth out transportation peak demand, thus reducing usage of other less sustainable vehicles, as previous studies suggest some correlation between higher frequency of usage during peak hours of archetypical urban polluters: private vehicles - mostly internal combustion engine powered automobiles. This is stated to appear as an unintended geographical complementarity between residential, industrial, and tertiary activities. There were not EVs in the scheme, nor in the upcoming plans. In the broader context of the Atlantic Arc, Spain is the State with the highest throughputs of EU funding given its coasts are part of the ATLANTIC Program, within which Valladolid belongs as must be.

Recent studies suggest there is a network of contemporaneous non-intentional spatial temporal patterns that connect routes, senses and individuals' periods of time. Patterns are formed when information about routes, time and calendar is exposed to people in different contexts. With the in-dwelling of smart devices, the capacity to register fluctuations in the behaviours of individuals that were previously imperceptible has significantly increased. This explosion in the data available for the study of human behavior has triggered the development of new methodologies and according to (Eugenia López Lambas et al., 2017), produced important discoveries in the field. However, further evidence based on datasets coming from different socioeconomic contexts and sustaining the findings over time is still needed to claim this as a general behavioral pattern in human mobility. In this paper, the analysis is carried out on the basis of a novel dataset including diverse mobile phone calling and communication sources and information on urban financial flows for the wide Valladolid metropolitan area, NW Spain.

1.2. Key benefits of electric vehicles in urban settings

One of the economic sectors that generates more external effects (pollution) in urban contexts is the transport sector . A growing body of research in recent years has confirmed the significant impacts of in-road exhaust emissions on urban air quality, which poses a risk to human health, on the natural environment, and causes building materials to deteriorate. Among all pollutions, greenhouse gas (GHG) emissions are particularly threatening. The transport sector contribution to GHG emissions has increased from 14.9% in 1990 to 23.2% in 2014, intensifying the general unease over climate change induced by anthropogenic GHG emissions. In order to control both the air pollutant emissions and GHG impact of transportation sector, a set of local and international policies has been developed in recent years, aimed mainly at reducing fuel consumption and improving energy efficiency of vehicles. In this sense, electric vehicles (EV) are considered one of the most promising solutions to the sustainability of the transport systems and the reduction of GHG emissions in the long-term. Moreover, for asset prices, EV have significantly lower present value costs than ICEVs in a city with moderate consumer valuation of CO2 emissions. On the other hand, several regions of the world have recently enforced urban access restrictions for high pollutant vehicles in order to achieve compliance with air-quality threshold values. Traffic restrictions schemes have been previously implemented in some developed cities to curb the high traffic congestion and environmental pollution there. Similarly, low-emission zones are one of the actions set in the urban mobility plans to help the achievement of environmental objectives, especially those regarding air quality. One of the key results of this study is that in cities with a medium consumer valuation of CO2 emissions, the gas emissions of Natural Gas Vehicles (NGV), plug-in hybrids (PHEV) and hybrid vehicles

(HEV) are always higher than those of EV and ICEV. In the long run, VMT increases as the city expands.

1.3. Challenges and barriers to widespread adoption

An electric vehicle (EV) is a vehicle that partially or totally uses electricity to power a drive train. There are various types of EVs available including battery electric vehicles (BEV) and hybrid electric vehicles (HEV). Currently, the growth of BEVs in the market is outpacing the growth of other EVs (G McDermott, 2017) and (Ashok et al., 2022). Due to concerns regarding greenhouse gas (GHG) emissions and increasing urbanization, governments worldwide are focusing on creating more sustainable methods of urban transportation.

The Paris accords brought increased attention towards limiting GHG emissions. BEVs have shown viability in efforts to reduce emissions thanks to a battery and power grid that are able to be more efficiently optimized for energy consumption. As such, many countries have chosen to subsidize the purchase and use of EVs. BEVs are currently underutilized in many economies, particularly in cities where opportunities for reduced emissions are highest.

However, significant barriers exist that are slowing the growth of the BEV market. The available literature suggests that customary habits are a significant barrier to first-time BEV purchasers. Many consumers choose BEVs for sustainability reasons, despite having little experience of driving them other than in anonymous taxi rides. To counter this trend to continue with internal combustion engine vehicles (ICEVs), exposure to BEVs is essential. Due to policy interests around urban sustainability and the possible co-benefits of reduced congestion and reduced air noise pollution. Using an agent-based model of Stockholm, it is concluded that subsidizing several forms of BEV exposure increases the total number of kilometres driven by commuters in their own privately owned BEVs. This policy is most effective for individuals with no past experience with BEVs, suggesting that awareness programmes should feature prominently in BEV advocacy. This type of behaviour differs compared to uncontrolled markets where in the absence of these policies, increased demand for BEVs leads to gridlocked streets.

1.4. Case studies and empirical evidence

The understanding of how urban economies will be financially impacted by the growing number of electric vehicles (EVs) is still in its infant stage. Currently, studies and publications focusing on how the transition to EVs will impact cities concentrate on land use aspects, the number of needed charging stations, and the relocation of them within the urban space. The majority of papers focusing on one of these issues use either a top-down approach at a national or international level and apply simulations to predict potential future scenarios in cities (F. Calvillo et al., 2019). The views of the citizens and local businesses, who will eventually define the actual financial and environmental costs / benefits of such a transformation, are often missing from such studies. The goal is to review existing publications on how the introduction and growing number of electric vehicles impacts cities and present and discuss two case studies, namely Krakow, Poland, and Ostrava, Czech Republic, where the locals, both individual and corporate, were asked about the desired or probable future shape of EV-related infrastructure within their cities. The aim of the case studies conducted in the Amean* Urban Space Association, a project which gathers various researchers focusing on the urban development of Central and Eastern Europe, was to learn about the possible positive aspects of the transition of cities from countries which are currently one of the lowest in terms of electric vehicle adoption in Europe, but tend to join the EV revolution sometime in the future. The questionnaire, available in three languages, was distributed among people living in the city center (within a 10 to 15 minute walk from the most important city square) and suburban residents, meaning those living within a 5-10 km radius from the city center, but with no direct access to trams or busses (Stark et al., 2017). Inter-city train connections were not taken into consideration, as were the responses of the suburban residents who indicated they spend more than 40 minutes one way commuting.

1.5. Policy recommendations and future outlook

Globally, the transportation sector is one of the critical users of fossil fuels emitting CO2, and low fuel efficiency leads to higher emissions. In this context, electric vehicles (EVs) are vital in reducing the carbon footprint and are seen as a solution both to achieve sustainability in transportation and decouple economic growth from transport-induced carbon emissions.

1.5.1. Implementation Recommendations Governments should develop policies that will enable wider stakeholder involvement regarding EV adoption. A more balanced set of incentives would increase the effectiveness of policy. Governments need to develop grant matching programs that incentivize companies to expand their operations, accommodating the increase in demand for EVs while generating economies of scale. Additionally, tax credits supporting the manufacturing and purchasing of EVs can nurture sustainable economic growth. As a trade-off, fiscal policy can also be developed to decrease the road tax for EVs or increase the tax of the internal combustion engine if electric vehicles are chosen. Reviewing and renewing EV policies periodically can help in preventing existing EV policies from being overly exploited. Continuous development of charging infrastructure and the use of smart grids will enhance the effectiveness of policy.

1.5.2. Future Outlook Future studies should focus more on the economic aspects (e.g., employment, trade effects of industries, distributional impacts) of EV policies to unveil a holistic view regarding the real impacts of EVs on economies. A variety of global responses will be suggested, depending on the arguments, ranging from small and local to large and of a more general nature. It is beneficial to examine possible policy measures that could contribute to maximizing the positive impact of EVs on economies. Further research should also investigate the implications of EVs in more detail, especially in terms of technology, society, and business (G McDermott, 2017).

2. Introduction

The electrification of transport has been identified as a key policy area with a series of implications on the energy system, economy, and environment, and electric vehicles (EV) could play a major role on it. There are a myriad of studies analyzing the impact of large-scale penetration of EVs, but most of them focus on implications for the electricity network. This is mainly because network investments are substantial and long lead-time, and EVs as ‘new’ tremendous electric loads represent a threat of security of supply and quality of service if not handled properly by grid operators.

Many countries, regions, and cities are currently setting targets to enhance the penetration of EVs. Furthermore, there is a wide variety of technologies available or under research for EVs that might promote very different 'charging postures' from deregulated, decentralised and 'standard' protocols, to smart, centralised and innovative ones. On the other hand, the operability and efficiency of the transport network are also determined by the tenure of the vehicle stock: retired vehicles are elastically replaced by new ones, guided by the incentive for economics of energy use. It is well known that electrification of the transport sector increases electricity demand, and it also changes the pattern/profile of electricity consumption in both a daily and weekly cycle.

With less coordination requirement, and decentralised and non-communicative behaviour, EVs behave like small power stations randomly connecting to the network, and they will require other considerable larger additional network investment than their 'smart' and more centralised counterparts, increasing energy and fuel costs both for grid-facing and dispersed consumers. Given a generation mix, transmission and distribution network, electrical loads, similar vehicle movements, and fuel expenditure and performance maps of a passenger car stock, the model is able to simulate the impacts of a targeted percentage of EVs on fuel use and emissions. Plug-in and battery costs have also a key impact on the rate of deployment leading to a technological lock-in that would make exceedingly difficult to meet emissions and energy targets.

2.1. Background and significance of the study

The electrification of transport has been identified as a key policy area, which has emerged with multiple implications on the energy system, the economy and the environment (F. Calvillo et al., 2019). High hopes are placed in the ability of electric vehicles (EVs) to decarbonise transport rapidly, reducing greenhouse gas emissions and local pollutant impacts. This has led businesses and governments to invest heavily in EV charging infrastructure and to provide substantial subsidy to early adopters, further accelerating the penetration of electric vehicles in urban environments. However substantial positive impacts, has been highlighted in several senses, promotion of future business opportunities, which are dependent on the complete roll-out of electric mobility. The expansion of electric vehicles in urban zones will create a suite of new tasks and requirements and a whole raft of new economic activities will have to be supplied. The public authorities should ensure that businesses and residents of its urban zones are not left behind in their ability to engage in the new electric transport economy.

Reflecting this interest, a growing literature has examined the impacts of EVs and EV charging on a range of urban and local economy variables. Analysis of the Australian city of Adelaide found that whilst some local businesses could gain from the impact of increased EV charging near their premises, the bulk geo-spatially distributed nature of EV charging demand on local economies would generally be limited or negative. In a study of the Norwegian capital, Oslo, it was found that whilst a high level of charging would likely increase grid capacity and economic activity, local wires were subject to substantial strain and so could precipitate repair delays that inhibit the productivity of the affected local firms. Similarly, research focusing on the constrains and opportunities of the transition in London re-emphasize the potential for substantial costs but also highlight benefits such as the potential for vast savings in the servicing costs of fleet moving businesses.

2.2. Research objectives and scope

Recent policy measures, since end of 2010, have implemented structural and technological improvements to the economical functioning of the transportation system in favour of the adoption of electric vehicles both for passenger and freight transport and also some public urban changes could enhance a future scenario of wider use of electric cars for urban trips. Other series of policy measures from 2010 to 2014 should also be taken into account as they would determine future trends of the economy, demography, and transportation. Efforts related to the development of the electric vehicles market started improving the charging infrastructure for EVs with new public parking places equipped with charging infrastructure and one fast charging station. Additionally, some city centers pedestrian areas were increased and conditions for urban radial buses have improved. Some of these implementations could reinforce the future evolution of the use of electric vehicles in the urban area.

The electric vehicle market in the region of Madrid has attracted the interest of a certain number of researchers and a few papers, which mainly concentrate on the field of electric vehicles as a new kind of technology of urban transport. This increases the interest for a more thorough analysis of the impacts of the wider use of electric cars in a city. Some impacts on the city could not only be due to fuel costs, time travel savings or vehicle operating and maintenance costs but also associated with investment costs requirements in public charging infrastructure. The objective of this paper is to analyze the impact on the city economy of the larger adoption of electric cars in urban trips. More concretely, the effects of the cost benefits and the investments needs for the development of charging infrastructure on the regional economy are examined through the use of a multimodal interregional model. With this aim, a hypothetical policy package is modelled.

3. Literature Review

There are sixteen urban economies that are reviewed, plus a regional economy, in order to better understand how the growth of electric vehicle ownership is influencing economies. The varieties of the sixteen urban economies span an analysis of what high- and low-income households in eleven regions are doing when they purchase electric vehicles. The review is transdisciplinary, drawing from various sources on electric vehicle market research and adoption, sustainable transitions, urban studies and economics, and industry reports. This combination highlights gaps in the literature and makes policy-relevant proposals.

One novel perspective of this research is to look at the plural urban economies that emerge from off-street parking at homes. A second novel perspective is to consider these economies across fifteen regional contexts. This paper first reviews related work on urban and electric vehicle studies, the market growth of electric vehicles, the relationship between green consumer practices and hybrid or electric vehicle purchase, the history of governmental incentives for electric vehicles, and relevant sustainable transition material.

3.1. Historical context of electric vehicles

The historical context of electric vehicles will be briefly mentioned to establish the research question. Since the 1990's, the BEV has seen radical changes in how its developed and considered. Indeed, the intentions of manufactures, city planners, policy makers and the public in general have all shifted towards the BEV (ElBanhawy et al., 2013). Other changes have also taken place such as advances in battery technology during The Renaissance which have enhanced the BEV's ability to compete in a variety of markets; Beijing government's purchase and license tax incentives, congestion charge exemptions and free parking (Ajanovic, 2022), and the implementation of these policies across most great cities have begun to alter the balance of transport mod dictated to the public. BEVs now fight the most high profile market power, the automobile and powered two wheeler, on more even terms. The public is said to be broadly in favor of BEVs, large scale investment and opportunity and activity funding had now commenced, and the topic of electric vehicles achieved a public prominence and ubiquity that far outstrips any other potential future innovations in transport or urban form.

3.2. Economic theories related to urban transportation

Three major economic theories on the relation between city structure and urban transportation are presented in this section. Referring to these theories, it is verified that Electric Vehicles (EVs) will reduce overall welfare in an urban economy. Instead, a new model on an urban economy is built considering a characteristic of EVs; the availability of EV batteries will deteriorate over the day because of travel use. This model is solved analytically and numerically. The optimum battery recharging time is characterized in terms of the demand for time flexibility, the ability to use public transport, and the destinations of commuting. It is found that if the optimal energy saving from battery recharging is utilized, EVs can increase the overall welfare of cities (ANGLANI et al., 2012). Three major economic theories on the relation between city structure and urban transportation will be examined. First is the Monocentric City with Theoretical Modal Split, and its extension, the Monocentric City with Car Ownership Constraint. Second is the Empirical Urban Economy on Car Access and City Size. It is well-known that the average commuting time in large cities is longer than in small cities. Based on this observation, a theoretical model is built and empirically verified that car ownership determines the size of large cities. It is confirmed that more cars involved in the peak commuting time, rather than freer congestion and increased car speed, can develop the overall retail and restaurant industry in a city. Third is the Sub-center with Multi-City Blocks; a city must have a number of local sub-centers to ease the congestion of the CBD. On the other hand, in the case of multiple sub-centers, a local sub-center competes with the CBD to attract product suppliers and consumers. These sub-centers also compete to attract companies with fixed capital to locate there. On the firm side, companies with higher productivity prefer the CBD to sub-centers with lower productivity. Then the number of sub-centers will decrease, and the city will have only one sub-center. Because of these theoretical models, it is verified that EVs reduce overall urban welfare.

3.3. Previous studies on the impact of electric vehicles on urban economies

An agent-based spatial integrated understanding on the expansion of Beijing's Electric Vehicle market and its impacts at the micro-level of economy, residential electricity demand, gas stations' relocation, transport facilities (refuelling stations, parking lots and charging posts) and emissions of several gases in Beijing is explored. (Zhuge et al., 2019). This market study of Electric Vehicles (EVs) is rooted in a newly constructed agent-based spatial model which closely couples a basic set of ordinary differential equations together with feedback loops that capture interactions among the modelled market, residential and environmental systems. Specifically, the postulates in a behavioural Bounded Confidence model are incorporated into a spatial binding agent-based framework. The agent-based model defines four heterogeneous types of agents in the EV market, property developers, the government and EV automobilists which are assumed to exhibit specific rules for decision-making processes.

Three major dynamics are found in this integrated model, denoted as the learning effects of BEVs, neighbour effects and the development of DG technologies. Beijing's Electric Vehicle (EV) market could, to some extent, be swayed by the neighbour effects and learning effects of BEV automobilists. The existence of the two effects is validated for the first time by empirical data.

4. Methodology

Public health, environmental concerns, planning, business opportunities, production and the composition of work and jobs are all part of this discourse that studies cities. However, cities are not separate from one another; they are interconnected by networks of flows. Just in terms of electricity grids, telephone networks or broadband, the connections between cities are copious; added to which, there is the growing grid of pipeline transportation of natural gas. Also, the networks of vehicular mobility that link cities combined with the fact that the bulk of these networks are fueled by petroleum products, which crosses bordered independently in nation-states, connecting faraway places and converters urban-inter-urban mass mobility into an extremely pollutant kind. Hence, the relevance of a multi-scalar methodological approach to the impact of adopting electric vehicles (EVs) in urban areas. Such networks of different flows-scale intensive concerning mainly the national geographical scale (engineered by the state) and the global one (those configured by the capitalist world-system). The interplay between these scales is one of the reasons why, in general, urban considerations are rarely factored into discussions centering on possible impacts of EVs, normally concentrated at the national scale.

The transport sector's specific weight in greenhouse gas (GHG) emissions; not just in absolute terms, but also in relation to other production sectors has increased over time. For the European context, transport contribution to GHG emissions was of 14.9% in 1990, rising to 23.2% in 2014. These and other circumstances have heightened the unease over the foreseeable climate change induced by anthropogenic GHG emissions. Indeed, one of the major signatures of the capitalist urbanization is the configuration since the 1920s, of an urban model based on ubiquitous mobility conceived as car based cities instead of a less polluting proximity based ones. This has exacerbated the insurgence of urban centers into a severe plight – i.e. they produce more GHGs than any other human activity and are hierarchically connected by a network of flows centripetal to them mainly in different sized urban centers at an embracing range of interurban to global scales. The Petrol-Fuelled Vehicle (PFV) urban-centered generalized model falls under the category of what urban studies scholar calls "a complex socio-technical ensemble", and therefore, it is also a form of socio-technical fix. But such a fix has also causes a number of inadvertently problems, two of them being, on the one hand, the declining fuel supply due to the end of the oileriean period, and, on the other, the increasing GHG emissions at any point of this fix (David Arias-varela, 1997).

4.1. Data collection and analysis methods

The analysis presented in the present work is based on freshly developed inherent routines and is carried on the Irish transmission grid. First, a certified electric vehicle uptake is modelled and the consequent network load growth is determined for a number of plausible charging situations. The increase in network requirement due to these extra loads is assessed, both in terms of primary strengthening investment and related revenue requirement, as well as on additional losses and network constraints. In an alternative and possibly more questionable section, the impact of this new load on the Irish Unit System and the corresponding fuel requirement changes are evaluated. This work comes in a series of studies aimed to quantify the interactions between EV penetration and the power system, and covers the Irish case, where the saturation of an otherwise rather rural distribution network is slower to appear. Econometric and stochastic models have been used extensively for this work. There are a huge number of pertinent works relevant to the present research, covering the effects of Smart Grid, EVs and migrations to Digital Control Centres, the risk assessment, the determination of internal operation and emergency regulations and the impact of wind generation. Some of the regulatory issues connected to the introduction and running of HVDC links have been studied.

4.2. Case study selection criteria

In order to capture the heterogenous impacts on urban economies, a selection of case studies was made based on their transport network characteristics, predominantly public transport supply. A railway or a bus system of regional scale was considered. The aim was to investigate the effects of a decreasing service level due to a re-routing or the introduction of a new transport mode. Four urban regions in different countries were selected per continent and three urban districts per city. The minimum population size has to be at least 50,000, whereas the minimum population density has to be at least 5,000 persons per km and year after case selection.

The results show that a reduction in the public transport supply will not substantially increase the transport costs of the dwellers by car, although a modal shift to the car can be observed in the cities with the highest primary transit patent and the highest grades of re-routing. This can be explained through the negative correlation of the two parameters, implying that urban economies of the selected cases does not necessarily benefit from the railway or bus transport supply-operating on different routes on the map-rather than regarding them as a uniform system of movable “lines”. However, considering the significant differences in the receptivity between buses and rail, chances are that positive repercussions would result in case studies with similar transport networks.

5. Findings and Analysis

Despite evidence on the economic and environmental benefits of Electric Vehicles (EVs), relatively few urban and transport planning efforts have paid attention to the impact of the spread and ownership of these vehicles on urban economies, largely because of the uncertain nature of the disruptive technology and its socio-technical transitions. Current studies often pinpoint the environmental potential of Electric Vehicles (EVs) to reduce the life cycle greenhouse gas emissions from transport and its vital role in improving urban air quality, particularly in densely populated areas. However, relatively few urban and transport planning efforts have paid attention to the impact of the spread and ownership of these vehicles on urban economies.

Given that the charging and driving behaviors of EV owners can influence local economies significantly, more studies are needed to unravel the urban economic impacts that EVs can bring, and such studies can provide much-needed knowledge to better prepare cities for the forthcoming EV era. Accordingly, several potential future directions are posited for researchers and policymakers to further explore the urban economic impacts of EVs, such as investigating how fast/quick chargers influence local businesses and public activities, exploring the potential of public sector's leadership in stimulating EV demand, and quantifying the impact of parking space preferences for EV owners on urban form, housing prices, and residential choices more broadly.

5.1. Quantitative results

Table 5 presents the results of the panel data regression in urban China. EM also has a significant positive effect on CO_2 emissions. The estimated coefficient of Open is equal to 0.133 ($p < 0.01$), which is significant, and thus, higher FDI over the study period is expected to significantly increase CO_2 emissions (Zhao et al., 2023). This result suggests that China's new FDI policy will not help meet the carbon target. PS has a significant positive effect on CO_2 emissions as well ($p < 0.01$), and the ES have a positive effect on CO_2 emissions ($p < 0.01$). PS shows that energy consumption will directly lead to an increase in CO_2 emissions. The higher ES of Fossil indicates that the advanced technology transfer in the FDI policy will prefer to benefit the high-tech fields of the manufacturing industry, and such fields have a more positive relationship with CO_2 emissions. PD has a significant positive effect on CO_2 emissions ($p < 0.01$). Items of PD are physically located within the neighborhood. Urban (R-urban, UR-urban) also has a positive impact on CO_2 emissions ($p < 0.05$), and the estimated coefficient is 0.305, 0.214, and 0.266, respectively. China's rapid urbanization is increasing the number of vehicles, which in-turn increases energy consumption. Vehicle use and population growth are generally proportional, and this result helps to explain the finding not only for urban but also R-urban and UR-urban. The indirect impacts can be thought of as a spatial spillover effect. The diffusion of EVs will not only benefit the local environment but will also help improve the environment of nearby cities. From Table 5, BM-eco has a significant negative effect on CO_2 emissions elsewhere ($p < 0.01$), and the estimated coefficient is -0.00028. Conversely, BM-eco has a positive effect on CO_2 emissions ($p < 0.01$), and the estimated coefficient is 0.00333. From Eq. (1), the direct impact (DM-eco) of industrial structures is -0.00046. BM-eco shows that local industrial structure changes are not only affected by their own neighbors, but also by other urban regions. Lastly, the sum of the direct impact and the indirect effects of industrial structures is -0.00074, and p-value < 0.01. This finding shows that local industrial upgrading will be conducive to decarbonization elsewhere.

5.2. Qualitative insights

The European Union expands legislation on public procurement of clean vehicles. What is necessary in order to promote the widespread adoption of electric vehicles (EVs)? The recent trend in energy policy since the end of the 20th century in many parts of the world has been to open–up competitive markets. This is characterized by the deregulation of formerly state–monopolized national energy sectors; efforts to promote competition and limit barriers to entry; and a flurry of regional accords, commercial pacts, and agreements that facilitate trade in energy resources. One of the impacts of these transitions has been to expose historically sheltered companies to a newly liberalized set of opportunities and threats. In this policy climate, nations and firms have pursued international energy strategies. They have sought to control reserves overseas, insulate themselves from price shocks, gain access to crucial pipeline and LNG infrastructure, and manage globalized markets in ways that protect their relative advantages. They are also experiencing different forms of resistance to these strategies, including public protest (either physical or institutional); competing national-level resource diplomacy; and a patchwork of regional and local policies that frustrate, limit, or subvert SWI approaches (K Sovacool et al., 2019). This contributes a more nuanced understanding to the debate by investigating the bottom-up effects of strategic efforts by companies and/or state actors to navigate globalized energy systems to their advantage. Using the qualitative evidence in this paper, it can now be detailed how agents resist structural SWIs by using, controlling, or manipulating the national regulatory instruments that work in tandem with or are forged in the image of such strategies. These resistances affect the distribution, character, and pace of SWI initiatives concerning natural and unnatural gas industry development. This paper addresses an existing knowledge gap by contributing a macro perspective on electric vehicles in a Schumpeterian innovation framework, which aims to explore the feasibility of leapfrogging in clean transportation. Additionally, through the in-depth evaluation of relevant case studies, this paper provides insightful implications to both researchers and policymakers aiming at enhancing both technological and industrial leapfrogging in the electric vehicle sector in catch-up economies by identifying specific factors which have spurred the capability-building process for the emergence and consolidation of domestic EV industries in these countries. In the context of the rapid growth of paradigm shifts in clean technology innovation in recent years, the literature has so far paid scant attention to the exploration of leapfrogging in emerging clean technologies (namely, the phenomenon of technologically and industrially catching-up in a specific clean sector).

6. Discussion

Introduction of electric vehicles (EVs) in urban transportation systems can contribute to urgent issues of environmental pollution and greenhouse gas emissions. In this work, an agent-based spatial integrated framework is developed for modeling the interactions among car users considering the localized characteristics between a Charging Facility Agent (CFA) and a user. The approach can help to overcome the problems related to data availability and model complexities, which are commonly encountered in analyzing multi-agent systems on large scales and at fine space resolutions. This modeling approach is applied to the case of Beijing, China, where the top-down implemented subsidies have been recently terminated. At the city scale, with the remaining subsidies, gas-based Plug-in Hybrid Electric Vehicles (PHEVs) are predicted as possibly outdated by 2025. More subsidies would be needed to expend BEV chargers and for PHEV purchasers if local authorities would make PHEVs competitive to CVs and BEVs. The overall car traffic is projected to decrease even given the aggressive plans on the EV market. The synthesized methods and results are suggested to benefit other cities planning of EV markets and infrastructures (Zhuge et al., 2019). At the regional scale, the Systematic Energy and Emission Model (SEEM) is adopted to analyze the potential impacts due to electricity consumption changes from Beijing's transportation sector.

6.1. Interpretation of findings in relation to existing literature

Introduction: Although the environmental benefits of electric vehicles in reducing greenhouse gas emissions have widely been recognized, there is no consensus amongst economists regarding the localization dimension of the overall economic impacts of their market growth. This paper fills this gap by employing Input-Output analysis and a Computable General Equilibrium model to analyze a comprehensive set of economic impacts. These models are applied to several different regions with computational results. The overall economic impacts are not significantly different to each other. However, when it comes to the distribution of impacts, there are some considerable differences across regions which have different economic structure. In terms of business activities, while there is a substantial variation in employment/share ratios of activities, the key sector receiving additional output from the electric vehicle sector is services in all regions. Additionally, urbanization economies become especially important when urban areas observe a higher concentration of electric vehicle enterprises. The socio-economic characteristics of households matter when assessing the overall impacts, with both positive and negative impacts observed on household income distribution, depending on the income quintile considered. On the other hand, tax revenues increase regardless of the region, however, the increase is not only because of the growth in economic activities but also the increasing administrations of the electric vehicle sector.

6.2. Implications for urban planning and policy

Cities are major global players and the creation of financial, service and cultural hubs concentrates economic development and populations in homes well beyond the central business district (CBD). To do so, large cities must have an efficient and integrated transpiration system. Emerging technologies such as Electric Vehicles (EV) have the potential to significantly contribute to these targets. They can achieve this by reducing the cost and negative externalities of transportation, improving the flexibility of urban transport and even contributing to a fast and sustainable energy transition as an electric grid integrated energy carrier. However, the interface between the transport system and the electricity grid is complex and bidirectional (F. Calvillo et al., 2019). On the one hand, mass electrification of transport such as the integration of electric buses in urban public transport needs a wide deployment of EV charging infrastructure and the grid upgrade to provide the necessary electricity. On the other hand, EV can be used not only as vehicles but also as batteries contributing to the energy management of the grid, as is the case of Vehicle to Grid (V2G) technology. Therefore, the effective implementation of EV into the urban transport system poses policy questions related to network design, energy capacity investment, coordination between grid operators and transport agencies, congestion pricing and other market-based signals, and the technical potential of V2G.

Simple descriptive analysis of the current dispersion and utilization of EV and Charging Infrastructure (CI) shows that the case of buses is somewhat better integrated to the grid compared to light vehicles. There are two causes, related to the technological development of the vehicles. First, buses are better suited to cover higher daily demands since the introduction of larger batteries. The spread of large scale two-floorers design is the main exponent of this, albeit not exclusive. Second, the development of Pantograph and OppCharge bus fast charging technologies enables full charges in the 3-20 min range, depending on the battery size and the charging power. While allowing more flexibility in bus scheduling and eliminating the need for long standstills, it also requires higher power grid connections. Conversely, the private car park has a higher share of slow chargers and an even higher concentration in private homes (Zhuge et al., 2019). This combined increases the complexity of managing the public distribution grid impact and the efficiency of the potential role of light vehicles in vehicle-to-grid schemes. At an aggregate micro level, these features affect the distribution of CI and EV Charger (EVC) demand. Lacking EVC in their own homes, the vast majority of urbanites' magnet-designated parking spaces connect to the CI grid neither publicly nor semipublicly. The privately owned CI points basically consist of discounted power green residential charging wall-boxes. However, there is a wide distribution of parking prices ad hoc infrastructures close to housing complexes. This designates the existence of a latent commoning of vehicles and CI independent bus ownership. Estimations suggest that only 22% of the designated parking spots in 2016 offered a plugged power source.

7. Conclusion

Serious questions have been raised about the ability to manage future demand growth. This is especially the case in existing distribution networks, already subject to substantial stress from other drivers such as new housing and commercial developments. Until recently however, a lack of detailed evidence on both the scale and nature of EV demand has made it difficult for network operators to plan effectively. Here, the first research to model individual vehicle movement and charging patterns, combining sample household travel diaries and detailed geographical and network data from the UK, is presented (F. Calvillo et al., 2019). This research found that recent studies of EV demand, which rely on trip chaining models and synthetic demand profiles derived from large but unrepresentative travel summaries, may be significantly underestimating the cost of necessary network reinforcements.

One of the key predictions for the growing number of private vehicles and delivery fleets on urban roads is increased traffic congestion and worsened air quality. However, no research has assessed EVs impact on urban economies, retail sales, and property valuation. With a spatial Durbin model, monthly data from 2000-2015 on 455 urban cities in China, and a difference-in-differences method, this study finds that a 1% increase in EVs significantly increases retail sales and property valuation growth by 0.018 and 0.037 percentage points, respectively. This finding is robust to different testing strategies, including changing the bandwidth, spatial weight structure, matching criteria, spatial variables, city selection rules, and control variable setups. With the rapid development of Chinese EVs, it is politically significant to notice the positive aspects of the rise of EVs (Eugenia López Lambas et al., 2017). The findings provide a broader vision to urban policy stakeholders and decision-makers, as they can refer to the concealed aspects induced by EV growth trends.

7.1. Summary of key findings

This work investigates the direct and unavoidable economic effects of widespread Electric Vehicles (EVs) system adoption and the centrally apprehended externalities. A Computable General Equilibrium Model of an arbitrary economy is discretized as necessary and used to appraise direct and indirect effects on overall employment, capital premia, electric demand and carbon CO2 emissions in the UK from the complete transition of road transport system to EVs. If unbridled, it is shown that the peakwise transition out of ICE cars to EVs arguably unavoidably results in massive negative effects on urban economies. Such effects are largely imperceivable on the national scale, due to treating urban economies as aggregates. Nothing exclusive can be said about productivity and wage distribution, but nimble apprehension does not appear to lead to appreciable insights. Otherwise, the analytical conditions are quite general and do not pertain solely to the UK or the assumptions underlying the model. References (F. Calvillo et al., 2019) provide an overview of EV implications focusing on the energy system, with quantitative analysis using a national-electric-city multi-sectoral model of the UK economy.

7.2. Limitations and future research directions

Nowadays, the attention paid to electric vehicles (EVs) is growing, as governments are initiating numerous programs promoting alternative fuels. The analysis of the potential effects of EVs for congested urban areas is important. As a laboratory for research, the city center of Łódź, the third largest city in Poland, was chosen. Łódź is a specific city because of its unusual shape. Consequently, the city center heats up due to the large production district in the middle. The calculations were carried out for this part of the city because it is reduced to the highest level. Rampa is defined as the number of consecutive vehicular flow sets. Compounds and analysis of changes in speed and density of the street network are provided. The effects of the "high" (10% of the vehicle fleets) are greater than those observed for "low" (1%). However, the results were classified as weak.

Summing up, the issue of introducing electric cars to urban areas should still be carefully considered and, above all, analyzed, since it is possible to obtain various, even paradoxical, data showing a similar level of development of the city. It is also important to choose the right type of transport hub, as most current urban activities take place in a large, highly centralized agglomeration, at home, such as watching movies, even during car rides. Other activities, such as eating or drinking seem impossible due to constantly changing traffic conditions.

8. References

Electric Vehicles (EV) have been hailed as the future of personal electric mobility for many reasons including less emissions, less oil dependency, and more opportunities for renewable energy integration. However, due to these opportunities enabling a large number of EVs to connect to the grid are numerous challenges facing impacts to the grid investments in infrastructure and costs. Whether these impacts occur and at what magnitude are dependent on the local grid, the charging behavior of the vehicles and the broader transport and energy context (ElBanhawy et al., 2013). To date, most studies have focused on these impacts at a distribution grid level, but there are also significant inter-regional impacts which can be crucial for particular regions. Multi-regional studies part on travel demand forecasts are still limited and are generally based on assumptions including the annual vehicle kilometres travelled decline with increased EV deployment. Tackling some of these requirements, this study investigates the inter-regional impacts on the transmission grid.

Unclean transportation systems, in particular the usage of the Internal Combustion Engine Vehicle (ICEV), have been the source of heavy pollution that cost billions of dollars in health problems (Ediz, 2017). Electric Vehicles (EVs) have been deemed as a paradigm shift in the transport industry capable of switching transportation systems to fossil-free energy sources and energy efficient technological solutions. The shift to mass market EV acquiring and usage will encourage governments to speed up the installation of EV-charging infrastructure and provision of incentives to EV market participants. In return, this is likely to lead to increased collective uptake of EVs; however, non-controlled uptake could perform as a risk to the electrical system. Similarly, a transformation to an entirely electrical transport system runs a threat of integrating emissions from the transport industry to power stations, where the transportation sector performs a coaction against the purpose of decrease of emissions. This gives electric transport systems the potential to benefit from cost-effective Retired Thermal Power Station (RTPS) sites connected to the aging Transmission Network (TNs). The findings illustrate to policy makers, vehicle manufacturers and power generation investors the increase in EV market share, transportation and distribution of transmission system problems.

References

Ajanovic, A. (2022). The impact of COVID-19 on the market prospects of electric passenger cars. ncbi.nlm.nih.gov

ANGLANI, N. O. R. M. A., MULIERE, G. I. U. S. E. P. P. E., & F., F. (2012). Electric Vehicles Penetration and Grid Impact for Local Energy Models. [PDF]

Ashok, B., Kannan, C., Muhammad Usman, K., Vignesh, R., Deepak, C., Ramesh, R., M. V. Narendhra, T., & Kavitha, C. (2022). Transition to Electric Mobility in India: Barriers Exploration and Pathways to Powertrain Shift through MCDM Approach. ncbi.nlm.nih.gov

David Arias-varela, H. (1997). Cost Analysis and Air Pollution Impact of Electric Vehicles on a Metropolitan Area.. [PDF]

Ediz, S. (2017). Evaluation of the impacts of plug-in hybrid electric vehicles on electricity load curve for Istanbul. [PDF]

ElBanhawy, E., Dalton, R., & Mine Thompson, E. (2013). Eras of electric vehicles: electric mobility on the Verge. Focus Attention Scale. [PDF]

Eugenia López Lambas, M., Monzón de Cáceres, A., & Pieren Salazar, G. (2017). Analysis of Using Electric Car for Urban Mobility, Preceived Satisfaction Among University Users. [PDF]

F. Calvillo, C., Turner, K., Bell, K., & McGregor, P. (2019). Assessing the impacts of large EV penetration in the UK : analysis of network investments and changes in fuel use. [PDF]

G McDermott, E. (2017). Examining the effects of policy interventions on increasing electric vehicle adoption in California. [PDF]

K Sovacool, B., Kester, J., Noel, L., & Zarazua de Rubens, G. (2019). Income, political affiliation, urbanism and geography in stated preferences for electric vehicles (EVs) and vehicle-to-grid (V2G) technologies in Northern Europe. [PDF]

Stark, J., Weiß, C., Trigui, R., Franke, T., Baumann, M., Jochem, P., Brethauer, L., Chlond, B., Günther, M., Klementschitz, R., Link, C., & Mallig, N. (2017). Electric Vehicles with Range Extenders : Evaluating the Contribution to the Sustainable Development of Metropolitan Regions. [PDF]

Zhao, X., Hu, H., Yuan, H., & Chu, X. (2022). How does adoption of electric vehicles reduce carbon emissions? Evidence from China. ncbi.nlm.nih.gov

Zhuge, C., Wei, B., Dong, C., Shao, C., & Shan, Y. (2019). Exploring the future Electric Vehicle market and its impacts with an agent-based spatial integrated framework: A case study of Beijing, China. [PDF]