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The Impact of Recessions on Traffic Volumes: Does Economic Resilience alter the Relationship?

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Abstract

This paper focuses on the relationship between economic activity and traffic volume on European country-level. Economic activity is proxied by three leading indicators in the body of existing literature, namely GDP per Capita, the unemployment rate and the oil price. Moreover, this paper also tests whether resilience of an economy alters the relationship between economic activity and traffic volume. The extent to which the economies of European countries are considered resilient is determined by the Resilience Index applied in this paper. Using a Fixed Effects model, outcomes are that economic activity and traffic volume are positively related. Evidence for the expected faster increase in traffic volume after an economic downturn has not been found. By contrast, an opposite relationship has been found, where economically non-resilient countries record a higher level of traffic volume post-recession. This outcome could be explained by the shape of the Environmental Kuznets Curve (1955), where countries in a different stage of economic growth have a different view towards the environment. The third part of this paper focused on economic development and traffic volume heterogeneity. It follows that the outcomes of the general relationship are mostly in line with the major developed European countries. Hence, there is evidence for both economic development and traffic volume heterogeneity. Policy implications are that economically non-resilient countries should use periods of economic downturn to bring forward both infrastructural expansion and repair plans, as this would minimize the negative externalities of construction. Concerning the economically resilient countries, governments should use economic recessions to bring forward only infrastructural repair plans, since the total benefits of road expansion will decline much faster for these countries.

Abbreviations

Abbreviation	Meaning
2SLS	Two-Stage Least Squares
CEE	Central and Eastern Europe
EKC	Environmental Kuznets Curve
GDP	Gross Domestic Product
HDI	Human Development Index
HUR	Harmonized Unemployment Rate
IV	Instrumental Variable
MME	Microeconomic Market Efficiency
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Squares
VKT	Vehicle Kilometers Traveled
VMT	Vehicle Miles Traveled

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1. Introduction

The Great Recession of the late 2000s was the source for substantial reductions in congestion all around the world (RTL Nieuws, 2010; Moschovou & Tyrinopoulos, 2018; Texas A&M Transportation Institute, 2019). Moreover, in the economically recovering period right after the Great Recession, congestion numbers turned back to levels prior to the financial crisis (Texas A&M Transportation Institute, 2019). This relates to the assumption that traffic congestion is positively related to economic activity.

The aftermath of the financial crisis was that some regions experienced a much faster economic recovery than others. In other words, some regions are more economically resilient to negative shocks than other regions (ESPON, 2014). Martin (2012) adds that "these three major recessionary shocks have been far from geographically even in their incidence", referring to the UK, USA and mainland European countries during the last three economic recessions, which took place in the early 1980s and 1990s and in the late 2000s. Also, Martin argues that these different performances are due to the resilience of certain economies. However, the concept of economic resilience varies substantially across scientific literature, and the indicators to measure economic resilience differ even more. Briguglio et al. (2006) describe that economic resilience has been used in the scientific literature in three different ways. Namely, to indicate that an economy can (1) recover rapidly, (2) to resist the effect and (3) to avoid the shock (Briguglio et al., 2006)[1]. No matter what definition is used, more resilient economies will probably have to deal with returning congestion issues in an earlier stage after the economic recession than less resilient economies.

If this is the case, then that might ask for a different infrastructural time planning in more economically resilient countries, compared to less economically resilient countries. Such a change in infrastructure planning can apply to both temporary and permanent travel demand shocks in case of a recession. For example, if a region suffers from a temporary travel demand shock, this could imply that there might be more space for infrastructural construction plans, due to less traffic volume on the road in that period. Policy makers will then be able to anticipate on this by bringing infrastructural projects forward. However, if a travel demand shock permanently affects travel demand, this could imply that infrastructural construction plans might be postponed due to the lack of financial resources and the reduced urgency of the problem. If governments are more aware of how resilient their economy is, they will be able to anticipate more adequately and can coordinate better on infrastructural construction plans soon.

For the policy implication to hold, the relationship between economic shocks and traffic volume needs to be researched more in-depth. This paper will test whether the resilience of an economy has a

[1] Both Martin (2012) and Briguglio et al. (2006) are core publications of the scientific literature on the topic of economic resilience. This paper will therefore refer to these publications frequently, besides the complementary literature.

moderating effect on the relationship between economic crises and traffic volumes. Therefore, the main research question of this paper reads as follows:

To what extent do economic shocks affect traffic volumes in European countries, and can resilience alter this effect?

In this paper, a Resilience Index is created based on the outcomes of the most recent economic recession (2008-2010) in terms of change in per capita GDP, unemployment and export volume. This index is applied in situations before and after this recession. The three indicators are chosen because in the existing literature they are frequently used for measuring the impact of an economic recession. The Resilience Index indicates which European economies are considered 'resilient' and which are 'not resilient'. The main motive for testing the three indicators aggregated in one index is to regress the resilient and not resilient country groups separately, in order to test whether the degree of economic resilience causes heterogeneity between the two groups. The relationship between economic shocks and traffic volume is regressed for the full sample (H1) and the resilient and non-resilient subgroups separately (H2). For robustness of the model, a Robust Resilience Index is included in the second hypothesis. The robust index applies different weights to the three indicators. It is expected that the resilient countries are more capable of boosting the economy to levels prior to the economic shock, and hence reporting larger increases in traffic volume, compared to not resilient countries.

The relationship between economic shocks and traffic volumes is also tested for potential heterogeneity in two other ways. First, the sample will test for potential heterogeneity in terms of economic development, where a GDP threshold will divide the transition and developed country subgroups (H3a). Prior economic research namely found that transition countries generally record more volatile GDP changes following a recession, which could be a source of heterogeneity. Second, the sample will test for potential heterogeneity in terms of traffic volumes, where a VKT threshold will separate the major EU countries and the smaller EU countries (H3b). A more detailed description of the thresholds will be given in the methodology section. Finally, an instrumental variable analysis is included to test for causality and robustness of the regression models.

This paper is structured as follows: Section 2 gives an overview of the body of existing literature on the economic activity-traffic volume relationship. The third section formulates the hypotheses that are central to this study. Section 4 gives an overview of the data sources, modifications and characteristics. The fifth section provides the methodology that is used in this research and argues why is chosen for this approach. The sixth section gives a detailed overview of the regression analysis results. Section 7 concludes.

2. Literature Review

As mentioned in the introduction, the concept of resilience is not straightforward. Across scientific literature, the interpretation of the concept 'resilience' varies. The same holds for the indicators of how to measure the rate of resilience in regional economies. This literature review is intended to give a clear and concise overview on how the concept is interpreted across the economic literature. Other elements of this section focus on the relationship between economic activity and transport indicators, recessions and travel demand, and heterogeneity in transition countries.

2.1. Types of Resilience

The concept of resilience in economic literature can be interpreted in multiple ways. This section is intended to explain that one should be careful to directly connect resilience to economy as the term can also be used in other sciences.

Resilience can also be interpreted from another point of view, such as engineering and ecological resilience (Martin, 2012). From the technological perspective, economic resilience of a region can be predicted by Friedman's Plucking model (1964). In short, the Plucking model predicts that economic shocks generally are temporary. The model argues that such a shock is not likely to cause structural problems in terms of long-term growth rates (Martin, 2012). In other words, an economy returning to its pre-recession level after the economic shock is more often the rule rather than the exception. Claeys and Walsh (2015) add that economists generally attribute the recovery of an economic recession to "decisive economic policies", such as quantitative easing or labor market reforms. However, according to the Plucking model, it is natural for a recovering economy to show relatively higher growth rates, when the initial negative shock also was relatively large. An economy that has been hit relatively hard by an economic recession, will show higher growth rates when it returns to its pre-recessionary level, compared to an economy that has been hit relatively little by the same economic recession. Therefore, using the standard economic growth model could show a distorted image (Claeys & Walsh, 2015).

Another definition of resilience that is used in scientific literature is ecological resilience. A phrase that economists often relate to this is economic 'hysteresis'. Martin (2012) defines ecological resilience as the "role of shocks or disturbances in pushing a system beyond its 'elasticity threshold' to a new domain". If the outcomes of the shock are above this threshold, then this might change complete labor markets, and bring the economy into a new state. On the other hand, if this threshold is not reached, then the economy will be able to return to pre-recession growth levels. The extent to which regions are ecologically resilient is measured by the height of the threshold. If a region has the capacity to create a higher threshold, then the region is more resilient (Martin, 2012). But how is this related to hysteresis? Hysteresis refers to "a form of path dependence – that is, it describes a process whereby the past has a lasting influence on the present and future" (Setterfield, 2010).

Setterfield (2010) describes two potential cases how hysteresis can modify a regional economy. The first case shows that economic hysteresis during recessions often causes structural changes to regional economies. This is due to a change in behavior of the economic actors. When the recessionary shock is from a certain level of severity, it could for example modify an economy in terms of sector composition (Setterfield, 2010). The result is that the negative economic shock "permanently lowers the level of output or employment", even though economic growth levels return to pre-recessionary shock rates (Martin, 2012). The second case argues that economies will be disrupted mainly in terms of reduced amount of business activities, rather than lower growth rates, following an economic shock. Martin describes that the destructive effects of a recession on firm bankruptcies substantially outweigh the post-recession newly opened businesses (2012). Moreover, an economy in downturn might also have consequences for the long run business climate of the region. The economic hysteresis of a region might cause a chain reaction across local supply chains. For example, if a furniture store goes bankrupt, then this will have consequences for firms upward in their supply chains, such as sawmill companies. In other words, multiple sectors will be hit if a recession occurs. This will on its turn lead to less investments and reduced job creation. Therefore, if a region suffers from such hysteresis, then the region is considered less resilient (Martin, 2012).

The third and last type of resilience, as described by Martin, is the so-called 'adaptive resilience'. Adaptive resilience is the "capacity of a regional economy to reconfigure", which means that it can adapt after a recession and create jobs in a new sector (Martin, 2012). Regions which are considered to have the adaptive resilience capacity are generally more innovative. Moreover, if many firms in a region can terminate less productive activities and modify these into more productive activities in another sector, then this will make a regional economy more adaptively resilient (Martin, 2012).

When comparing the three types, adaptive resilience is the most in line with the Resilience Index of this research. This is the case since the two remaining types are not in the scope of this research. Nevertheless, adaptive resilience is in the scope of this research since economies which have the power to adapt will record higher GDP per capita and lower unemployment levels. Hence, adaptive resilience will be seen as the source of resilience in this research. In the following section, the potential methods on how to measure economic resilience will be explained.

2.2. How to measure Economic Resilience?

As mentioned in the introduction, Briguglio et al. (2006) broadly defined the three potential definitions of economic resilience, which are used frequently among economists. The first definition of economic resilience they describe is the ability of an economy to "recover quickly from a shock" (Briguglio et al., 2006). Economies that are flexible will be able to react adequately and bounce back. In this way, economies that are resilient will record pre-recession growth levels quickly after the negative shock. A factor that contributes to this type of economic resilience is a solid fiscal position, which makes room for policymakers to invest efficiently and relaunch the economy (Briguglio et al., 2006).

The second potential definition of economic resilience that is often used in scientific literature is the ability of an economy to "withstand shocks" (Briguglio et al., 2006). This implies that an economy has the capability to absorb the shock such that the overall result is mostly negligible or even non-existent. Again, flexibility in the workforce could play a key role for the level of resilience in an economy. This could be measured by means of three factors. These are the ability of a government to engage in discrete expenditures and tax cuts in case of recessions, and the extent to which a labor force is multi-skilled. If the government has access to a multi-skilled workforce, this will enhance the ability to absorb economic shocks by "shifting resources" to a better performing sector (Briguglio et al., 2006).

The third potential definition, as mentioned by Briguglio et al. (2006) is the ability to "avoid the shock altogether". According to this definition, a country needs to be self-sufficient and should not depend on others. From this perspective, countries which are not resilient mainly include small island states and countries with a high export balance.

In order to understand the differences between the three potential definitions of resilience, the authors use an influenza virus outbreak as metaphor. In the first definition of resilience, someone gets infected, but the person recovers quickly from the virus. In the second definition, someone withstands the effects of the virus, for example by showing immunity. Finally, in the third definition, someone avoids getting infected by avoiding virus hotspots (Briguglio et al., 2006).

Rose and Liao (2005) on the other hand identify economic resilience in two other categories: inherent and adaptive resilience. Inherent resilience is the ability of a market to respond properly to demand shocks or price signals under normal market conditions. Adaptive resilience is the ability of a market to function properly in times of crises. To give an example, if a manufacturing firm has access to substitutes for input goods, the firm is considered adaptive resilient, as the manufacturing firm is not dependent on a single supplier (Rose & Liao, 2005).

Since the two measurement points of the Resilience Index are before and after the economic shock, there is no information on whether particular countries were withstanding the shock or just recovered quickly from the shock. As 'bouncing back' is the weaker restriction of the two (i.e. no need to bounce back if no economic shock occurred), this definition will be used in order to measure economic resilience.

2.2.1. Economic Resilience and Vulnerability

The fact that there are multiple definitions of resilience also means that the outcome differs. According to the latter definition, small island states such as Malta and Singapore, are 'not resilient'. However, Singapore traditionally records high levels of GDP per capita. In a paper from Briguglio and Galea (2003), they address this issue with the so-called 'Singapore Paradox'. The Singapore Paradox explains that resilience is not the same as vulnerability. Singapore may be vulnerable due to the high export balance and dependency on other nations. However, if Singapore for example has a strong fiscal position and a flexible workforce, the island state can anticipate upcoming recessions in order to minimize economic damage. Countries may thus have resilient economic policies that will reduce the recessionary impact despite their vulnerability.

To find out what type of countries are most vulnerable, Briguglio et al. (2006) established a vulnerability index. Indicators for this were degree of economic openness, export concentration and the dependency on strategic imports. Economic openness is measured by the share of GDP that is dedicated to export. If a large share of the economy is depending on exports, then could a negative foreign demand shock have severe consequences for the stability of the exporting country's economy. Export concentration is measured by how diverse the export product range of the exporting country is. If a country exports a wide range of products and services, then should a one-sided demand shock not have too severe consequences. The dependency on strategic imports is measured by ratio of imports, which are considered to be primary goods, to GDP. Food and beverages, energy sources and toiletries are among these goods. The outcome of the vulnerability index confirms most of the expectations. Small countries and islands, such as Singapore and Malta tend to score higher on the index (Briguglio et al., 2006).

In order to find the relationship between vulnerability and resilience, Briguglio et al. (2006) also constructed a resilience index. The resilience index however consists of much more indicators, compared to the vulnerability index. This is because economic resilience can be achieved through multiple approaches. The resilience index consists of four elements, each representing multiple indicators. These elements are "macroeconomic stability, microeconomic market efficiency, good governance and social development" (Briguglio et al., 2006). For each of the indicators holds that they are characterized by a high degree of influenceability by policy makers. This implies that the indicators can be improved by means of policy making. Moreover, each of the indicators should be related to the degree of resilience of a particular economy.

In line with the argument of Briguglio et al. on good governance is the finding of Rios and Gianmoena (2020). They found that the quality of government is the most important determinant of economic resilience. This determinant is measured by an index, constructed by Charron, Dijkstra and Lapuente (2014). The quality of government index includes components such as corruption, rule of law, governmental effectiveness and accountability (Charron et al., 2014). Other important determinants of economic resilience, according to Rian and Gianmoena, are the share of young individuals in the population, the volatility of business cycles, the degree of human capital, historical employment rates and regional sector composition (2020).

Macroeconomic stability is characterized by a solid fiscal policy, tempered inflation and reasonable unemployment rates. The variables included are the budget deficit to GDP ratio, aggregated unemployment and inflation rates and the debt to GDP ratio (Briguglio et al., 2006). These factors are till a certain extent comparable to the entry requirements of potential European Union members. Each of the above-mentioned factors is influenceable by governmental policies and together they indicate which countries enjoy macroeconomic stability. Macroeconomic stability is of major importance for the degree of resilience of an economy. This is the case since stable economies tend to be more capable of dealing with adverse shocks.

The second element of the resilience index of Briguglio et al. (2006) is microeconomic market efficiency (MME). MME is characterized by two sub-categories: “the size of government and the freedom to trade internationally” (Briguglio et al., 2006). The sub-categories on its turn consist of a wide set of variables. The size of the government represents factors such as average government expenditures and marginal tax rates. The freedom to trade sub-category represents factors such as trade barriers, tariffs and exchange rates. MME is vital for the degree of resilience of an economy since it indicates to what extent resources are being allocated efficiently. Well-functioning resource allocation enables an economy to easily adjust markets and efficiently absorb negative demand shocks (Briguglio et al., 2006). According to Hallegatte (2014), microeconomic resilience could be measured by several indicators. Among these are the household economic vulnerability, the average amount of savings, whether individuals are properly insured or not and socioeconomic protection (Hallegate, 2014).

Good governance is the third element of the resilience index. The indicators of this element are harder to translate into actual digits since these are more subjective and not measurable with numbers. Indicators of this element are “judicial independence, impartiality of courts, protection of intellectual property rights, military interference in the rule of law, the political system and the integrity of the legal system” (Briguglio et al., 2006). Good governance is crucial for the degree of resilience of an economy, since low performance on these indicators might cause social chaos during economic crises, which could have severe consequences for the functioning of an economy (Briguglio et al., 2006).

The remaining element of the resilience index is social development. Social development can be measured via many approaches. In order to capture a large share of the social development indicators and to make it comparable despite heterogeneity between counties, Briguglio et al. (2006) decided to utilize the social development indicators used by the Human Development Index (HDI) from the UNDP. Hence, the social development indicators are related to education (i.e. adult literacy rate and educational participation) and health (i.e. life expectancy). The reason that social development is essential for the degree of resilience of an economy is that better performing nations both have the ability to reduce the urge for national unrest and also will be able to create an environment for social dialogue. Good performance in terms of social development will thus contribute to social support, which enhances adequate policymaking during economic downturns.

Whereas Briguglio et al. (2006) use the HDI index from the UNDP for measuring resilience, Atkins, Mazzi and Easter (2000) use the same index to measure vulnerability. Atkins et al. (2000) namely argue that resilience is one of the factors influencing vulnerability. They explain that vulnerability consists of two components. Firstly, "the incidence and intensity of risks and threat" and secondly, "the ability to withstand risks and threats and to bounce back from external economic and environmental shocks" (Atkins et al., 2000). The authors refer to impact and resilience, respectively. Also, their definition of resilience is mostly like the definition used by Briguglio et al. (2006).

The outcome of the resilience index shows that some of the countries which are most vulnerable also are the most resilient to economic shocks. The three countries with the highest ranking namely are Singapore, New Zealand and Hong Kong (China), respectively (Briguglio et al., 2006). This outcome makes sense as import-dependent countries generally have high stakes for a thriving and stable development of the world economy. Briguglio, Cordina, Farrugia and Vella (2009) distinguish four potential outcomes for the countries in the sample: "best-case, worst-case, self-made and prodigal son". Best-case countries are not vulnerable to external shocks and adopt resilient economic policies. Into this category fall most western European countries, the United States and Japan. Worst-case countries, on the other hand, are vulnerable to external shocks and do not adopt resilient economic policies. Under this category come nations such as Nigeria, Iran and Madagascar. The self-made scenario refers to countries which are considered to be vulnerable to economic shock, but they adopt policies in order to improve their economic resilience. The small countries and island states such as Singapore and Hong Kong (China) end up in this category. Prodigal son refers to the type of countries whose exposure to exogenous shocks is relatively low, but do not adopt resilient economic policies. Countries that fall into this category are for example the BRICs [2] (Briguglio et al., 2006). BRIC countries are characterized by a substantial land mass, large population and a similar rapid pace of economic growth (Eurostat, 2012). To sum up, small dependent island states do not necessarily have to be hit the hardest in case of an exogenous shock. If these countries adopt resilient economic policies, they can minimize the economic damage in case of recessions. Therefore, adequate policy measures are one of the key factors of economic resilience.

2.2.2. Other Factors that contribute to Economic Resilience

Brakman, Garretsen and Van Marrewijk (2015) found that European regions that are more urbanized were more resilient during the Great Recession of 2008-2010. In their definition of resilience, they only researched the initial impact. By contrast, the major cities within these regions experienced relatively many problems with the same recession. Brakman et al. (2015) therefore conclude that more urbanization is not per se a source for resilience. However, the authors do find that regional sector composition does play a role for economic resilience. They argue that urbanization and regional sector

[2] Brazil, Russia, India and China

composition often go hand in hand, as urbanization is a source for specialization. Brakman et al. (2015) found that regions with a relatively high output in medium and high tech industries experience substantially lower unemployment rate changes, compared to regions which produce less medium and high tech goods and services, which indicates that specialization is a source for economic resilience.

A thought that is shared by many economists is that identifying the determinants of economic resilience is a complex task, which requires more future research (Fingleton, Garretsen & Martin, 2012; Martin & Sunley, 2015; Sensier, Bristow & Healy, 2016). Sensier et al. (2016) argue that “resilience is a complex, multi-dimensional entity that is unlikely to be measurable by one simple indicator or composite index alone”. This quotation summarizes the main issue with research on economic resilience. In this complex phenomenon multiple answers (indicators) could be true in order to explain resilience. Nevertheless, the regional outcome of economic downturns is in many papers measured by the same indicators. These are changes in (un)employment and GDP per capita (Brakman et al., 2015; Fingleton et al., 2012; Sensier et al., 2016). If one wants to research a relationship in which the degree of resilience is an input variable, the use of an index is much more logic, since most papers use the same outcomes to measure resilience.

2.3. The Relationship between Economic Activity and Transport Indicators

The body of literature on the relationship between economic activity and traffic volumes shows some ambiguity in outcomes. McMullen and Eckstein (2012) found a “bidirectional causation” between Vehicle Miles Traveled (VMT) and economic activity in the US, depending on the cyclical fluctuation, till the year 1982. However, after 1982, the bidirectional causality no longer applies to the relationship because of better estimations. During economic upturns, McMullen and Eckstein found that GDP growth Granger-causes VMT growth (2012). Paradoxically, VMT growth seems to Granger-cause GDP growth during economic downturns. Again, this conclusion is only valid till 1982, when the estimation improved. After 1982, the causality is only from GDP to VMT, and not the other way around. Besides, they consider transport to be a derived demand, which weakens the statement that VMT causes economic activity. This implies that the demand for transportation only occurs as a result of demand for another good or service (Charles, 2010). Hence, they consider VMT to be “an indicator of a turning point in the macroeconomic business cycle” only (McMullen & Eckstein, 2012). Moreover, practically no statistical relationship was found between VMT and GDP growth in urban areas in the US. This could be the result of less public transport alternatives for less densely populated areas. McMullen and Eckstein conclude that in most cases, the causal relationship is from economic activity to VMT, as “conventional wisdom” suggests (2012).

Puentes and Tomer (2008) found that VMT growth generally has followed a similar pace for rural as well as urban areas. However, rural VMT dropped from 2003 onwards, while urban VMT kept rising. If this trend continues to appear, this could be a source for heterogeneity between more and less densely populated regions. Puentes and Tomer (2008) also argue that the causal relationship between economic activity is only monodirectional, since lower VMT levels will not cause less economic activity at national scale. Litman (2020) shares this vision and explains that higher average incomes could increase energy consumption and traffic volume, but that does not necessarily have to mean that more traffic volume increases average incomes. Litman adds that “VMT and GDP correlate since vehicle expenditures account for a significant portion of household, business and government consumption” (2020). However, more VMT will not increase social welfare, since more VMT only implies that a larger share of the personal income is spent on the vehicle, which means that personal expenditures on non-transport activities also partially decrease.

The southern European countries have been hit relatively hard during the Great Recession. Moschovou and Tyrinopoulos (2018) investigated the effect of this economic downturn to the transport sector in Greece. They found a distinction between passenger car transport and freight transport during and after the crisis. Even though both types of road transport initially (2008) recorded substantial reductions, passenger transport is returning back to pre-recession levels. Passenger transport namely seems to have a positive relationship with employment. The freight transport sector however still suffers from the aftermath of the Great Recession. Greece’s GDP seems to depend too much on the freight transport sector, which could explain their relative bad economic performance in the years after the crisis. Greece also differs from other EU-countries in the relationship between passenger traffic volume and economic activity, as passenger traffic in Greece showed much sharper reductions following an economic recession, compared to other European nations (Moschovou & Tyrinopoulos, 2018).

Nanaki (2018) found that net income exhibits a positive relationship with total car sales, while fuel prices, the (un)employment rate and inflation rate were negatively associated with total car sales. During the Great Recession all these factors contributed to a substantial reduction in car sales, strengthened even further by the governmental austerity policies. This implies that more economic activity contributes to a higher personal income, which in turn raises car sales (Nanaki, 2018).

Weerasekera and Amarasingha (2017) found in their survey that employed individuals contribute more to Vehicle Kilometers Traveled (metric equivalent of VMT) on average, compared to unemployed individuals. Consequently, elderly individuals contributed less to Vehicle Kilometers Traveled (VKT), since they left the working population age. These findings are in line with the assumption that higher unemployment rates decrease total VKT.

The oil price, an important transport indicator, can potentially also be a predictor of upcoming recessions. Imbert (2020) argues that “spiking oil prices” can cause economic recessions. He found that oil prices almost doubled just before each of the last three US recessions. The *Guide to the Markets* report (2019) found similar results. The report measured how often “Commodity Spikes” occurred prior to the last US recessions (Guide to the Markets, 2019). A Commodity Spike is defined as a 100% or more rise in oil prices within an 18-month period. In the last six recorded recessions, a Commodity

Spike occurred five times. Therefore, it is assumed that volatility of the oil price is not in the best interest for the sustainability of the economy. Of course, the oil price is more relevant for oil producing countries, such as the US, Russia and Saudi-Arabia. However, a local recession can "quickly spread through multiple channels to other industrialized countries", and a little later to other countries (UN, 2011). The Great Recession of the late 2000s is a perfect example of this. Moreover, a higher oil price will increase fuel prices and will lead to higher manufacturing costs (Beattie, 2020). Therefore, the oil price is an important indicator for economic activity, also for countries that do not produce oil (ECB, 2009).

2.4. Economic Output, VKT and Resilience

Melo, Graham and Canavan (2012) found that infrastructure investments result in two Granger-causal relationships. The first effect is an increase in economic output (GDP). This is due to improved accessibility and connectivity of the region. The region is now able to better attract workers from outside. The second effect is that infrastructure investments, measured by the amount of lane miles, induce travel demand (VMT). GDP and VMT therefore both show a positive Granger-causal relationship with infrastructure investments (Melo et al., 2012). This indicates that GDP and VMT of a region increase simultaneously a while after infrastructure investments took place. This double Granger causality also suggests that GDP and VMT are positively related. As economic resilience is generally measured by the change in GDP (Brakman et al., 2015; Briguglio et al., 2006; Sensier et al., 2016), a relationship between economic resilience and VKT / VMT is plausible. However, literature on the direct relationship is scarce. Since the concept of economic resilience is gaining attention among economists last years, literature on the economic resilience – travel demand relationship is likely to increase (Chacon-Hurtado, Kumar, Gkritza, Fricker & Beaulieu, 2020).

Maciejewska, Marquet and Miralles-Guasch (2019) researched the shifts in travel demands in Catalonia before and after the Great Recession from the late 2000s. Unemployment rates rose from 6.5% to 22.5% between 2007 and 2012, respectively. This substantial increase in unemployment was the source for a major shift in travel demand and purpose. Work-related trips decreased with approximately one-third of the total, whereas demand for leisure trips recorded an increase in the same time period. The economic recession caused higher unemployment rates and therefore lowered commuting travel demand. Maciejewska et al. (2019) argued that the cause of the lower travel demand is twofold. Besides the reduced urge for commuting (more unemployment), less monetary resources also contributed to this overall decrease as more individuals opt for commuting by public transport. Nielsen (2015) argues that the Great Recession made individuals more aware whether a car trip really is necessary to reach a destination. He claims that the recession changed individual travel behavior. Good urban planning and accessibility will increase urban resilience, which is the "adaptation or resistance to the changing economic and other circumstances" (Nielsen, 2015).

Each of the researchers mentioned in this section claims that economic recessions could potentially alter car travel demand. As resilient economies generally are impacted less by economic recessions, this would indicate a potential distinction in travel behavior between economically resilient and less resilient regions.

2.5. Heterogeneity between European Countries

The pace of economic growth in European countries is far from similar. The catching up growth of Central and Eastern European (CEE) countries is mainly due to the recent exposure to the open market economy and the accompanying globalization. The result is an above average growth in GDP (Canuto & Lin, 2010). However, this high pace also makes transition countries more prone to economic recessions when the capital flow is not regulated properly. Undermining capital flow policies will cause economic instability and thereby vulnerability during crises. The consequence was that transition countries recorded the largest swing in current account balance during the Great Recession. Among the European bottom five countries in current account balance shifts are Latvia, Estonia, Lithuania and Hungary (Canuto & Lin, 2010). CEE countries on average are experiencing the weakest output recovery among all transitioning economic regions around the world following the Great Recession (Mitra, Selowski & Zalduendo, 2009). They argue that these countries have benefited greatly from open trade, but that the opening up made the transition countries more vulnerable due to "policy weaknesses" and "global imbalances" (Mitra et al., 2009). A sound economic policy reform is the key to recovery for countries to benefit from globalization properly (Mitra et al., 2009).

Both above-mentioned papers note the distinctive economic growth path of the economically transitional countries in Europe. In other words, transition countries record more volatile changes in GDP following an economic recession, compared to developed countries. This implies that there might be a form of heterogeneity between developed and transition countries as the effects of economic shocks are researched. Dell'Ariccia, Detragiache and Rajan (2008) also expected such a problem in transition countries. They namely argued that recessionary shocks might hit transition countries more severe, due to the lack of access to foreign finances. Dell'Ariccia, Detragiache and Rajan (2008) therefore included an interacting dummy variable in order to try to solve the heterogeneity problem.

2.6. Conceptual Framework

This section is intended to give a short overview of the discussed literature review. The conceptual framework will function as the bridge between the literature and the empirical analysis.

2.6.1. Critique on Existing Literature

Brakman et al. (2015) argue that specialization in a few sectors of medium- and high-tech is a source for economic resilience of a region. However, specializing too much on a few sectors could also make a region vulnerable when a demand shock in that sector occurs. For example, a region is specialized in producing particles for airplanes or road transport. The negative demand shock in transportation because of the Coronavirus in 2020 has also hit regions with much high-tech in transportation present as air transport almost fully came to a standstill. Brakman et al. (2015) could therefore make a distinction between the different sector compositions in which a region can specify.

Rios and Gianmoena (2020) used the Quality of Government Index of Charron et al. (2014) as a source for economic resilience. However, this index was used for other purposes, and therefore excluded some important economic factors that contribute to economic resilience.

McMullen and Eckstein (2012) found a bidirectional causation between GDP and VMT till 1982. Afterwards, the estimations improved substantially, such that the causation from VMT to GDP disappeared. This indicates that the estimations before 1982 were not accurate and makes these results less plausible.

Puentes and Tomer (2008) found that urban and rural VMT used to follow a similar pace, till 2003 when they diverged. However, other scientific literature that backs up this conclusion is rather scarce. Nanaki (2018) found that net income is positively related to car sales and that fuel prices, unemployment and inflation are negatively related to car sales. These results seem plausible but are insufficient for this research. Car sales namely only indicates the amount of newly registered cars and does not include the number of vehicles already present, even though this data is relevant for the number of cars sold.

2.6.2. Distinction between Types of Resilience

In order to provide clarity on the definition of economic resilience, this paragraph will highlight the different types of resilience mentioned in the literature review. First, Martin (2012) distinguished between the types of resilience across sciences. The purpose of Martin’s paper is to explain that economic resilience is not the same as engineering and ecological resilience. Logically, this paper focuses purely on economic resilience. Second, the goal of the paper by Briguglio et al. (2006) was to distinguish the three mostly used definitions of economic resilience across scientific literature. The definition from Briguglio et al. that will be used in this paper is that economic resilience is the ability to “recover quickly from a shock” (2006). This definition makes it possible to find multiple degrees of economic resilience, while the two remaining definitions mostly focus on countries that avoid the shock altogether. As practically all European countries are hit by the Great Recession of 2008-2010, the two remaining definitions will not hold for most countries (ESPON, 2014). As mentioned earlier, since the measurement points of the Resilience Index are before and after the economic shock, this gives no information on whether countries were withstanding the shock or recovering rapidly. Since ‘bouncing back’ is the weaker of the two restrictions, this definition will be chosen as the definition of economic resilience.

Third, Briguglio et al. (2009) argued that there generally are four types of countries in the vulnerability – resilience relationship. These are "best-case, worst-case, self-made and prodigal son" (Briguglio et al., 2009). The purpose of this country distinction is to compare Briguglio's outcomes with the results of this research as a robustness test.

2.6.3. Connecting Theory to Empirical Research

The main purpose of this paper is to better understand the relationship between economic shocks and traffic volume in general. Economic shocks will be imitated by three main factors. These are the change in GDP per capita, unemployment rate and oil price. McMullen & Eckstein (2012) and Moschovou & Tyrinopoulos (2018) both found that reductions in GDP contribute to a decrease in VMT. Moreover, Weerasekera and Amarasingha (2017) found that an increase in employment also causes more travel demand. Following this logic, it indicates that an increase in unemployment causes VMT to drop. Furthermore, Imbert (2020) argues that "spiking oil prices" often occur just before a global economic recession. GDP per capita, unemployment and the oil price will together be tested in order to find the impact of economic activity on traffic volume.

As mentioned above, the indicators of economic resilience vary widely across the scientific literature. However, papers that try to measure the impact of an economic recession to a particular country often use the same indicators, namely the change in GDP, the change in unemployment and the change in export volume. Thus, researchers that focus on the impact of an economic recession on something else (and use the severity of a recession as input variable) have much less doubts about what indicators to use. This finding makes the utilization of a Resilience Index more logical. The strategy of using output rather than input indicators in an index is similar to the Social Progress Index approach (Deloitte, 2019). They argue that this approach presents results of what countries actually achieved, which does not necessarily have to be the case when using inputs.

Two measures that are used frequently are GDP per capita and (un)employment (Brakman et al., 2015; ESPON, 2014; Fingleton et al., 2012; Sensier et al., 2016). Therefore, both factors will be incorporated in the Resilience Index that will be established in the methodology section. The third factor of the Resilience Index is the change in export, as economic recessions are characterized by substantial fluctuations in export markets (Martin, 2012). As mentioned above, it is assumed that the oil price could also affect economic activity and is therefore included in the regression. However, the oil price is not likely to be a good indicator for the Resilience Index. This is the case since there are no major oil producing countries in our sample, which means that the countries in the scope of this research all are dependent on oil import. This dependency means that the oil import price regulation is completely exogenous. OECD confirms this statement as national oil import prices in the EU are practically the same for all countries (2020a). As there is almost no distinction between EU countries, it would not make sense to include such an indicator to the Resilience Index. Therefore, the change in export will together with the change in GDP per capita and unemployment indicate which countries are considered to be more and less economically resilient. Whether the degree of resilience of an economy affects the economic shock – VKT relationship will be tested in the second part of this research.

***Figure 1**: Schematic Overview of the Basic Relationship*

To clarify the basic relationship from hypothesis 1, a schematic overview is given above.

The third and final part of this research will test whether there is heterogeneity present between developed and transition European countries. Canuto & Lin (2010) and Mitra et al. (2009) namely indicate that transitioning economies tend to react differently to economic recession than developed countries. Therefore, the third hypothesis will test whether or not heterogeneity is present in the sample.

Section 3 will provide a more in-depth argumentation for the establishment of the three hypotheses.

3. Hypotheses

The aim of section 3 is to give a brief overview of the three central hypotheses in this paper. The three hypotheses are together designed to touch upon all elements of the research question and provide a complete answer. The research question reads as follows:

To what extent do economic shocks affect traffic volumes in European countries, and can resilience alter this effect?

The first hypothesis focuses on the relationship between economic shocks and traffic volumes in general. However, economic shocks are not directly measured by a numeric value. Instead, economists use a wide range of indicators to measure these shocks. In order to measure the severity of a crisis properly, this paper will measure economic shocks by means of three indicators that are used frequently among economists.

The first indicator is GDP per capita. Recessions generally cause substantial demand reductions, as individuals postpone their investments because of the economic uncertainty. Moreover, economic recessions traditionally result in high unemployment rates, which means that average per capita income decreases. For this reason is GDP per capita one of the most frequently used indicators for economic shocks among economists (such as Brakman et al., 2015; Briguglio et al., 2006; Griffith-Jones & Tanner, 2016).

The second indicator that will be used to measure economic shocks is the unemployment rate. Due to the sudden demand shock, less labor force is necessary to fulfill the needs of the consumer. In addition, as their income decreases, companies are forced to lay off their employees in order to prevent the company from making a loss. The third factor that contributes to unemployment during economic recessions is governmental austerity policies. Each of these three events contribute to higher unemployment rates in times of recessions. Therefore, the unemployment rate is a broadly used indicator of economic shocks (among others Brakman et al., 2015; ESPON, 2014; Fingleton et al., 2012; Sensier et al., 2016).

The third indicator of economic shocks is the oil price. Oil is of major importance for the functioning of the economy. It is the main energy source for transportation and manufacturing of goods. Many firms across the supply chain therefore are dependent on the height of the oil price for the sake of their own profitability. This suggests that the oil price is a good indicator of economic shocks. Imbert (2020) and Beattie (2020) already argued that the oil price is related to economic recessions.

McMullen and Eckstein (2012) found that GDP growth Granger-causes VMT growth. This means that in economic upturns, after a while, individuals drive more on average. For example, a rise in income might motivate people to buy a vehicle at a given point in time. The same holds for economic downturns. Economic uncertainty might motivate people to sell their car or to drive less (and save on fuel costs).

Moschovou and Tyrinopoulos (2018) performed a case study on Greece during the Great Recession. They found that Greek traffic volumes substantially declined in this period. The freight transport sector in particular accounted for a large share of this decline. These findings are in line with the assumption that economic activity is positively related to traffic volume.

Weerasekera and Amarasingha (2017) found that employed individuals travel more on average by car than unemployed individuals. This suggests that commuting accounts for a large share of the total VKT. As generally less individuals are employed in times of an economic recession, unemployment is assumed to be negatively related to traffic volume.

Therefore, the first hypothesis reads as follows:

H1: Economic Shocks are negatively related to Traffic Volumes in European Countries.

The second hypothesis is intended to provide an insight in the relationship between economic resilience and traffic volume. A similar model used to test the first hypothesis will be used, but the sample will be divided into two categories: resilient and not resilient countries. To find out under which category each country falls will be calculated with the Resilience Index. The Index will be explained in further detail in the Methodology section.

A core publication on economic resilience is Briguglio et al. (2006). The paper gives an overview of the three mostly used definitions of economic resilience. As mentioned in the Conceptual Framework, the definition this paper will use is the ability to "recover quickly from a shock" (Briguglio et al., 2006). Melo et al. (2012) found that infrastructure investments, measured by the amount of highway lane miles, Granger-cause both an increase in GDP and VMT. The increase in GDP is due to the better accessibility and connectivity of the region. The improved accessibility also contributed to an increase in VMT. However, since the relationship is Granger-causal, it indicates that GDP and VMT did not rise directly after the investments. This is logically the case, since it for example takes a while for new firms to settle in the area because of the improved accessibility. After these events took place, an increase in GDP and VMT was the result. This indicates that GDP and VMT are positively related.

Maciejewska et al. (2019) researched the economic performance of Catalonia (Spain) during the Great Recession. At the lowest point of the crisis, the Catalonian unemployment rate had risen with 16% up to 22.5%. The result was a shift in travel purpose, with substantial declines for commuting traffic. Total VKT dropped mainly because of the reduction in commuter trips. Simultaneously, leisure trips demand compensated some of the VKT reductions, but on aggregate VKT still declined. This indicates that unemployment is negatively related to VKT.

As resilient economies record a higher GDP per capita and lower unemployment rates (during and) quickly after economic recessions, and since these two indicators are in line with VKT, this suggests that resilient economies tend to record higher VKT levels after and less sharp VKT declines during recessions. The second hypothesis will test whether resilient economies tend to show a significantly different VKT performance, compared to not resilient economies.

Therefore, the second hypothesis is the following:

H2: Economic Resilience has a mitigating effect on the Economic Activity – Traffic Volume relationship.

The third and last hypothesis focuses on heterogeneity between European countries. Canuto and Lin (2010) explain that transition countries, such as the CEE countries, record an above average GDP growth, because of globalization. However, they argue that such catching up behavior also makes them more prone to economic shocks. This is due to their lack of foreign finances in case of economic downturn. The result is that transition countries record the largest swing in current account balance among all countries. Mitra et al. (2009) agree on this vision and add that the CEE countries perform the worst among all transition countries in terms of output recovery during a recession. The CEE countries strongly benefited from their entrance to the free market, but it also made them more prone because of "policy weaknesses" and "global imbalances" (Mitra et al., 2009). Solid economic policy reforms would be a solution in order to profit from the opening properly, according to the authors.

Dell'Ariccia et al. (2008) also agree with the vision that a lack of foreign finances might cause more economic damage for transition countries in case of recessions. Dell'Ariccia et al. therefore included a dummy variable that indicates whether a country is 'transitioning' or 'developed'. This should solve heterogeneity issues in terms of economic performance during and after recessions.

Similar to Dell'Ariccia et al. (2008), this paper also researches the effect of an economic crisis in both developed and transition countries. For this reason, a dummy variable for transition countries will also be established and included in the regression. If it is the case that transition countries perform economically bad during recessions, this implies that transition countries on average will record a sharper decline in GDP per capita, a higher unemployment rate and a substantial change in export volume.

Whether this is true or not and thus also has an impact on traffic volumes will be researched in the third hypothesis. Therefore, the last hypothesis will test whether a form of heterogeneity between countries is present in terms of economic development within the economic activity – traffic volume relationship.

The third hypothesis therefore reads as follows:

H3a: Heterogeneity in terms of economic development affects the Economic Activity – Traffic Volume relationship.

Besides potential economic development heterogeneity, deviating outcomes between subgroups may also arise because of the major difference in traffic volume sizes. As visible in the scatterplot (see descriptive statistics), a group of four countries recorded a substantially higher level of VKT, compared to the other countries in the sample. To find out whether these major countries record significantly different results, will be tested in hypothesis 3b.

H3b: Heterogeneity in terms of traffic volume affects the Economic Activity – Traffic Volume relationship.

4. Data

The fourth section provides an insight into the source of the variables that are used in this research. Moreover, this section gives a detailed overview of how the variables are measured and how they should be interpreted.

4.1. Data sources and availability

All variables in this research are retrieved from the Organization for Economic Co-operation and Development (OECD). This is due to their comprehensive availability of transport-related data. First, the dependent variable (traffic volume), which is central to the research question and the hypotheses. Traffic volume data is on country level because of the unavailability of regional data. The countries in the sample are the 27 current European Union members and the United Kingdom, which still was an EU member in the final year of this research. The time span of the dependent variable (and thereby the research) namely is from 1995 to 2018. This period is chosen since it includes the Great Recession (2008-2010). Moreover, in the years before 1995 some former Soviet states did not yet exist (e.g. the Baltic states and Slovakia). Some EU countries, however, are lacking traffic volume data and are therefore excluded from the research. These include Austria, Ireland and Luxembourg. Some other countries lack traffic volume data only for a few years of this research's time span. Therefore, these countries are included in the dataset with less observations. These are Greece, the Netherlands, Portugal, Slovenia, Lithuania, Cyprus and Malta. All aggregated, 504 observations with traffic volume data are left in the sample.

Moreover, data on the three independent variables is retrieved from the OECD. These are GDP per capita, the unemployment rate and the oil price. As discussed in the literature review, all three variables are an indicator of the state of the economy. Third, data of all control variables is retrieved from the OECD. These include population, infrastructure investment, motorized vehicle tax and the change in export. However, most control variables have some missing observations. Since these observations are dropped when missing data, 285 complete observations are left in the sample. And finally, the instrumental variable (tertiary education spending) is also retrieved from OECD. Data on the tertiary education spending is only available from the years 2008 till 2015. Hence, only 130 observations are left in the sample for the instrumental variable analysis. Overall, the countries that have missing observations are both developed and transition countries. This is likely to reduce the likelihood of biases due to missing observations. However, the years in which the missing observations occurred are mostly from the first years of this research's time span. In essence, from 1995 till 2005 are 134 recorded observations, whereas in the time span 2006 till 2016 are 151 recorded observations. The last two years from the sample are missing completely. This could be a source for biases. However, the likelihood of biases here is limited since the difference in observations between the two time periods is limited.

Besides this, 2017 and 2018 are the last years of the sample, which only means that the time span of this research is decreased by two years. Therefore, the likelihood of biases due to missing observations is limited.

4.2. Description of the Data and Variables

The data that is used in this research is in panel structure. Panel data means that the dependent variable could show both within- as between-variation. In other words, the traffic volume could vary over the years and between countries. For robustness, an instrumental variable analysis will be included after answering the three hypotheses. Section 5.4. will elaborate more on the instrumental variable analysis.

4.2.1. Dependent Variable

Traffic volume is the dependent variable in each of the hypotheses. The traffic volume is measured by the total Vehicle Kilometers Traveled (VKT). VKT refers to the "total movement of passengers … and is expressed in million passenger-kilometers" (OECD, 2020b). The existing literature sometimes refers to Vehicle Miles Traveled (VMT). VMT is measured by the Imperial system and VKT by the Metric system. Therefore, the two measurements are in essence the same. VKT outcomes are on the national level and measured annually.

4.2.2. Independent Variables

The three independent variables central in this research are GDP per capita, the unemployment rate and the oil price. GDP represents the total added value by producing goods and services of a country in each time period. As countries with larger populations generally have a higher total GDP, the average GDP (or GDP per capita) has been included. This should give a fairer comparison.

The national unemployment rate is the second independent variable in the models. As most European countries experience an aging population, the average share of unemployed adults will rise. However, this does not necessarily have to indicate that individuals lost their job because of the economic tide. When only the individuals in the working population age are included, this will give a clearer picture. Therefore, the Harmonized Unemployment Rate (HUR) has been chosen over the general unemployment rate. The HUR excludes for example students and the elderly in the calculation. Only those individuals that "are available for work and have taken specific steps to find work" (OECD, 2020c). Moreover, this calculation is seasonally adjusted, which provides a better interpretation of the results.

The remaining independent variable is the oil price. None of the countries in the sample is an incumbent in the oil producing industry. This means that all countries in the sample are dependent on the import of oil. Therefore, the oil price data refers to the average crude oil import prices.

4.2.3. Control Variables

Population size is included in all regression models. Since VKT, the dependent variable in this research, is measured in absolute terms, estimates could be biased. This could be the case since large countries practically always record higher VKT levels, because of their population size. Therefore, population size must be controlled for in the regression models. Moreover, the variable infrastructure investments measures the annual amount of money that is invested in infrastructure projects. A major share of these expenditures is dedicated to road expansion. An increase in the road supply is likely to enlarge traffic volumes, due to better accessibility and initially reduced congestion. Therefore, infrastructure investments are included in the regression as a control variable. Vehicle tax is the third control variable in this model. This variable measures the height of the vehicle tax revenues, as percentage of GDP. When vehicle taxes rise, compared to GDP, car usage becomes relatively more expensive. This could on its turn reduce VKT levels. To account for this, vehicle tax is included as a control variable in the regression models. The final control variable is the export share. This variable measures the ratio between total export volume and GDP. Since exportation of goods accounts for a substantial share of global goods transportation, an increase in total export is likely to increase VKT. Hence, countries that have a high export share are expected to record relatively high VKT levels. To account for export-oriented countries, the export share is controlled for in the regression models.

4.3. Descriptive Statistics

This section firstly discusses the descriptive statistics of variables of interest extensively. Then, a brief overview of the descriptive statistics of the control variables is given. Afterwards, a scatterplot between VKT and GDP per capita will be analyzed.

4.3.1. Variables of Interest

The dependent variable, VKT, has a mean value of 212070.5. This means that, on average, all inhabitants together cover 212070.5 million passenger-kilometers by car annually. The mean is based on the 25 EU-countries in the sample between 1995 and 2018. Moreover, the standard deviation exceeds the mean, with a value of 294790.1 million passenger-kilometers. This indicates that values in the sample differ substantially. However, this can be explained by the fact that the values are not controlling for population size. Consequently, the minimum and maximum value of the sample are 1606 (Latvia, 1996) and 1027745 (Germany, 2016) million passenger-kilometers, respectively.

GDP per capita is the first independent variable. The mean value of the 25 EU-countries over 24 years is $25400.95. Contrary to VKT, GDP per capita is controlling for population. The result is a much smaller dispersion of values with the mean more than twice the size of the standard deviation ($11094.38). The minimum and maximum value of GDP per capita are $5419.91 (Romania, 1995) and

$53746.80 (Sweden, 2018), respectively. The unemployment rate is the second independent variable. As the value is a percentage, the sample ultimately ranges from 0 to 100%. The mean value of the sample is 9.01% and only includes individuals in the working age, who are actively searching for a job. Again, the standard deviation is less than half the value of the mean (3.88%). The lowest and highest[3] unemployment rates recorded in the sample are 2.27% (Czech Republic, 2018) and 26.12% (Spain, 2013), respectively. The oil price is the remaining independent variable. Whereas the variable barely shows between-variation (between countries), the variable shows substantial within-variation (over the years). The complete distribution is also visible in Figure 2. The mean value of the crude oil import price is $56.70 per barrel. The standard deviation, mostly created by the within-variation, is $32.27 per barrel. The lowest and highest crude oil import prices are $11.66 and $113.49 per barrel, respectively.

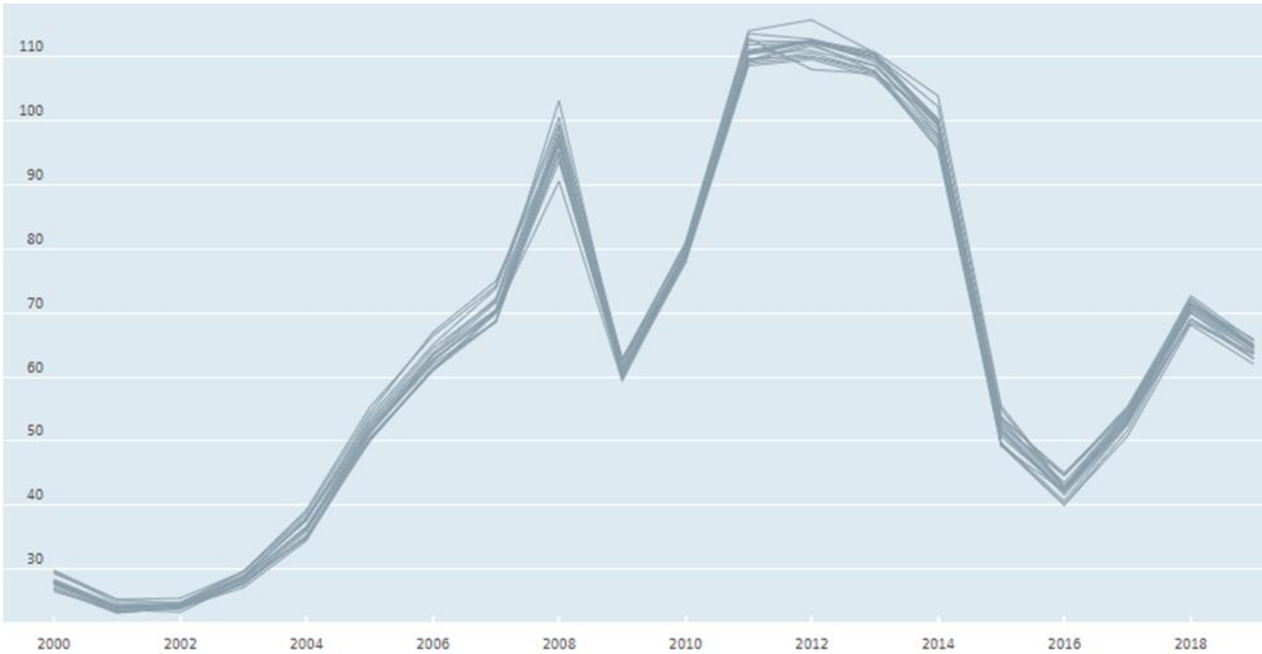

Figure 2*: Crude Oil Import Prices (in USD/barrel) for the 28 EU-countries. Source: OECD, 2020a.*

4.3.2. Control Variables

The descriptive statistics of the control variables are given in the table below.

Variable	Interpretation	Mean	Standard Deviation	Minimum	Maximum
Population	In Millions	21.772	24.161	0.435	82.657
Infrastructure investment	Annual amount in EUR	$2.67x10^9$	$3.69x10^9$	1,000,000	$1.45x10^{10}$
Vehicle tax	as % of GDP	0.514	0.432	0	2.273

[3] Greece recorded a higher unemployment rate in 2013 (27.47%), but this observation is excluded from the sample due to lacking VKT data.

Export share	as % of GDP	46.841	19.497	14.287	96.216
Education spending	Absolute amount in EUR	11,633.18	5,410.901	306.101	26,320.05

***Figure 3**: Descriptive Statistics of the Control Variables*

4.3.3. Scatterplot

In the figure below, the scatterplot between VKT and GDP per capita is displayed. A few features of the scatterplot stand out in particular. First of all, the positive relationship between VKT (vertical axis) and GDP per capita (horizontal axis). The relationship is positive since the line of fitted values is upward sloping. If this relationship turns out to be statistically significant, one of the three independent variables in the models already seems to be in line with the existing literature on this topic. Moreover, the sample broadly seems to be divided into two subgroups. These are the major VKT countries (VKT > 500,000 million passenger kilometers) and the minor VKT countries (VKT < 500,000 million passenger kilometers). The major VKT country subgroup includes France, Germany, Great Britain and Italy. The minor VKT country subgroup includes the remaining countries in the sample. To find out whether the traffic volume size affects the relationship, will be tested in hypothesis 3b.

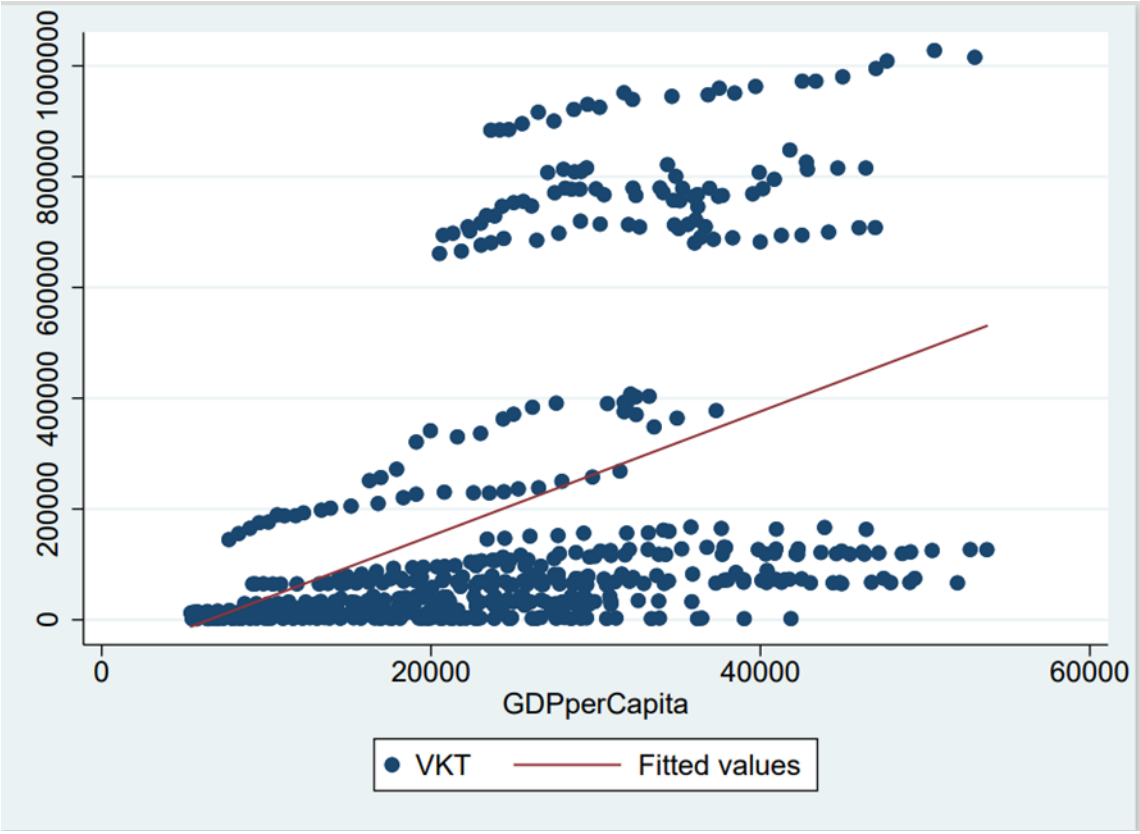

***Figure 4**: Scatterplot*

4.3.4. Correlations

As the correlations between the independent and control variables cannot be too high in order to present accurate regression estimates, a correlation matrix is included below. Most variables only show little correlation between each other. However, two of the control variable correlations almost exceed the rule of thumb of 0.900. These are GDP per capita with education spending (IV), with a correlation of 0.875, and population with infrastructure investment, with a correlation of 0.894. This could indicate that there is a form of multicollinearity between GDP per capita and tertiary education spending and between population and infrastructure investments. The first high correlation is between an independent variable and a potential instrument. In other words, both variables will not be used together in the same regression. In the IV-analysis, tertiary education spending will replace GDP per capita. Moreover, one of the restrictions of a potential instrument is the relevance criterium:

$$Cov\ (Education\ Spending,\ GDP\ per\ Capita) \neq 0$$

This implies that the correlation between both variables is not allowed to be equal to zero. The second high correlation is between two control variables. As long as the correlations of these two variables with the independent variables are all low, multicollinearity will not have major consequences for the accuracy of the estimates (Allison, 2012). Moreover, since in most models both log as level variables are included, the magnitude of the coefficients already cannot be interpreted. Besides the ones mentioned, the remaining correlations all seem fine. The figure with the correlation matrix is shown below.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) GDPperCapita	1.000							
(2) Unemploymentrate	-0.287	1.000						
(3) Oilprice	0.450	0.040	1.000					
(4) Population	0.188	0.101	0.109	1.000				
(5) Infrainvestment	0.221	0.017	0.107	0.894	1.000			
(6) Vehicletax	0.315	-0.353	-0.181	-0.279	-0.270	1.000		
(7) Exportshare	0.021	-0.130	0.248	-0.563	-0.531	-0.106	1.000	
(8) Educationspend~g	0.875	-0.272	0.336	0.109	0.165	0.295	-0.044	1.000

Figure 5*: Matrix of Correlations*

5. Methodology

The fifth section of this paper describes the statistical methods used in this research. First, the standard model will be explained. Afterwards will be elaborated on the Resilience Indices and heterogeneity issues. Finally, the instrumental variable analysis will be explained further.

5.1. The standard model

As stated above, the data in the first models is in panel structure. The regression method that is applied in the three hypotheses is ordinary least squares (OLS). Logically, the regression models cannot control for all factors influencing VKT. This is translated in a larger error term in the regression models. To reduce this noise, a fixed effects approach is included in the regression. A fixed effects model controls for factors influencing VKT but that do not change (much) over time. This approach is of major importance for data in panel structure as such factors cannot be included in the regression, but might explain some of the between (country) variation. Examples of factors that explain VKT but that do not change (much) over time are most geographical factors, such as population density and average distance to work and transportation hubs. These factors are not likely to fluctuate much as they (residents, firms and (air)ports) are settled at a particular location. These parameters might not contribute much to within variation (same country but in different years) of VKT, but could explain much of the between variation (between countries). Factors such as population density and average distance to work and transportation hubs namely are likely to explain why one country records more VKT annually than another country. If countries are more densely populated, this could indicate that average commuting distances decreases, as firms are likely to settle near where people live. Similarly, if the average distance to transportation hubs (i.e. (air)ports and train stations) is smaller, this might imply that road transportation is also shorter.

The standard regression model is the following:

$$VKT_{it} = \beta_0 + \lambda_i + \beta_1 GDPperCapita_{it} + \beta_2 Unemployment_{it} + \beta_3 Oilprice_{it} + \beta_4 (Population)_{it} + \beta_5 Infrainvestment_{it} + \beta_6 log(Vehicletax)_{it} + \mathcal{E}_{it}$$

The λ_i in the regression model indicates the size of the fixed effects. As these effects do not change over time, the subscript of the lambda only shows the $_i$, and not $_{it}$.

5.2. Resilience Index

To find out whether the degree of resilience of an economy affects the relationship between traffic volume and economic activity, a resilience index is established. The index measures individual country performances during and after the economic downturn. Due to a lack of data, only the Great Recession of the late 2000s could be researched. As mentioned above, the resilience index is based upon three measures: the change in GDP per capita, unemployment and export volume. In the general resilience index, all three measures have the same weight and thus are equally important (33.33%). For sensitivity of the results, a second resilience index is created with different weights. In the robustness model, the change in GDP per capita and unemployment weigh for both 40%, while the change in export volume accounts for the remaining 20%. For this distribution is chosen, since the existing literature on economic resilience focuses mainly on the first two factors, and to a lesser extent on export volume. The years measured are 2009 and 2012. For most European countries, 2009 was the year that the Great Recession reached its lowest point. In 2012, on the other hand, most of the European countries were recording economic growth again, with some countries recovering stronger than others. The definition of economic resilience chosen in this paper, “to recover quickly from a shock”, indicates that economic resilience measures how well countries recovered from a shock. If a year before the Great Recession was chosen instead, the index might not be able to distinguish between countries that did and did not get hit by the economic recession. For this reason, the years 2009 and 2012 has been chosen.

Data on GDP per capita and export volume are both measured in actual units. Therefore, the percentual change between 2009 and 2012 is calculated and ranked from largest positive change to largest negative change. The best performing country scores 25 points, the worst performing country scores 1 point. Since the unemployment rate already is a percentual score, the actual change between 2009 and 2012 is calculated. Again, the country that scores best (sharpest decline in unemployment) receives 25 points, while the country that scores worst receives only 1 point. The accumulated score of the three indicators together gives a final ranking. The upper half of the list are considered to be economically ‘resilient’. Similarly, the lower half of the list are economically ‘not resilient’. The general resilience index is visible in Figure 6.

Rank	Country	Resilience Score	Classification
1	Estonia	73	Resilient
2	Latvia	69	Resilient
2	Lithuania	69	Resilient
4	Germany	55	Resilient
5	Slovakia	54	Resilient
6	Belgium	50	Resilient
7	Hungary	46	Resilient
8	Czech Republic	45	Resilient
9	Malta	43	Resilient
10	Poland	42	Resilient
11	Romania	41	Resilient
12	The Netherlands	40	Resilient
12	Sweden	40	Resilient
14	Denmark	37	Not Resilient
15	Finland	35	Not Resilient
16	Great Britain	34	Not Resilient
17	France	32	Not Resilient
17	Slovenia	32	Not Resilient
19	Bulgaria	28	Not Resilient

20	Portugal	25	Not Resilient
21	Italy	23	Not Resilient
22	Spain	19	Not Resilient
23	Greece	17	Not Resilient
24	Cyprus	15	Not Resilient
25	Croatia	11	Not Resilient

Standard Resilience Index (relative weights: each component 33.33%)

***Figure 6**: The General Resilience Index*

The outcome of the resilience index indicates that the Baltic states performed best. What also stands out is the large share of CEE countries with a resilient economy (8 out of 13). Among the not resilient economies are most Mediterranean countries, which can be explained by the fact that these countries got hit relatively hard during the Great Recession. Comparing these results with the vulnerability index from Briguglio et al. (2006), four out of the five European countries in the category 'self-made' are also resilient in the index above. Estonia, Latvia, Lithuania and Malta therefore succeeded to become economically resilient despite their economic vulnerability. Similarly, the two European countries that in the vulnerability index are 'worst case' (Cyprus and Croatia) also are the stragglers in the general resilience index. Moreover, some countries which are 'best case', are not resilient in this index. This is logically the consequence as a vast majority of the countries in the sample are in the category 'best case'.

The model for robustness broadly shows similar results, except of two borderline countries. The Netherlands swapped qualifications with Finland, which makes the Netherlands and Finland not resilient and resilient, respectively. This is the case since the Netherlands scores very well on export balance recovery, while Finland performs well on tackling unemployment. Since changes in country qualifications between both weights barely appeared, the arbitrariness of the resilience qualification threshold (till position 13) is limited. The sensitivity test, with different weights, and the scores of the individual components are visible in the Appendix (A1 and A2).

5.3. Economic Development and Traffic Volume Heterogeneity

In the literature review it is argued that there might be heterogeneity between counties in different stages of economic development when it comes to economic growth. To test whether this is the case and if this heterogeneity affects the relationship between traffic volume and economic activity will be tested in the third hypothesis. In the third model, a dummy variable is included which indicates that a country is economically transitioning. The threshold will be 75% of GDP per capita mean in 2007, which is the median year of the sample. In other words, if an observation has a GDP per capita lower than $20,923.2375, the dummy variable will hold the value "1", indicating that the country is considered economically transitioning in that particular year. Similarly, if an observation has a higher per capita GDP than this threshold, the value of the dummy variable will hold the value "0", indicating that the country is considered economically developed in that particular year. The threshold of 75% is chosen as the European Commission used a similar threshold to account for GDP growth heterogeneity (2016).

Moreover, as visible in the scatterplot, four countries in the data set have a substantially higher level of VKT, compared to the remaining countries in the data set. These countries are France, Germany, Great Britain and Italy. This could indicate that there is a form of traffic volume heterogeneity present. Therefore, the sample will again be divided into two subgroups, which will be regressed separately. The threshold for the group of large traffic volume countries is at 500,000 million passenger kilometers.

5.4. Instrumental Variable Analysis

To test for causality and improve robustness, an instrumental variable (IV) will be included in the model, using a Two-Stage Least Squares-model (2SLS). An IV can only be related to VKT through the independent variables, and cannot be directly related to VKT. An example of a potential IV is tertiary education spending. Countries that spend on average relatively much on tertiary education are assumed to have a more well-educated population. Better education will, on its turn, increase GDP per capita, as human capital is increased and the country becomes more attractive for foreign firms looking for productive labor forces. Besides GDP per capita, tertiary education could also reduce unemployment levels, as there is generally high demand for skilled employees among firms. Tertiary education spending thus could influence both GDP per capita and unemployment rates. Moreover, tertiary education spending will not affect VKT directly, as traffic congestion is a worldwide phenomenon and not limited to developed nor transition countries. Tertiary education spending therefore has the potential to be a suitable IV for the first two independent variables. Santos and Vieira (2012) already used the share of individuals engaging in tertiary education in their research as an IV. Since the per capita spending on tertiary education is a relatively similar indicator, this could justify the use of tertiary education spending as an IV in this research. In section 6.4., an IV analysis with tertiary education spending will be tested.

Concerning the independent variable oil price, a suitable IV could not be found. This is due to the lack of available data on oil-related variables. Dées et al. (2008) broadly define four causes of oil price change, namely demand, supply, extreme events and future oil market conditions. Among these factors, demand and extreme events are researched in this paper. Data on the remaining two indicators, supply and future market conditions, could not be found.

6. Results

In this section the outcomes of the regression analyses will be described, by means of the three hypotheses. The first hypothesis focuses on the general relationship between economic activity and traffic volume. The standard regression model is visible in section 5.1. Moreover, the second hypothesis researches the same relationship, but specifies on the role that economic resilience plays in this relation. The third and last hypothesis tests for potential heterogeneity between countries on both economic development and traffic volume. And finally, to test for causality and improve robustness, an instrumental variable analysis is included.

6.1. The standard model

	(1)
VARIABLES	VKT
GDPperCapita	1.079***
	(0.264)
Unemploymentrate	-3,297***
	(556.2)
Oilprice	-116.7**
	(51.55)
Population	5,413***
	(1,038)
Infrainvestment	1.94e-06**
	(9.35e-07)
log_Vehicletax	-18,785***
	(6,069)
Constant	146,127***
	(28,071)
Observations	286
Number of countrynum	16
R-squared	0.416

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 7: *Standard Model Results (H1)*

The outcome of the standard panel data regression with fixed effects is reported above. Other standard regression models are visible in A3 in the Appendix. Regarding the first hypothesis, both regular variables and logarithms of variables are included, which means that only the sign and significance of the variable can be interpreted, and not only the magnitude of the coefficient. The first independent variable, GDP per capita, is positive and significant at a 1% level (p-value = 0.000). This is in line with the assumption that economic activity and traffic volume are positively related. During recessions, when GDP per capita decreases, traffic volumes therefore also decreases, as the sign of the coefficient is positively related to VKT. The second independent variable, the unemployment rate, is negative and significant at a 1% level (p-value = 0.000). As unemployment levels generally rise in times of economic downturn, this outcome is also in line with scientific literature. For example, if less individuals are employed, less commuting is required and hence, VKT should decrease. The remaining independent variable and last indicator of economic activity, the oil price, is negative and significant at a 5% level (p-value 0.024). Again, this is in line with the existing body of economic literature. As mentioned in the literature review, spiking oil prices have recently proven to be good indicators of economic recessions. This implies that oil prices should rise in case of economic contraction. Hence, the oil price should be negatively related to VKT, which is the case in this regression model.

Concerning the controls, adding some variables is inevitable in order to create reliable estimates. An example is population, as VKT must rise when population increases. In line with this assumption, the population variable is positive and significant at a 1% level (p-value 0.000). Moreover, the height of infrastructure investments is positive and significant at a 5% level (p-value 0.039). This indicates that an increase in infrastructure spending (i.e. road expansion) contributes to more road usage. Finally, the height of a nations' vehicle tax (as % of GDP) is negative and significant at a 1% level (p-value 0.002). If vehicle tax revenues are relatively higher, car usage becomes relatively more expensive. This might discourage individuals to use their car or purchase one and hence, reduce VKT.

Thus, besides the factors proxying economic activity, with the original relation of interest remaining robust, the parameters population, infrastructure investment and vehicle taxes also affect VKT. The regression output is visible in A3 in the Appendix.

6.2. Resilience Index

The second hypothesis holds that all variables included are logarithms, which means that interpretation of the size of the coefficient is possible. The outcome of the panel data regression with fixed effects, separated on economic resilience, is visible in the figure below.

First, the countries that are economically "not resilient". GDP per capita is positive and significant at a 5% level (p-value 0.040), with a coefficient of 0.118. This indicates that if GDP per capita rises with 1%, VKT on average rises with 0.118%, ceteris paribus. Moreover, the unemployment rate is negative and significant at a 1% level (p-value 0.000), with a coefficient of -0.114. This suggests that if the unemployment rate rises with 1%, VKT will on average decrease with 0.114%, everything else held constant. The oil price is negative and significant at a 5% level (p-value 0.041), with a coefficient of -0.024%. Hence, if the oil price rises with 1%, VKT will on average reduce with 0.024%, ceteris paribus.

VARIABLES	(1) log_VKT	(2) log_VKT
log_GDPperCapita	0.118**	-0.139***
	(0.0570)	(0.0414)
log_Unemploymentrate	-0.114***	-0.113***
	(0.0226)	(0.0185)
log_Oilprice	-0.0235**	0.0208*
	(0.0114)	(0.0117)
log_Population	0.862***	1.752***
	(0.262)	(0.209)
log_Infrainvestment	0.0317**	-0.0127
	(0.0145)	(0.0131)
log_Vehicletax	-0.0898***	-0.0766***
	(0.0340)	(0.0196)
log_Exportshare	-0.0679	0.137**
	(0.0555)	(0.0566)
Constant	8.306***	8.384***
	(0.626)	(0.553)
Observations	155	131
R-squared	0.621	0.592
Number of countrynum	8	8

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

(1) = 'not resilient'

(2) = 'resilient'

Figure 8*: Resilience Index Regression Results (H2)*

Regarding the control variables, the population size is positive and significant at a 1% level (p-value 0.001), with a coefficient of 0.862. This means that if the population of a country rises with 1%, VKT will increase with 0.862%, ceteris paribus. Moreover, total infrastructure investments are positive and significant at a 5% level (p-value 0.030), with a coefficient of 0.032. Thus, if total infrastructure investments rise with 1%, VKT is estimated to increase with 0.032%. A more elaborated road network leads to an improved accessibility. This seems to convince individuals to take the car. The size of vehicle tax revenue, as a percentage of GDP, is negative and significant at a 1% level (p-value 0.009), with a coefficient of -0.090. Hence, if the vehicle tax revenue rises with 1%, VKT will decrease with 0.090%, all else being equal. Namely, if taxes related to driving become relatively more expensive, this might discourage individuals to take the car and therefore reduce VKT. And finally, the total value of exports as percentage of GDP. The export share is insignificant in this model (p-value 0.223). This implies that countries that have economies dependent on export do not necessarily record higher traffic volumes, compared to countries that are less export oriented.

Second, the countries that are economically "resilient" are being researched. Two outcomes stand out, namely the sign of GDP per capita and the sign of the oil price. GDP per capita is negative and significant at a 1% level (p-value 0.001), with a coefficient of -0.139. This means that if GDP per capita increases with 1%, VKT will decrease with 0.139%, ceteris paribus. Since the category "resilient" includes mainly sound economies with a relatively high growth rate, this result might indicate that car usage changes as countries enter a different stage of economic growth. An example of such a theory is the Environmental Kuznets Curve (EKC) from Kuznets (1955). The EKC describes that emissions per capita decrease at a certain point of economic development, because of innovation and the financial capacity of tackling climate change. These developments might contribute to the discouragement of car usage. The positive sign of the oil price coefficient could be due to a high demand for oil. A high demand for oil could be caused by a high demand for car travel. As mentioned in section two, transport is a derived demand, which for example means that longer average commuting distances are translated in both a higher demand (price) for oil and more VKT.

Concerning the remaining parameters, the unemployment rate is negative and significant at a 1% level (p-value 0.000), with a coefficient of -0.113. Hence, this outcome is practically the same for both resilient and non-resilient countries. Moreover, the population coefficient is again positive and significant at a 1% level (p-value 0.000), but the size of the coefficient is about twice as large: 1.752. This indicates that a 1% increase in population will lead to a 1.752% increase in VKT, ceteris paribus. Contrary to the non-resilient country regression, the amount of infrastructure investments is insignificant in this model (p-value 0.335). At the same time, the total value of exports is positive and significant at a 5% level (p-value 0.017), whereas this parameter is insignificant in the other group. The coefficient of the total value exported is 0.137. Hence, a 1% increase in total export value, relatively to GDP, leads to a 0.137% rise in VKT, all else being equal. The positive sign of the coefficient makes sense, as exporting goods requires transportation. Following this logic, an economy that is export-dependent will therefore require much transportation facilities, which will increase VKT. Finally, the vehicle tax is again negative and significant at a 1% level (p-value 0.000), with a coefficient of -0.077. Comparing this result with the non-resilient country group, the coefficient is somewhat smaller, but this is not a noteworthy difference.

To improve the robustness of the Resilience Index, a sensitivity test is established with different weights to the three components. Concerning the non-resilient country group, not much has changed. The only major change is the significance of the variable export share. In the original model, where the export share has a weight of 33.33%, the export share is insignificant. However, in the robustness resilience model, where the export share has a weight of 20%, the export share is negative and significant at a 5% level (p-value 0.041), with a coefficient of -0.129. The significance of the export share in this model follows this logic. In the robustness model, the relative weight of export share is smaller compared to the standard resilience index. Therefore, countries that perform relatively bad on export are labeled more often as non-resilient. This explains why the sign of the coefficient is negative in this model. Similarly, if the resilient countries, with better export performances, are included into the model (the first hypothesis), the sign of the export share coefficient turns positive.

Concerning the group of countries that are considered ‘resilient’ in the robustness model, the most important change is the significance of the oil price variable. In this model, the oil price is positive and significant at a 1% level (p-value 0.005), compared to the significance at a 10% level (p-value 0.079) in the standard model. Moreover, the export share variable is not significant anymore in this model. The full robustness model results are visible in A4 in the Appendix.

Overall, the model with the Resilience Index is robust, as the produced regression results are to a large extent similar to the regression results of the Robust Resilience Index model.

6.3. Other forms of Heterogeneity

6.3.1. Economic Development Heterogeneity

In the third hypothesis, the sample is divided once again into two groups. These are countries that are economically transitioning (GDP < $20,923.2375) and countries that are economically developed (GDP > $20,923.2375). The model is precisely the same as in the first hypothesis, namely with both regular variables and logarithms of variables. Therefore, the magnitude of the coefficient cannot be interpreted.

First, the group of countries that are economically developed. Concerning the three independent variables, GDP per capita is positive and significant at a 1% level (p-value 0.000), which does not differ from the first hypothesis. The unemployment rate is negative and significant at a 1% level (p-value 0.000), which again does not differ from the first hypothesis. The oil price variable, however, is less significant in this model. Excluding the transition countries, the oil price variable is negative and significant at a 10% level (p-value 0.083), compared to being negative and significant at a 5% level (p-value 0.024) in the standard model.

A lower level of significance occurs more frequently in the control variable outcomes, namely in the population and the infrastructure investment variables. The significance level of the population variable reduces to 5% (p-value 0.042), with the sign of the coefficient remaining positive, whereas the infrastructure investment variable turns insignificant. Finally, the vehicle tax variable remains negative and significant at a 1% level (p-value 0.001), which is comparable to the outcomes of the standard model..

Secondly, the group of countries that are considered to be economically transitioning. In the data set, 183 observations have a GDP per capita below $20.923,2375. However, due to lacking control variable values, only 38 observations are left (out of 183). By contrast, the number of observations of economically developed countries is 247 (out of 321). Therefore, the issue of lacking data is mainly a problem of transition countries and not of the developed countries. A justification of this result could be that transition countries have less financial resources available to provide accurate and complete statistics. As there are only 38 observations left in this part of the sample, the coefficient estimates become less accurate. Therefore, one should be careful in interpreting the coefficients. Concerning the independent variables, GDP per capita is insignificant in this model, which contrasts from the developed country subgroup. The unemployment rate, however, is negative and statistically significant in this model (p-value 0.033). Comparing this outcome with the developed country subgroup leads to a lower level of significance, but both negative and significant. The oil price variable is also insignificant in this model, whereas the coefficient is significant at a 10% level in the developed country subgroup. Concerning the controls, the population variable is positive and statistically significant at a 1% level (p-value 0.004). The remaining controls, infrastructure investments and vehicle tax, are statistically insignificant in this model. The lower level of significance for most of the variables in this regression model, compared to the developed country subgroup, indicates that there might be a form of heterogeneity between developed and transition countries. However, this reduction of significance could also be caused by the low number of observations. The results of hypothesis 3a are shown in the figure below.

VARIABLES	(1) VKT	(2) VKT
GDPperCapita	1.197***	2.910
	(0.269)	(1.785)
Unemploymentrate	-3,250***	-1,768**
	(673.7)	(779.1)
Oilprice	-87.75*	-440.6
	(50.47)	(300.0)
Population	2,378**	60,737***
	(1,165)	(18,903)
Infrainvestment	1.45e-06	-2.14e-06
	(9.31e-07)	(3.51e-06)
log_Vehicletax	-32,743***	-6,847
	(9,516)	(6,868)
Constant	245,207***	-1.063e+06***
	(33,102)	(361,371)
Observations	248	38
R-squared	0.342	0.715
Number of countrynum	16	10

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

(1) = Developed countries
(2) = Transition countries

Figure 9*: Economic Development Dummy Results (H3a)*

6.3.2. Traffic Volume Heterogeneity

Besides economic development heterogeneity, traffic volume heterogeneity could also be present in the models. This could be the case since France, Germany, Great Britain and Italy recorded substantially higher traffic volumes, compared to the other countries in the sample. This distinction is clearly visible in the scatterplot in the descriptive statistics section. The regression model is the same as for the economic development heterogeneity hypothesis, except that the sample is now divided into large and small traffic volume countries. As mentioned earlier, the threshold for large traffic volume countries is at 500,000 million passenger kilometers.

First, the group of countries with relatively small traffic volumes. What stands out is that two of the three variables of interest are statistically insignificant. Namely, both GDP per capita (p-value 0.393) and the oil price (p-value 0.831). The unemployment rate is negative and significant at a 1% level (p-value 0.000). Concerning the control variables, the results are more similar to the first three hypotheses. Population and infrastructure investments are both positive and significant at a 1% level (p-values 0.000). Moreover, the height of the vehicle tax, as a share of total GDP, is negative and significant at a 5% level (p-value 0.021).

Second, the group of countries which recorded relatively large traffic volumes (i.e. France, Germany, Great Britain and Italy). Contrary to the first group, the regression output of this group shows a high level of significance for the independent variables, but only insignificant control variables. GDP per capita is positive and statistically significant at a 1% level (p-value 0.000). Moreover, the unemployment rate and oil price are both negative and statistically significant at a 1% level (p-values 0.001 and 0.000, respectively).

These results indicate that there could be traffic volume heterogeneity present in the model. Regression results for both groups separately should solve this issue and give more precise estimates. The main difference between the two subgroups is that the independent variables are only significant for the group of major traffic volume countries, whereas the control variables mostly are significant for the group of minor traffic volume countries. Only the population variable is negative and statistically significant at a 10% level (p-value 0.087). The number of observations is not likely to play a role in this distinction, as both groups should have enough observations to provide decent estimates. The small traffic volume country subgroup namely has 197 observations and the large traffic volume subgroup has 88 observations. The regression output of hypothesis 3b is given in the figure below.

VARIABLES	(1) VKT	(2) VKT
GDPperCapita	-0.110	4.708***
	(0.129)	(0.744)
Unemploymentrate	-2,652***	-6,918***
	(272.3)	(1,939)
Oilprice	-5.929	-436.6***
	(27.82)	(108.7)
Population	13,452***	-3,553*
	(737.4)	(2,050)
Infrainvestment	3.68e-06***	-1.43e-06
	(7.98e-07)	(1.38e-06)
log_Vehicletax	-6,576**	-5,263
	(2,823)	(29,761)
Constant	-51,031***	963,133***
	(8,888)	(128,223)
Observations	198	88
R-squared	0.788	0.680
Number of countrynum	12	4

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

(1) = Minor traffic volume countries. (VKT < 500,000 million passenger kilometers)
(2) = Major traffic volume countries. (VKT > 500,000 million passenger kilometers)

Figure 10*: Traffic Volume Heterogeneity Results (H3b)*

6.4. Instrumental Variable Analysis

To test whether the relationships are causal or only correlations, and to improve robustness, an IV analysis is included. As mentioned in the methodology section, tertiary education spending will function as the IV in this 2SLS-model analysis.

In figure 10, the results of the IV-analyses are reported. In the first column, GDP per capita is instrumented by tertiary education spending. In the second column, the unemployment rate is instrumented by tertiary education spending.

Concerning the first model, the instrument turns out to be positive and statistically significant at a 10% level (p-value 0.097). This indicates that the significance level of the instrument has been reached, but that this relationship is not very strong. Most of the other variables stay statistically significant with the expected sign, even though the significance of the variables weakens for most. This indicates that a causal relationship is possible. However, the causality of the relationship cannot be established with complete certainty. This is due to the low level of significance of the instrument (p-value 0.097) and the reduced level of significance of the remaining variables. Therefore, the claim that this relationship is causal is most likely too difficult to prove.

Concerning the second model, with the unemployment rate being instrumented, the results are more clear. The instrument is statistically insignificant at a 10% level. Moreover, all of the remaining variables, except for the population variable, are insignificant. This indicates that tertiary education spending is most likely not a suitable instrument for the unemployment rate. The two restrictions that have to be met for an instrument to be valid are the instrument relevance and instrument exogeneity. According to figure 4, the correlation between the unemployment rate and tertiary education spending variables is non-zero. This indicates that the instrument relevance criterion holds. Therefore, it is probable that the instrument exogeneity criterion does not hold. The instrument exogeneity restriction implies that the instrument is not allowed to be correlated with the error term. If this is the case, then the restriction of instrument exogeneity is violated and the instrument is invalid.

	(1)	(2)
	2SLS	2SLS
VARIABLES	VKT	VKT
GDPperCapita	1.910*	10.71
	(1.142)	(11.13)
Unemploymentrate	-5,613***	69,966
	(1,642)	(104,786)
Oilprice	-324.8	-2,214
	(282.4)	(2,574)
Population	11,512***	8,704**
	(683.9)	(4,030)
Infrainvestment	3.18e-06	3.26e-05
	(4.32e-06)	(4.23e-05)
Vehicletax	23,676*	253,817
	(13,405)	(339,353)
Exportshare	504.9*	5,084
	(276.3)	(6,585)
Constant	-57,591	-1.287e+06
	(41,543)	(1.700e+06)
Observations	130	130
R-squared	0.958	0.156
Educationspending	yes	yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

(1) = GDP per Capita is instrumented
(2) = Unemployment rate is instrumented

Figure 10: *Instrumental Variable Analysis Results*

Another explanation for this result could be that the relationship between economic activity and traffic volume is not causal. Hence, in that case, the relationship would only be a correlation then. However, since the 2SLS-analysis with GDP per capita being instrumented provides more statistically significant results, a violation of the instrument exogeneity assumption in the second model is plausible. Therefore, the currently reported IV results do not give a clear answer to the question whether the relationship between economic activity and traffic volume is causal. Future research is needed to provide a more clear answer to this issue. In the final section, all suggestions for further research are aggregated.

7. Conclusion

The final section provides conclusions to the hypotheses and the main research question of this paper. Afterwards, the main limitations of this research and suggestions for further research are proposed. Finally, some potential policy implications of these outcomes are given.

7.1. Main Conclusions

In the first part of this research, the basic relationship between economic activity and traffic volumes has been researched. The first hypothesis read as follows: *Economic Shocks are negatively related to Traffic Volumes in European Countries.* The three variables of interest (i.e. GDP per capita, unemployment rate and the oil price) are all in line with this hypothesis. Namely, in case of economic downturns, GDP per capita decreases. Since the relationship between GDP per capita and VKT is positive and statistically significant, this indicates that VKT also decreases in times of economic downturn. The opposite relationship holds for the unemployment rate and the oil price, which both rise in case of economic downturn. As expected, both relationships with VKT are negative and statistically significant. Hence, the results of the remaining two variables of interest also confirm the first hypothesis. Therefore, the first hypothesis of this paper is accepted.

The second part focused on the extent to which economic resilience alters the relationship between economic activity and traffic volumes. The Resilience Index determined whether the European countries were characterized as either 'resilient' or 'not resilient'. Afterwards, both groups were regressed separately with a log-log model. Concerning the non-resilient country group, the results are largely similar to the results of the first hypothesis. However, this is not the case for the resilient country group. Two of the variables of interest, GDP per capita and the oil price, report opposite signs in the results. Moreover, the coefficient of the population variable is twice as large in the resilient group, compared to the non-resilient group. This indicates that resilience of an economy is not a condition for a quick recovery of the traffic volume level. This finding is not in line with the expectations from the introduction, where it was expected that economically resilient countries would record higher traffic volumes earlier in the recovery from an economic shock. As mentioned in the result section, this surprising finding could be due to the course of the EKC, where the resilient countries are in a different stage of economic growth. In this further stage, public transport is a more competitive alternative to the car, in combination with the population being more environmentally aware.

In the third part, two forms of potential heterogeneity are tested. These are economic development and traffic volume heterogeneity. Concerning economic development, the outcomes between the developed and transition countries differ substantially. On the one hand, the sample with only the developed countries has delivered results comparable to the standard relationship from hypothesis 1. On the other hand, the relationship with only the transition countries included has delivered completely different outcomes. This indicates that there is a form of economic development heterogeneity. However, the low number of observations in the sample could also be the cause of this, with less precise outcomes. Concerning traffic volume heterogeneity, the outcomes between the two subgroups again differed substantially. Namely, the variables of interest in the major traffic volume countries are as expected, whereas the variables of interest in the minor traffic volume countries are mostly statistically insignificant. Contrary to this, for the control variables the results are opposite. The minor traffic volume countries are mostly statistically significant, with expected sign, whereas the major traffic volume countries report only statistically insignificant results. Moreover, the number of observations are sufficiently large for both subgroups. Therefore, there is an indication for traffic volume heterogeneity in the relationship.

The final part of the results consists of the IV-analyses, using the 2SLS regression method. Firstly, GDP per capita is instrumented by tertiary education spending. Most of the variables are statistically significant, which means that there is an indication of a causal relationship. However, due to the reduced level of significance of the regression estimates, causality cannot be proven with full certainty. In the second part of the IV-analyses, the unemployment rate is instrumented by tertiary education spending. The 2SLS-approach delivered mostly statistically insignificant variables, including the instrument. There is indication that this outcome is caused by a violation of the instrument exogeneity assumption. However, it could also be the case that the current relationship is only a correlation.

To summarize, the main research question of this paper read as follows: *To what extent do economic shocks affect traffic volumes in European countries, and can resilience alter this effect?* This research found that economic activity is positively related with traffic volumes, and that there is an indication that this relationship is causal. However, causality of the relationship cannot be claimed with full certainty, since the statistical significance of the IV-analysis is low. Moreover, it could be the case that the instrument exogeneity assumption is violated, which would make the IV-estimates invalid. Further research is necessary to find more evidence for causality of the relationship. Concerning the economic resilience section, there is no evidence that resilience is mitigating this effect. This research found even an opposite effect, potentially due to the course of the EKC, as written by Kuznets (1955). Moreover, this paper found evidence for economic development and traffic volume heterogeneity. Mainly the transition countries with minor traffic volume levels behaved differently than expected. Conversely, in the major developed countries the relationship was more in line with economic literature. This finding confirms the recent critiques that economic literature has been too Western-centric and asks for more culturally dispersed economic literature.

7.2. Limitations and Suggestions

Concerning the data, a limitation of this research is the many missing observations, which substantially reduced the sample size and interrupted some individual time series. A reduced accuracy of the regression estimates could be the consequence. If data in the near future is more complete, this could lead to more accurate results. Moreover, two of the correlations between control variables approach the threshold of 0.900. The threshold might not be reached, but since these correlations are still very high, this asks for caution when interpreting the results. A potential issue with high correlations is the increased chance of multicollinearity which would make the regression results invalid. This should be taken into account when interpreting the regression results.

Furthermore, the Resilience Index (in Methodology Section) is only based upon one recession. Due to a lack of data, older recessions cannot be included. However, every economic recession has a different origin and will therefore always harm some countries more than others. Including more recession into the Resilience Index could have changed the division between resilient and non-resilient countries. For example, the current economic recession caused by the COVID-19 pandemic is another type of recession origin. In the spring of 2020, Italy, France and Spain were hit relatively hard in terms of infections. This is also the reason why these countries were economically hit the hardest in Europe. Therefore, because of the uniqueness of each economic recession, it would be wise to include multiple recessions in the Resilience Index. Hence, including the economic recession following the COVID-19 pandemic to the Index is a suggestion for future research.

A potential endogeneity problem could be the lack of data on total vehicles on the road. This is likely to have an influence on VKT, but no available data on this has been found. Population is mostly proxying for the total number of vehicles, but this variable is obviously not exactly similar. Nanaki (2018), for example, used annual car sales data in order to control for this. Since annual car sales data is not available either, the claims made by Nanaki could not be tested in this paper. The absence of this data could be the source for an omitted variable bias in the current relationship. Future research could include more accurate control variables to replace the total number of vehicles in order to improve the currently established relationship. Moreover, Nanaki (2018) mentioned that economic activity increases personal income and that personal income on its turn increases car sales. Having access to the appropriate data could therefore also help with finding the existing indirect relationships.

As mentioned in the Result section, another potential issue could be the small sample size of the transition country subgroup with only 38 observations. Again, lacking data observations is the cause of this potential issue. Since the regression results of the transition country subgroup differ substantially from the developed country subgroup, this asks for caution in interpreting the results. A few outliers could namely have a major impact on the regression estimates. A suggestion for future research will be to have a more complete data set, as this will mitigate the issue.

Finally, future research could delve deeper into the question whether the currently established relationship between economic activity and traffic volume is a causal relationship. On the one hand, with GDP per capita being instrumented, the instrument is statistically significant, indicating a potential causal relationship. On the other hand, with the unemployment rate being instrumented, there is no indication of a causal relationship. However, this could also be due to a potential violation of the instrument exogeneity assumption. Future research could for example find a more suitable instrument that could provide a more clear answer.

7.3. Policy Implications

For policy implications, the question whether the established relationship is causal is of major importance. Assuming that the relationship between economic activity and traffic volume is a causal relationship, the policy implications are the following. As there is a positive relationship between economic activity and traffic volume, governments should use the recessions to bring forward infrastructural plans in order to minimize the negative externalities of constructing or repairing roads. In the non-resilient countries, congestion will keep returning to levels prior to the recession in the upcoming decades. As recovery from an economic shock will generally take longer for non-resilient countries, compared to resilient countries, this gives the governments some extra time to catch up with infrastructure projects. For the resilient countries, governments should ask themselves whether investing in infrastructure expansion is really necessary and whether it is not better for them to only catch up with infrastructure repairing projects. Since these countries are in a different stage of economic growth, as described in the EKC, the population is likely to become more environmentally aware and may choose for greener transportation alternatives. A change in the national opinion towards transport pollution could make infrastructural expansion plans in the near future redundant.

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Appendices

***A1**: Robustness Resilience Index*

Rank	Country	Resilience Score	Classification
1	Estonia	73.2	Resilient
2	Latvia	69.6	Resilient
3	Lithuania	67.8	Resilient
4	Germany	58.2	Resilient
5	Slovakia	51	Resilient
6	Belgium	49.8	Resilient
7	Malta	48.6	Resilient
8	Sweden	46.2	Resilient
9	Romania	45.6	Resilient
10	Hungary	44.4	Resilient
11	Poland	43.8	Resilient
12	Czech Republic	41.4	Resilient
13	Finland	39.6	Resilient
14	Denmark	37.2	Not Resilient
15	Great Britain	36.6	Not Resilient
16	The Netherlands	36	Not Resilient
17	France	33.6	Not Resilient
18	Bulgaria	32.4	Not Resilient
19	Slovenia	27	Not Resilient
20	Italy	21.6	Not Resilient
21	Portugal	20.4	Not Resilient
22	Spain	14.4	Not Resilient
23	Croatia	12.6	Not Resilient
23	Cyprus	12.6	Not Resilient
25	Greece	11.4	Not Resilient

Sensitivity test (relative weights: GDP per capita and Unemployment - 40%; Export balance - 20%)

***A2**: Individual Component Ranking*

Rank	ΔGDP per Capita	ΔUnemployment	ΔExport
1	Lithuania	Estonia	Lithuania
2	Estonia	Latvia	Estonia
3	Latvia	Germany	Slovakia
4	Poland	Malta	Latvia
5	Slovakia	Finland	Czech Republic
6	Bulgaria	Sweden	The Netherlands
7	Germany	Lithuania	Slovenia
8	Romania	Belgium	Hungary
9	Sweden	Romania	Belgium
10	Malta	Czech Republic	Portugal
11	Belgium	Great Britain	Greece
12	Hungary	Hungary	Spain
13	Denmark	France	Germany
14	Great Britain	Denmark	Denmark
15	France	The Netherlands	Poland
16	Finland	Slovakia	Italy
17	The Netherlands	Poland	Cyprus
18	Czech Republic	Italy	France
19	Croatia	Slovenia	Great Britain
20	Slovenia	Bulgaria	Romania
21	Italy	Portugal	Malta
22	Portugal	Cyprus	Finland
23	Spain	Croatia	Sweden
24	Cyprus	Spain	Bulgaria
25	Greece	Greece	Croatia

Rankings per subject

A3: Other Standard Model Results (H1)

VARIABLES	(1) VKT	(2) VKT	(3) VKT
GDPperCapita	1.043***	1.053***	1.053***
	(0.301)	(0.297)	(0.297)
Unemploymentrate	-2,967***		
	(570.1)		
Oilprice	-112.5**	-112.0**	-112.0**
	(53.05)	(52.71)	(52.71)
log_Population	176,392***	161,786***	161,786***
	(51,956)	(50,713)	(50,713)
Infrainvestment	2.27e-06**	2.42e-06**	2.42e-06**
	(9.58e-07)	(9.38e-07)	(9.38e-07)
log_Vehicletax	-18,174***	-16,180***	-16,180***
	(6,305)	(6,123)	(6,123)
log_Unemploymentrate		-29,954***	-29,954***
		(5,464)	(5,464)
Constant	-206,018	-126,071	-126,071
	(144,835)	(140,428)	(140,428)
Observations	286	286	286
R-squared	0.383	0.389	0.389
Number of countrynum	16	16	16

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

***A4**: Robustness Resilience Index Results (H2)*

VARIABLES	(1) log_VKT	(2) log_VKT
log_GDPperCapita	0.160**	-0.0968***
	(0.0641)	(0.0370)
log_Unemploymentrate	-0.0839***	-0.137***
	(0.0226)	(0.0185)
log_Oilprice	-0.0313**	0.0317***
	(0.0122)	(0.0110)
log_Population	0.839***	1.619***
	(0.271)	(0.205)
log_Infrainvestment	0.0362**	-0.0149
	(0.0145)	(0.0133)
log_Vehicletax	-0.0799**	-0.0786***
	(0.0360)	(0.0192)
log_Exportshare	-0.129**	0.0534
	(0.0627)	(0.0477)
Constant	8.009***	8.843***
	(0.672)	(0.513)
Observations	145	141
R-squared	0.585	0.628
Number of countrynum	8	8

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

(1) = ‘not resilient’

(2) = ‘resilient’