UNIVERSITY OF TRENTO

Doctoral School of Social Sciences

Doctoral programme in Economics and Management

Assessing the potential effects of the Brenner Basis Tunnel Opening: socio-economics changes and possible behavioural interventions

a dissertation submitted in partial fulfillment of the requirements for the Doctoral degree (Ph.D.) doctoral programme in Economics and Management

Giorgio
Lombardi
Academic Year 2021/2022

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The aim of this thesis is to analyse the potential effects of the planned Brenner Pass opening in 2028. The thesis is divided into 3 studies: in the first, we will provide a methodological description of possible approaches to be used in this type of analysis. In the second, we will propose an experiment to understand if it is possible to exploit the default effect to induce a modal shift towards the most sustainable means of transportation: the train. In the third study, we will conduct a simulation by applying the model constructed by Monte et al in 2018. The simulation results demonstrate that the opening of the Brenner Base Tunnel will lead to an increase in welfare in the Trentino-Alto Adige region (+0.2%), along with other socio-economic changes such as increased commuting and housing costs. The results of the second study highlight the potential of a simple policy based on the default effect, pushing over half (54%) of the participants to repeatedly choose the most sustainable option.

Keywords: Logistics, modal shift, spatial economics, experimental economics, default effect, green economy.

Summary

Introduction 6
References: 9
Infrastructure development and economic growth: a methodological review 10
1. Introduction 10
2. Reduced form model 11
A. Generalised Method of Moments (GMM) 12
B. Instrumental variable (IV regression) 13
B.1. Planned Route IV 16
B.2. Historical Route IV 17
B.3. Inconsequential Units Approach 19
3. General equilibrium approach 21
A. Quantitative spatial model: assumptions, building block and selection criteria 22
A.1 Assumptions 22
A.2 Endowments 24
A.3 Equilibrium 24
A.4 Selection criteria 25
B. From reduced form to general equilibrium 27
4. Discussion 28
A. Reduced form vs General equilibrium 28
B. Reallocation vs growth 29
C. Well-targeting 30
5. Conclusions and future developments 31
References 33
Modal shift to sustainable import-export: Nudging through the default effect 35
Abstract 35
1. Introduction 35
2. Literature review: 36
2.1 Default effect: 36
2.2 Green economy and default effect: 37
2.3 Default effect and ethical features 37
2.4 Default effect and repeated choices. 38
3. Material and methods 38
3.1 Research questions: 38
3.2 The experiment 39
3.3 The treatment 42

3.4 The sample 43
3.5 The questionnaire 44
4. Analysis 44
4.1 Logit regression 44
Robustness test 54
4.2 Additional analysis 55
5. Conclusion and future developments 56
References: 59
Appendix I 60
Appendix II 62
The potential impact of Brenner Basis Tunnel: an empirical simulation 63
Abstract 63
1. Introduction 63
2. The model 66
2.1 Preferences and endowment 66
2.2 Production 68
2.3 Goods Trade 69
2.4 Labor mobility and commuting 70
2.5 General equilibrium 72
3. Dataset 74
3.1 Trade (Bilateral trade, import/export): 75
3.2 Commuting: 76
3.3 Employment: 76
3.4 Wage: 77
3.5 Income: 77
3.6 Land: 77
4. Results 78
5. Conclusion and future development 81
Appendix I: Results 83
Appendix II: Data sources 86
Appendix III: Data 87
References 90
Conclusions and future developments 92

Introduction

In 2028, the Brenner Basis Tunnel (BBT), also known as the Brenner Base Tunnel, is set to be inaugurated, providing a direct high-speed rail connection between the cities of Innsbruck and Bolzano. The entire rail line will seamlessly integrate with existing routes, ultimately linking Munich in Germany with Verona in Italy. With a project cost of 8.54 billion euros as of January 1st, 2023, the BBT is anticipated to wield significant impacts not only on local economies but also on a national scale.

The primary purpose of the BBT is to facilitate efficient freight transportation, offering the unique capability of loading trucks directly onto trains, thereby enhancing trade opportunities. However, the tunnel will also be open to passenger trains, underscoring its potential for broader societal implications beyond purely economic considerations. Indeed, the expected reductions in travel times will greatly benefit commuters, particularly for those travelling between Bolzano and Innsbruck. The current two-hour and fifteen-minute journey will be significantly shortened to a mere 44 minutes, promising enhanced accessibility and connectivity between these two cities.

Beyond the immediate benefits of streamlined transportation and improved trade prospects, the BBT is poised to exert far-reaching effects on both the local and national levels. As it fosters greater economic integration and connectivity, the tunnel is expected to influence patterns of urban development, investment, and job creation in the regions it serves. The ensuing economic growth and increased opportunities may spur population movements and social transformations, as individuals and businesses capitalize on the newfound connectivity and accessibility provided by the BBT.

Moreover, the enhanced transportation options are likely to foster cultural exchange and collaboration between the regions along the BBT route. Facilitated travel will facilitate greater interaction and knowledge-sharing among communities, creating opportunities for cross-border collaborations, research partnerships, and joint initiatives.

As a major infrastructure project with wide-ranging implications, the BBT represents a significant milestone in Europe's transportation landscape. Its successful implementation is eagerly anticipated, and the subsequent impacts on trade, employment, urban development, and social dynamics are poised to shape the economic and social landscapes of the connected regions and nations.

This thesis aims to estimate all the effects generated by this event, both direct and indirect.

The first paper proposed is a comprehensive methodological review that draws from recent literature on the subject of infrastructure development and its impact on economic growth. This study is the culmination of our thorough investigation to identify the most appropriate model for analysing the specific event under consideration. The review delves into two distinct approaches: the reduced-form model and the general equilibrium model, elucidating their respective merits and limitations. To illustrate the various techniques developed over the years, the paper presents examples from the literature, showcasing the evolution of research in this domain.

Moreover, the paper embarks on the exploration of two persistently debated issues in this field: reallocation versus growth and misallocation of infrastructure. These two questions have remained open in the literature, warranting further investigation and analysis to better comprehend their implications on economic outcomes. The researcher aims to shed light on these complex matters, seeking to contribute new insights to the existing body of knowledge in the realm of infrastructure development and its potential effects on economic growth.

The work of Takman and Gonzalez-Aregall (2021) highlighted the ineffectiveness of the policies applied for encouraging a modal shift to sustainable freight (usually, from trucks to trains). For this reason, the second paper focuses on exploring the potential use of a default effect as a means to encourage local businesses to utilize the new railway line for exporting their goods. The study involves conducting an experiment that simulates the introduction of the opportunity to load trucks for exporting goods through the railway line. By these means, we aim to understand if a new approach to this kind of policy could be more effective than the current one.

During the simulations, participants were required to make choices regarding the mode of transportation for their exports over five rounds. They were presented with two options: train or trucks. Trucks were perceived as the more cost-effective and faster choice compared to the train, but their speed was contingent upon the traffic generated by trucks sent by other participants.

The sample of participants was divided into two symmetrical settings. In the first session, Option A (train) was preselected as the default choice, while in the second session, the opposite was true. This experimental design allowed for the testing of the research hypotheses.

By employing this experimental framework, we aimed to examine whether the default effect could influence the decision-making process of the participants. They hypothesized that the default option

would significantly impact the participants' choices, leading to a higher propensity for selecting the default option (train) when it was preselected.

The study's findings provide insights into the effectiveness of employing defaults as a nudge to encourage local businesses to utilize the new railway line for exporting goods. By manipulating the default option, we were able to observe variations in the participants' choices, thereby shedding light on the influence of defaults on decision-making behaviour.

In summary, the second paper explores the possibility of using a default effect to nudge local businesses towards exporting goods through the new railway line. Through a carefully designed experiment, we tested the impact of defaults on participants' choices between train and truck transportation options for exporting goods. The findings of this study contribute to understanding how defaults can be leveraged to influence decision-making behaviour and potentially drive increased utilization of the railway line for exports.

The third paper focuses on conducting a simulation of the opening of the Brenner Base Tunnel using the model proposed by Monte et al. (2018). This simulation model aims to provide insights into the effects that the tunnel's opening will have on commuting patterns, the housing market, general prices, and the overall welfare of the provinces involved.

By utilizing the simulation model, we can assess the potential implications of the Brenner Base Tunnel on several key aspects. Firstly, the effects on commuting patterns can be examined, including changes in the volume and direction of commuting flows between Trentino, Alto Adige, and neighbouring regions. The model can provide insights into how the tunnel's improved connectivity may influence the decisions of individuals regarding where to live and work, as well as the resulting impact on transportation demand and congestion.

Furthermore, the simulation can shed light on the housing market dynamics. The opening of the Brenner Base Tunnel may lead to shifts in housing preferences and demand, as individuals seek to take advantage of the improved accessibility to different regions. The model can analyse these dynamics and provide estimates of potential changes in housing prices and market conditions.

In addition, the simulation can assess the general price effects resulting from the tunnel's opening. Changes in transportation costs, accessibility, and competition may impact prices in various

sectors, as goods and services. The model can capture these effects and provide insights into the potential implications for consumers and businesses.

Finally, the welfare analysis conducted through the simulation can help evaluate the overall societal well-being resulting from the Brenner Base Tunnel's opening. By considering the cumulative effects on commuting, housing, prices, and other relevant factors, we can assess the net welfare gains or losses for the provinces of Trentino and Alto Adige.

Through the utilization of the Monte et al. (2018) model, this paper aims to provide a comprehensive understanding of the multifaceted effects that the Brenner Base Tunnel's opening will have on the local economies. The simulation-based approach enables researchers to explore different scenarios and quantify the potential impacts, thereby informing policymakers, businesses, and residents about the anticipated consequences of this major infrastructure project.

References:

Takman, J., & Gonzalez-Aregall, M. (2021). A review of public policy instruments to promote freight modal shift in Europe: Evidence from evaluations.

Infrastructure development and economic growth: a methodological review

This methodological review aims to furnish the reader with a large, clear view of the possible techniques and models that could be applied in the analysis of infrastructure development effects on economic growth. We propose a detailed list of the tools offered by the reduced form and general equilibrium model, furnishing in each case an example taken from the literature. In addition, we try to expand on two topics that are still open: reallocation vs. growth and misallocation of infrastructure. Lastly, a discussion about when to use one approach over the other, considering the aim and the case studied is offered.

1. Introduction

The impact of infrastructure development on economic growth has become a prominent topic in the growing literature. While it is focused on other aspects such as public investment and productivity and crowding out, the work of Aschauer (1989a, 1989b), recognized the pivotal role played by infrastructure public investment. Subsequently, a plethora of studies delved deeper into this area, providing more specific information not only on the magnitude of this impact but also on the underlying mechanisms.

Market access, facilitated by infrastructure, has been identified as a crucial factor in determining city growth (Redding, 2008). Through the effects caused by the improvement of market access, infrastructure development affects economic growth by several means. Indeed, infrastructure development significantly influences urban form (Baum-Snow, 2013, 2017) and plays a vital role in job reallocation and creation (Baum-Snow, 2007; Desmet & Rossi-Hansberg, 2013). Moreover, infrastructure development has positive effects on trade by reducing trading costs and price gaps among regions (Donaldson, 2018) and also impacts the real value of land (Donaldson, 2016, 2018). Furthermore, it enhances commuting and leads to welfare improvement (Monte et al., 2018).

In the literature investigating the effects of infrastructure development on economic growth, two major methodological approaches are commonly employed: the reduced form and the general equilibrium model. In this paper, we aim to describe the differences between these approaches and showcase the techniques and features associated with each one. To achieve this, we have selected a restricted pool of papers that directly apply these techniques and features, using them to show how those techniques and features are empirically applied.

Additionally, this paper aims to expand on two topics raised by Redding and Turner (2015): growth vs. reallocation and the importance of well-targeting. We believe that the growing literature can

offer further insights into these topics, especially through analyses of High-Speed Rail development (HSR) regarding the misallocation of infrastructure's topic.

The structure of the paper is as follows:

- Reduced form methodologies
- General equilibrium model features
- Discussion
- Conclusions

By delving into these different approaches and their outcomes, we aim to contribute to a better understanding of the impact of infrastructure development on economic growth and shed light on the most appropriate methodologies for specific research questions.

2. Reduced form model

The reduced-form approach has been widely employed in empirical analyses aimed at understanding the impact of infrastructure on economic growth in various economies. This methodology has been extensively utilized due to its ability to provide rigorous and quantitative insights into the relationship between two or more variables, for example, infrastructure development and economic expansion.

Researchers employ econometric techniques, such as the Generalised Method of Moments and instrumental variables, to isolate the direct effects of the independent variable from other confounding factors. The approach allows for the examination of different time frames and regional variations, contributing to a comprehensive understanding of the relationship's dynamics and heterogeneity across economies. In order to isolate the direct effects of an independent variable (e.g., infrastructure development) on the dependent variable (e.g., GDP) in a specific location (A), it is crucial to make the assumption that there are no external effects that could bias the model outputs. This implies assuming that the independent variable in location A does not have any impact on the dependent variable in location B (GDP) and vice versa. In other words, all the general equilibrium effects between the two locations are considered to be null.

The OLS regression is not used anymore by authors, due to the inconsistency of its results. Redding and Turner (Redding and Turner, 2015) attribute the cause of this inconsistency to the violation of the key assumption of exogeneity, due to the non-randomness of the location chosen for the treatment group. Hence, the location chosen for the treatment group (e.g., an area receiving a policy intervention) is often non-random and subject to endogenous factors. When the location of

the treatment group is not randomly determined but influenced by other economic, social, or policy-related factors, it introduces bias into the analysis. This bias arises because the treatment is not assigned independently of the potential outcomes, and thus, the treatment group and control group might have systematic differences from the start.

As a result, researchers shifted to more sophisticated methods, such as instrumental variables or GMM, to address endogeneity concerns and obtain more reliable estimates of the causal impact of infrastructure development.

A. Generalised Method of Moments (GMM)

The Generalized Method of Moments (GMM) is an econometric estimation technique used to estimate model parameters when the assumptions of ordinary least squares (OLS) regression are violated or insufficient, which resulted common in real-world datasets for the reason just explained.

The GMM approach is particularly useful when dealing with dynamic panel data models, time series data, or when the error terms are heteroskedastic (varying variance) and/or serially correlated (exhibiting temporal dependencies).

The core idea of GMM is to choose model parameters that minimize a set of moment conditions. These moment conditions are derived from the underlying economic theory and are typically expressed as the sample averages of certain functions of the data. The method relies on the principle that, in a correctly specified model, the theoretical moments should match the sample moments. By minimizing the discrepancy between these moments, GMM estimates the model parameters that best fit the observed data.

Many researchers (Baum-Snow et Al, 2003; Farhadi,2005) applied this method to deal with the presence of heteroskedasticity and serial correlation, being the best estimator in those scenarios.

Transport infrastructure and long-run economic growth in OECD countries (Farhadi, 2005)

In his comprehensive study, Farhadi examines the long-term effect of transport infrastructure on economic growth using panel data spanning 140 years (1870-2010) from 18 OECD countries. The analysis is divided into two distinct phases.

In the first part of the study, Farhadi explores the relationship between productivity growth, represented by both labour productivity and total factor productivity and the growth in the stock of infrastructure. To address the high heteroskedasticity and significant autocorrelation inherent in the

panel data, the author adopts the feasible generalized weighted least squares regression (FGSL). This approach proves to be the most efficient given that the variable "time" (years) has more observations than the individual units (countries) in the dataset.

In the second phase of the analysis, the focus shifts towards investigating the extent to which social returns on investments in the transport sector exceed their private returns. To address the presence of heteroskedasticity and serial correlation, Farhadi employs a two-stage Generalized Method of Moments (GMM) estimator method.

The model used by Farhadi is the following:

$$\Delta lnY_{it} = \alpha_0 + \alpha_1 \Delta lnK_{it}^{eq} + \alpha_2 \Delta lnK_{it}^{st} + \alpha_3 \Delta lnH_{it} + \alpha_4 \Delta lnK_{it}^{inf} + \varepsilon_{1,it}$$

Where:

- *Y* is real gross domestic product
- K_{it}^{eq} is the capital stock of machinery and equipment
- K_{it}^{st} is the capital stock of structure and non-residential building
- H is hours worked
- K_{it}^{inf} is the capital stock of infrastructure
- The lag consists of 5 years

To deal with potential omitted variable bias and endogeneity, the author applied the two-step system GMM. It consists of an initial analysis of the basic model. If the endogeneity bias arises, due to the correlation between explanatory variables and the error term, it is required to add instrumental variables to the model. Capital stock weighted by geographic proximity, population growth, urbanisation, and gold reserves were included in the model. By these means, the author was able to deal with the endogeneity of the dataset.

The results link the public investments in infrastructure positively to the workers' productivity: the author estimates that each 10% of investment is followed by a 0.14% raise in productivity. Furthermore, the return on investments on the social level was computed as around 20%. These results are consistent with the current literature, but their values are quite lower than the usual average.

B. Instrumental variable (IV regression)

The IV technique is widely used by researchers, due to its robustness in dealing with the endogeneity of the usual dataset.

The IV regression method aims to establish causal relationships between the independent variable/s and the dependent variable by using instrumental variables that have a strong correlation with the endogenous explanatory variable/s but do not directly influence the outcome.

Roads, railroads and decentralization of Chinese cities (Baum-Snow et Al, 2017)

This paper investigates the role of the infrastructure configuration in shaping the urban Chinese city form. The aim of this study is to estimate the magnitude of the worker's decentralization caused by the development of railway rays and ring roads. Furthermore, the authors deepen their analysis the impact of these infrastructure expansions on the city's GDP. The dataset used for the analysis reports the growth in population and GDP during 1990-2010.

The model used is the following:

$$\Delta_t ln y_C = -\Delta A_0 + A_1 r_t + \Delta A_2 ln y_P - \Delta A_2 ln y_{1990P} - \Delta B_0 x + \Delta_t \varepsilon$$

Defining

- y_C and y_P to be the population, employment, or output
- t is year
- C is central city
- P is prefecture
- r denotes transportation network measure
- x is a vector of observed control variables

The model proposed has some inner threats generated by the potential endogeneity of *r*, ln_{yp} and lny_{1990p}. Indeed, historically, central cities with higher productivity have often received a greater allocation of modern highways. Consequently, the coefficient on highways in this context might partially capture the influence of this unobserved attractiveness rather than solely representing a causal effect. Moreover, y_p is the sum of the population in the city and the prefecture outcomes. This could imply that A_1 captures a combination of both the direct effect of infrastructure on the central city outcome and the indirect effect that occurs through the influence of infrastructure on the prefecture outcome. In other words, it represents the joint impact of infrastructure on both the central city and the prefecture, taking into account the interdependent relationship between the two. For example, roads can lead to a decrease in the population of the central city as people move away to the prefecture remainder due to better accessibility. At the same time, roads can also contribute to an increase in the central city's population by attracting new residents to the

entire prefecture, including the central city. In this way, roads have a dual effect on the central city's population, both displacing some residents and attracting others.

To address the endogeneity concern associated with the variable "r," the authors employ information on the 1962 transportation networks as instrumental variables. The first-stage results validate the effectiveness of the components of the 1962 network system as strong individual instruments, given the controls utilized. Thus, the authors meticulously establish these controls by demonstrating a comprehensive understanding of the developmental process of these infrastructures. They conduct a thorough examination of the entire historical context concerning the 1962 network development, incorporating significant events such as the Sino-Soviet plan of 1950, which involved the nationalization of the housing stock and subsequently reduced commuting by placing residents closer to their workplaces, to the construction of five strategic railroad lines promoted by the Third Front Government (1964).

The control variables used were:

- The prefecture population in 1982
- Occupation shares in the manufacture sector in 1982
- Geographical area of the prefecture and city
- Indicator of provincial capital (indicates if the prefecture is the province’s capital or not)
- Fraction of high school or more in the prefecture in 1982

To deal with the endogeneity of y_p, the authors construct instrumental variables based on the migration shock that occurred between 1985 and 1990. The instrumental variable is represented by the ratio of out-migrants during the 1985-1990 period to the total number of out-migrants during 1995-2000. Despite initial concerns about the validity of the instruments, as data for other periods were unavailable, it was found that this instrumental variable significantly predicts Prefecture population growth.

The study's findings provide valuable insights into the impact of radial and ring roads on the urban structure of the city. Specifically, it is estimated that for each radial highway, approximately 4% of the central city population relocates to surrounding regions, leading to a considerable reduction of 20% in the central city's GDP. In comparison, the effects of ring roads are even more pronounced,

as they result in a significant displacement of 20% of the population and a substantial 50% reduction in the central city's GDP.

Moreover, the research delves into the implications of these infrastructure changes on welfare. The analysis suggests that such developments have an overall positive effect on welfare, leading to an estimated increase of approximately slightly lower than 2-3%.

In their review, Redding and Turner (2015) describe three categories related to the IV approach: Planned Route IV, Historical Route IV and Inconsequential Units Approach.

B.1. Planned Route IV

The planned route IV, pioneered by Baum-Snow (2007), is an instrument-building method that found its basis in previous plans of development.

Baum-Snow used the 1947 plan for the interstate highway network, using it as a prediction estimator for the actual number of highway rays the number that were planned. Many researchers applied this method in their works, such as Michaels et al (2012) and Hsu and Zhang(2012). Donaldson in its work (2018) proposed a variation: to use the planned but never built infrastructure (Placebo paragraph).

The fundamental law of highway congestion revisited: Evidence from national expressways in Japan (Hsu and Zhang,2012)

In their paper, the authors present a theory that extends the fundamental law of highway congestion, which posits that when a highway is congested, the travel speed on an expanded expressway returns to its previous level before the capacity expansion. The theory introduces the concept of a coverage effect, which considers the impact of longer road length on traffic given the capacity. Under this generalized framework, the authors demonstrate that the new equilibrium travel speed might be lower than its previous level if the coverage effect is present. In other words, the expansion of road capacity alone may not guarantee an improvement in travel speed if the coverage effect plays a significant role in influencing traffic conditions.

The focus of the empirical analysis is the relationship between road capacity (km) and traffic (measured by VKT – average weekday daytime). Their first attempt was to apply an OLS, but the correlations between km with the unobserved time-varying UEA-level determinants of VKT bias the

OLS estimation. Also, due to government policies, km are correlated with the error term. To deal with these correlations, the authors opted for the IV approach.

The researchers used the planned national expressways of the NCPD-4 (the fourth National Comprehensive Development Program) as an instrument for the actual growth of the national expressway. The first stage model proposed by the authors is the following:

$$\ln(K_{it}) = \sum_{1}^{4} \gamma_s R_i * 1(s \leq t) \; + \; X'_{it}\emptyset + \; K_t + \; \mu_i + \; v_{it}$$

Where:

- K_{it} is the roadway length (Km)
- $\gamma_{1-4}$are the incremental completion rates of NCPD-4 (1990-1994, 1994-1997, 1997-1999, 1999-2005)
- $R_i$is the planned expressway extensions (log)

Using four dummy variables for R necessitates the inclusion of four instruments associated with the variable. However, this approach raises concerns about weak identification, as the use of multiple instruments may result in less reliable estimates of the causal relationship between the variables. This compromises the statistical significance of the model, such that the F test 4.33, is below the critical value for weak instruments.

In order to use a unique instrument, the researchers flatten the four period length, assuming a constant annual completion rate. Including this assumption, the model is rewritten as follows:

$$\ln(K_{it}) = \; \theta(Y_t R_i) + \; X'_{it}\emptyset + \; K_t + \; \mu_i + \; v_{it}$$

Where:

- Y is the number of years since 1990 at time t
- θ is the annualized completion rate

The F test of this model is 11.83, above the critical value.

The findings of this paper confirm the theory proposed by the authors for which the elasticity of traffic to the road is at least 1 (results confirm that elasticity range between 1.24 and 1.34)

B.2. Historical Route IV

The Historical Route Instrumental Variable (IV) was conceptualized and introduced by Duranton and Turner (2012). In this approach, historical transportation networks serve as the foundation for the instruments used in the analysis. For instance, historical explorative routes between 1535 and 1850 have been utilized as a source of quasi-random variation in the development of the U.S. interstate

highway network at the end of the 20th century (Duranton and Turner, 2012). Similarly, in the context of Italian motorways, Roman routes have been employed as instruments (Santagata, 2022).

The critical requirement in employing such instruments is to ensure that they do not directly relate to the specific object of research, such as economic growth or trade. This precaution is taken to avoid the instruments absorbing the explanatory power of the independent variable(s) under investigation. By using historical transportation networks as instruments, researchers can address endogeneity concerns and obtain more credible estimates of the causal effects of interest.

Does investment in national highways help or hurt hinterland city growth? (Baum-Snow et Al, 2020)

The authors conducted a study to examine the impact of the introduction of national Chinese highways on the growth of hinterland cities. The dataset used in the study includes information on China's GDP and infrastructure system, particularly roads and railways, spanning from 1968 to 2010.

To assess the causal effect of infrastructure on prefecture GDP and population, the authors developed a comprehensive analytical framework. However, they acknowledged that the most challenging concern in their analysis is the potential interdependence of infrastructure measures (such as road efficiency km and market access typologies) with the same unobservable factors that influence GDP and population outcomes.

The system is the following:

- $Y_{it} = \alpha + \beta L_{it} + \psi E_{it} + X_i \delta + u_{it}$
- $L_{it} = \alpha_1 + \beta 1\ L_{i62} + \psi_1 E_{i62} + X_i \delta^1 + \eta^1_{it}$
- $E_{it} = \alpha_2 + \beta 2\ L_{i62} + \psi_2 E_{i62} + X_i \delta^2 + \eta^2_{it}$

Where:

- Y prefecture outcomes (GDP and Population)
- L access to domestic markets
- E access to international markets.

Authors try to face the correlation between u and the other two equations using a spatial lag model, but the missing robustness of the estimators, in conjunction with some structural problems that arise with the approach, as a structural endogeneity and the difficulty to compare the two structural

equations that were required to generate (market potential to prefecture outcomes and vice versa), made the approach not feasible. Therefore, the authors used instruments built upon the information of the 1962 road network ($L\ i\ 62$ and $E\ i\ 62$).

the findings show that unbalanced infrastructure development in China led to a worsening of disparities among locations. Even though the aggregate GDP raises around 2.88% due to the improved market access, using the primacy instruments, the results show that only in richer locations this raise in GDP is registered (0.5%). The underdeveloped prefectures suffered a decrease in their GDP values notwithstanding the improved road efficiency. We will deepen the topic of "reallocation vs growth" later, in conjunction with the results obtained through the general equilibrium approach.

The findings of the study reveal that the uneven distribution of infrastructure development in China has contributed to widening disparities among different locations. Although the overall GDP shows an increase of approximately 2.88% as a result of improved market access using the primacy instruments, this growth is predominantly observed in richer locations, with a recorded increase of 0.5% in their GDP values. On the contrary, underdeveloped prefectures experienced a decline in their GDP values despite improvements in road efficiency.

B.3. Inconsequential Units Approach

In their seminal study, Chandra and Thompson (2000) introduced the inconsequential unit approach. This approach leverages cases where an atypical settlement, typically a small and rural one, becomes connected to a significant infrastructure designed for a larger town. The linkage between the small settlement and the major infrastructure is often random, as it occurs when the settlement is situated along the planned infrastructure.

Building upon this approach, Banerjee et al. (2020) propose a variation by introducing hypothetical routes as instruments. These instruments are designed to connect small ports to major settlements. By creating these hypothetical routes, the researchers aim to capture exogenous variations in infrastructure access, allowing for the identification of causal effects.

On the road: Access to transportation infrastructure and economic growth in China (Banerjee et Al, 2020)

The study examines the impact of access to transportation networks on regional economic outcomes in China during twenty years characterized by rapid income growth. To address the

endogeneity issue associated with the placement of networks, the study utilizes a unique approach by exploiting the tendency of these networks to connect historical cities.

The independent variable in this study is constructed using a straightforward algorithm. For each historically significant city, the authors draw a direct line connecting it to the nearest Treaty Port (Harbours forcedly destined to foreign trade by Western powers such as British Empire and France during the 19th and 20th centuries) and/or the nearest other historically important city. In cases where there are two cities (or ports) with a difference in distances of less than 100 km, lines to both were drawn. These lines continued beyond the cities until they encounter natural barriers such as the Tibetan Plateau or the coastline, or until they reach a border with another country. This approach let the authors create a comprehensive measure of connectivity, enabling the investigation of the impact of transportation network access on regional economic outcomes in China during the period of rapid income growth.

The model proposed is the following:

$$y_{cpt} = \beta lnL_{cp} + \Gamma Z_{cp} + \rho_p + \gamma_t + \varepsilon_{cpt}$$

Where:

- Y outcome
- L shortest distance to the line
- Z controls
- ρ province fixed effect
- γ year fixed effect
- c county
- p province
- t year

If the proximity to the drawn line proves to be advantageous, $\hat{\beta} < 0$

Interpreting β as the causal effect of proximity to the line assumes that the sole distinction between locations close to the line and those farther away is the distance to the line itself. However, this assumption hinges on the premise that the choice of termini cities for drawing the straight line is not influenced by economically significant regions along the route. In other words, the research design relies on the selection of termini cities in a manner that avoids running a straight line through economically important areas.

The paper's findings indicate that regions in closer proximity to historical transportation networks exhibit slightly higher levels of GDP per capita, income inequality, the number of firms, and average firm profits. However, the magnitude of these differences is relatively small. Furthermore, the analysis does not reveal any evidence suggesting that distance from historical transportation networks influenced income growth during the studied period. These findings should not discourage proponents of transportation infrastructure investment as a means to stimulate economic development. Instead, they underscore the significance of considering other factors that play a crucial role in determining the economic impact of infrastructure. While transportation infrastructure can indeed contribute to economic growth, it is essential to recognize and address the multifaceted nature of economic development, where various factors interact to shape overall outcomes.

3. General equilibrium approach

The general equilibrium model is a sophisticated and comprehensive system of functions used to analyse the interactions among multiple variables that describe the object of analysis, such as national economies. Unlike the reduced-form approach, which only considers the direct relationships between variables, the general equilibrium model takes into account not only the inner connections but also the external influences and feedback mechanisms that can arise from changes in one or more variables.

In this class of models, changes in any individual variable can trigger a cascade effect that reverberates throughout the entire economic system, leading to adjustments and adaptations in other related variables. The complex nature of this approach allows for a clearer and more detailed vision of the interconnections among various economic factors, both direct and indirect, facilitating a deeper understanding of the intricate dynamics within the economic system.

One of the key advantages of the general equilibrium model is its ability to capture all equilibrium effects, including the variations caused by variables that may have indirect linkages with the object of interest. By considering these indirect effects, the model provides a more holistic and realistic representation of how changes in one part of the economy can ripple through and affect other sectors and regions.

Moreover, the general equilibrium model allows to generate of ex-ante predictions, offering valuable insights into the potential outcomes of policies that have not yet been implemented. This predictive capability is particularly useful for policymakers as it helps them anticipate the potential consequences of various policy interventions and make more informed decisions based on the expected outcomes.

In order to ensure the reliability of a general equilibrium model, it is essential to have proper theoretical guidance, as emphasized by Donaldson (2016). Prior to developing the model, certain assumptions must be established concerning its key features, such as preferences, production technology, and flows of ideas, among others, as elaborated in the following paragraph. If any of these assumptions do not hold, which can occur due to various reasons (e.g., conflicting assumptions like fixed population and fixed utility workers in Donaldson, 2016), the descriptive capability of the model becomes compromised.

A. Quantitative spatial model: assumptions, building block and selection criteria

In recent times, the vast majority of authors contributing to the literature on the relationship between infrastructure development and economic growth have adopted a Quantitative Spatial Model (QSM). In contrast to the Computable General Equilibrium (CGE) models, this type of model explicitly incorporates spatial characteristics, such as the location of economic agents and their interactions with neighbouring regions. As a result, QSM is commonly utilized in the analysis of spatial policies and regional development strategies, estimating the effects on infrastructure, transportation, urban sprawl, and the spatial distribution of economic activity.

In their review, Redding and Rossi-Hamberg (2017) offer a well-detailed taxonomy of the plethora of assumptions and building blocks that can be chosen in order to build a model. In this paragraph, we propose a resume of this taxonomy, furnishing a view of the common features used in the literature. Furthermore, a description of the three selection criteria will be furnished.

A.1 Assumptions

A.1.I Preferences

- Typologies of goods
    - Homogeneous, usually linked to labour mobility

    - Differentiated, usually linked to labour mobility, and goods differentiated by country origin
- Number of sectors
    - Single sector, or aggregated (as agriculture) – it preserves analytical tractability
    - Multiple sector, disaggregated – this approach lets to analyse issues such as structural transformation
- Amenities
    - Exogenous
    - Endogenous, determined with ex-post analysis of ex-ante identical locations
- Fixed local factors utility: e.g. residential land – congestion or dispersion force
- Preferences
    - Common – perfect mobility, perfect elastic labour supply at real wage
    - Idiosyncratic – preferred location, higher wages attract workers, elasticity determined by the degree of heterogeneity in agents' preferences.

A.1.ii Production technology

- Returns
    - Constant
    - Increasing – it leads to a self-reinforcing process of agglomeration, multiple equilibrium spatial allocations
- Productivity differences
    - Exogenous – useful to rationalise the observed employment and income data
    - Endogenous – e.g. knowledge spillover
- Input-Output linkages – crucial in determining modalities of specific sector or region shock spreading
- Fixed local factors in production – e.g commercial land, congestion force

A.1.iii Cost of trading goods

- Trade cost
    - Fixed
    - Variable – combined with assumptions of preferences and technology production generates prediction for bilateral trade. Suggested mathematical structure: gravity function
- Transport cost
    - Symmetric – have to if determined by only geographic distances
    - Asymmetric – determined by geographic and economic factors (as trade volumes)
- Frictions
    - Geographic – as mountains, rivers and so on
    - Economic – as borders, infrastructure networks
- Role of non-traded goods- crucial in shaping input-output linkages and local multipliers

A.1.iv Technology for Idea flows

- Knowledge
    - Externalities – frictions such as lack of a market, prices. Highly localized, decay rapidly with proximity (economic, geographic and/or technological)

    - Diffusion – in reduced form, the mechanism proposed: sharing, matching and learning
- Innovation – influenced by market size and innovation cost extent to share among consumers
- Transferability of ideas – frictions in transferring ideas, such as cost of transferring blueprints among countries

A.1.v Cost of moving people

- Migrations cost
- Commuting
    - In a monocentric city scenario, crucial to determine land price gradient
    - Non monocentric scenario, crucial in determining internal city structure
    - Models of system of city, in conjunction with amenities and productivities, are crucial in shaping the distribution of city sizes.
- Migration – commuting decision
    - Skill – a different level of skills allocates among different characteristics locations
    - Heterogeneity – gravity function form, positive proportionality with origin and destination sizes, negative with geographical distances
- Congestion in transportation – the extent of increased flows which leads to congestion increasing travel costs

A.2 Endowments

- Population and skills
- Spatial scope and units
- Capital and infrastructure

A.3 Equilibrium

- Market structure
    - Constants returns to scale – perfect competition
    - Increasing returns to scale – monopolistic competition
- General vs partial equilibrium – Area within equilibrium conditions hold (e.g. city, province, region, world)
- Land ownership and the distribution of rents
    - Landlords absence assumption – higher tractability, full general equilibrium effects cannot be incorporated
    - Presence of landlords, three ways to incorporate in the analysis
        - Global land portfolio – aggregates land rents and assigns shares to each landlords
        - Distribution of land rents locally to current residents
        - Completely local consumption of land rents – add local consumption to total labour income
- Trade balance
    - Trade balanced by assumptions
    - Computation of deficits

A.4 Selection criteria

Redding and Rossi-Hamberg (2017) furnish in the same paper three selection criteria, extremely useful to detect which assumptions and building block fit with the research that it would be carried on.

A.4.i Tractability

The first criterion for evaluating economic geography models involves both analytical and computational tractability. Traditionally, theoretical models in this field focused on a limited number of symmetric regions to maintain analytical tractability. However, recent technical advancements have expanded the possibilities, enabling the derivation of analytical results for large numbers of asymmetric locations connected by real-world transport networks. Notable works by Allen & Arkolakis (2014) and Allen et al. (2015) demonstrate the feasibility of obtaining equilibrium existence and uniqueness results through such advances.

Furthermore, innovative techniques developed by Desmet & Rossi-Hansberg (2013) and Desmet et al. (2016) have allowed for analytical characterizations of the dynamics of economic activity distribution across space. These methodological improvements, combined with the use of observed values of variables in an initial equilibrium, as explored by Dekle et al. (2007), facilitate tractable counterfactual analyses in theoretical models.

Additionally, the continued progress in computing power and computational methods has paved the way for solving systems of nonlinear equations involving a large number of locations within realistic computational timeframes. These developments have expanded the scope and applicability of economic geography models, enabling more sophisticated analyses of complex spatial interactions and economic dynamics.

A.4.ii Structural assumptions

The second criterion involves making decisions about the structural parameters and exogenous location characteristics that remain invariant to policy interventions when using a quantitative spatial model to examine the impact of place-based policies or transport infrastructure improvements. Researchers must carefully consider whether certain components, such as productivity and amenities, are exogenous or subject to agglomeration externalities, which may affect their stability in the face of interventions.

For instance, determining whether there exists an outside level of utility in the wider economy that remains constant or if there are exogenous prices or expenditures in world markets can significantly influence the selection of building blocks for the model. The goal is to ensure that the

assumed structural parameters and locational fundamentals remain consistent and unaffected by the policy changes being analyzed.

By addressing these questions and ensuring the constancy of relevant factors, researchers can enhance the robustness and validity of their analysis, avoiding potential biases and ensuring that the results are not vulnerable to the Lucas critique. Careful consideration of the invariance of structural parameters and location characteristics is essential for conducting reliable and informative policy evaluations using quantitative spatial models.

A.4.iii Connection between model and data

The third criterion involves considerations about the specific research question, the level of detail required for the analysis, and the availability of relevant data. Researchers must determine whether the focus is on understanding the aggregate effects of a policy or the impact on the distribution of economic activity across disaggregated spatial units. Understanding the distributional impact at the disaggregated level can be crucial for evaluating the overall effect of the policy.

The spatial units for which data are recorded play a vital role in the analysis, as different types of data are available at various levels. These data may include information on endogenous variables for each location, such as population and wages, as well as endogenous bilateral flows like trade and commuting.

Researchers may face data limitations and have to decide on the best approach to address them. They may need to use substitute data types if certain variables are unavailable or challenging to obtain. For example, quantitative models can often be solved using either endogenous bilateral flow data (e.g., bilateral trade) or data on exogenous frictions (e.g., transportation costs).

The choice of data also affects the estimation of the model's parameters. Researchers must determine whether the available data allow for structural estimation of the model's parameters or if the model needs to be calibrated using parameter values from external sources or previous studies. Ensuring the model's exact identification and having enough degrees of freedom to explain the observed data as an equilibrium outcome is crucial for accurate analysis.

Additionally, researchers need to assess whether the model is invertible, meaning that there exists a one-to-one mapping from the model's parameters and observed data to the unobserved

location characteristics or structural residuals. This is important to ensure that the model's predictions are valid and reliable.

To validate the model's predictions, researchers can undertake overidentification checks using moments not used in the calibration or estimation. These checks help assess the model's validity and ensure that it accurately reflects real-world dynamics.

B. From reduced form to general equilibrium

Over the years, several authors have proposed this particular combination (Donaldson and Hornbeck, 2016; Adao and Arkolakis, 2019). This particular approach divides the investigation process into two phases, starting from the reduced form to expand the analysis to the general equilibrium model.

The result of the reduced form could be used as a benchmark and/or a preliminary analysis to understand the nature of the causal effect of the independent variable/s on the dependent one, determining its magnitude as the correlation among those variables (direct or inverse proportion). Hence, this kind of approach is applied by Donaldson et Al (2016), as it will be explained in detail later.

Differently, Adao and Arkolakis (2019) exploit this approach to compute the required elasticities in order to develop their general equilibrium model. In this case, this approach is quite useful to estimate some necessary values, without requiring all the necessary data. This model can be applied when there is no need to fully understand the causes of a particular correlation but only to ascertain the effect of one variable on another.

Railroads and American economic growth: a "market access" approach (Donaldson & Hornbeck, 2016)

Donaldson & Hornbeck analyse the impact of the railroad on the U.S. economy, exploiting the historical data about the railroad network expansion between 1870 and 1890. The analysis conducted is structured in two stages. In the first one, they develop a reduced form model, using the OLS technique, to evaluate how the railway development affects land value. The authors' strategy was to estimate the value of land in a hypothetical scenario in which the railway expansion wasn't carried on.

The reduced form reveals that if the railroad wasn't developed, the land would value 60% less. Expanding the analysis to the general equilibrium approach, relaxing the assumptions of worker utility and population fixed (their mutual presence was considered inconsistent by the author due to worker utility could remain unchanged only if some workers migrate, and if the population doesn't changes, it is compulsory that the utility decrease) Donaldson and Hornbeck estimate the land value loss in the extremes scenario when U (worker utility) is fixed and N (population) decline and the opposite case.

Due to the rigid structure of the model, the variations of one variable affect directly the same entity the land value. The first analysis reveals that the loss value would be 58,4 %, meaning that the reallocation impact on land value has a small entity. The second model outputs a decrease of 19%, but even though the land value decrease is smaller than the reduced form output, the aggregate economic impact would be larger than the predicted one.

The results of both simple general equilibrium models open to different interpretations of the impact of railroad on the economy. Indeed, authors compute that the complete depletion of the agricultural sector will generate a GNP annual direct loss of 5.35%, but all the side effects, as migration and worker utility decrease would affect the US economy in a larger entity.

4. Discussion

A. Reduced form vs General equilibrium

The spatial economic literature presents two different approaches, the general equilibrium model and the reduced form model. In this literature, we aim to explore the author's decision-making process behind the application of one typology than the other one.

Donaldson (2016) assert that the empirical analysis can be conducted through the reduced-form approach. Indeed, in the literature, several authors face case studies through the reduced-form, due to it provides a direct link between the variables taken in the examination. Moreover, the reduced form approach doesn't require a large amount of data (in terms of a number of variables) to grant strong and robust prediction (Cascietta, 2020).

Notwithstanding the fairness of this approach, it is not always the fittest tool for the analysis. Indeed, the direct relationship between the two variables could be misleading (Desmet and Rossi, 2013). The example offered by the cited authors is the following: using the reduced form, specifically a log reg on the city size and labour wedge would be a statistically significant positive

effect, leading to conclude that higher frictions lead to greater city size. This is only one of the possible biases that can occur using the reduced form, as the spurious correlation. But it remains true that the reduced form is quite immediate and easy (easier than the general equilibrium model) to build, understand and explain. And it grants, in the case of empirical data, quite robust and precise estimation.

Anyway, where the reduced form is quite sharp in the single case analysis, the general equilibrium models are planned and developed not only to recreate the scenario taken into consideration but to understand and examine the general relationship among two or more variables, including all the indirect effects. Several studies use models proposed by other authors, demonstrating their applicability in different scenarios.

Furthermore, the general equilibrium aims to offer a large view of the web of relationships that shape an event (or a trend, such as the growth of a city, region, and so on). In their paper, Donaldson motivates their decision to move from the reduced form to the general equilibrium model. Other authors too, such as Arkolakis et al, made the same decision, in order to propose a new theory. An example could be the finding about the Seattle highway (Arkolakis): with the reduced form, it would be a lot more complex to understand that some road has a positive effect and other lead to a negative return, due to the simple (and not only) gives the direct but aggregate relationship among the variables.

The aim of this literature review is to suggest when to use one approach over another one. In empirical studies, such as case study one, and/or the aim is to understand a direct relationship among a restricted set of variables, the reduced form is the best option.

On the other hand, when the aim is to understand the relationship among two o several more variables and to state a common “rule”, the general equilibrium becomes the best approach. It would be the best approach also when the aim is understanding all the indirect, hidden trends.

B. Reallocation vs growth

In their review, Redding and Turner introduced the discussion about the direct proportionality between infrastructure development and economic growth. Indeed, the extent of the infrastructure expansion, especially at the urban level, appears to be “mitigate” by the reorganization of economic activities. In other words, the effect of new infrastructures on the

labour market is not purely on creating jobs, but also to reallocate them. Furthermore, it results that the primary effect of infrastructure development is the reallocation and not the creation. Hence, the positive effect on welfare and/or GDP results is lower than expected. In their review, Redding and Turner proposed two conclusions, notwithstanding the fragmentary evidence.

In the urban context, reallocation is at least important as the creation.

In not urban context, the main effect of infrastructure development is to draw economic activity towards the developed areas, often at the cost of less accessible and more remote regions.

From their publication, the literature deepens this topic. Therefore, we will try to enrich the debate about this topic by proposing a new point of view. Indeed, Redding and Turner seek the solution to the debate only in the reduced form literature. Desmet and Rossi (2013) computation showed that 50% of worker reallocation across countries would lead to an increase of only 3% in welfare, which could be easily invalidated by any small reallocation cost. Moreover, the general equilibrium developed by Donaldson (2016), the one that considers worker utility fixed and lets workers reallocation, estimated the positive effect generated by reallocation around 1.6%. The work of Baum-Snow (2017) gives us a clear hint about the "negative" effect of reallocation. Indeed, one of the threats recognized by Redding and Turner (2015) was the impossibility of reduced form approach to disaggregate all the effects of the reallocation. With its work on the Chinese urban form, Baum-Snow computed the GDP loss suffered by central cities (20 % per railway ray, even 50% in the presence of road ring).

C. Well-targeting

Another topic that arises in the literature is the effect caused by the geographical development of the infrastructure. The Allen and Arkolakis (2022) results of the model applied to the Seattle highway show that, even though there is a positive effect reported before, quite half of the infrastructure system has a negative impact on the social return of investment. This fact highlighted that, as underlined in the Redding and Turner conclusions, the allocation of these infrastructures is not random, but it is compulsory to consider that is affected by unobserved location characteristics, that also play a role in shaping economic activity. We reckon that it could be the main cause of the negative effects caused by the HSR highlighted in the proposed literature. Indeed, Shi, Baum-Snow, and Cascetta work on HSR attribute the main cause of the economic growth loss to the unbalanced HSR development. As was already reported, the absence of the HSR connection, in the presence of it in surrounding localities, exacerbates the

marginalization of the non-connected are. Moreover, Baum-Snow underlines the role of geographical HSR development in the area of economic activities specialization. In his scenario, the non-connection to HSR would lead to a complete depletion of economic activities with the only exception of the agricultural sector. By these means the rural areas would be completely left behind, increasing the disparities with the major settlements.

5. Conclusions and future developments

The literature offers two macro-categories of approaches, each providing a diverse array of features and techniques that equip scholars with suitable instruments for their research endeavours. It is crucial to carefully select the appropriate approach based on the research objectives. Case studies and investigations seeking to understand the direct effects of a set of variables on the object of interest often favour the reduced-form approach. In such cases, researchers need to thoroughly assess the dataset and utilize the plethora of instruments offered by this approach.

Several techniques exist that enable researchers to proxy missing data or obtain information necessary to fulfil the research objectives, even in the absence of directly related data. Moreover, the robustness tests allow researchers to confirm the reliability of the instruments applied, highlighting a significant strength of the reduced form approach.

On the other hand, if researchers aim to consider all possible interconnections among the entire set of variables, including external influences and general effects, the general equilibrium model becomes the preferred choice. This model offers a comprehensive analysis of the complex interactions within the economic system, shedding light on how changes in one variable can impact the entire equilibrium of the spatial economy.

In conclusion, the decision between the reduced form and general equilibrium approaches depends on the research goals. The reduced form approach is suitable for focused investigations of direct effects with robustness tests ensuring instrument reliability. Conversely, the general equilibrium model is instrumental when studying the broader interconnections and overall effects within the spatial economy, encompassing both internal and external influences.

The themes examined in this review, namely reallocation versus growth and misallocation of infrastructure, continue to be relevant in current literature. Specifically, the growing body of

research on High-Speed Rail (HSR) emphasizes the risks associated with an unbalanced development of this infrastructure, affecting both economic and social aspects. Moreover, the reallocation versus growth topic has gained more significance in recent literature, as it is recognized for its role in shaping urban form and influencing economic growth.

With the widespread adoption of HSR and the digital advancements linked to it, such as online booking systems and questionnaires provided through train Wi-Fi, there is a potential for gathering the required data more efficiently. This enhanced data availability is expected to shed more light on the aforementioned topics, offering valuable insights into the impacts of infrastructure development and its implications for economic and urban development.

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Modal shift to sustainable import-export: Nudging through the default effect

Abstract

The worsening of Global warming is leading researchers to study different solutions, in every field. There is an increasing literature that studies how behavioural biases could be exploited in the formulation and application of new policies. But the great majority of this literature is focused on domestic management as reducing waste and using public transport to subscribe to energy contracts that use renewable energies. In this paper, we want to propose a policy that involved firm owners, to see if the same behavioural biases can affect them and how much. Furthermore, we want to test the effect of ethical features on a default effect. The experiment is extremely specific: it will be the base for another study on the possible consequences of the opening of the BBT (Brennero Basis Tunnel, 2028).
Our results show that a simple default can affect a choice that should be completely rational as the choice of an export strategy of the own produced goods. Furthermore, they highlight the importance of an ethical feature in the application of a policy based on a default bias.
We conclude by proposing how this study could be developed and highlighting the importance of awareness about green themes of agents in their decision-making process.

1. Introduction

The negative impact of international trade on the environment, particularly the pollution caused by its usual means of transportation such as trucks and airplanes, has been well-documented in the literature (Brunekreef,1997). The effects of pollution on the environment and public health are varied and complex, prompting national governments to implement various strategies to reduce its impact. One such strategy that has been suggested at the local level is the use of rail transportation to export goods, which can potentially reduce pollution and provide other benefits such as faster transportation and improved working conditions for employees.

In this study, we aim to examine the effect of a policy that leverages the default bias in decision-making about export strategies. To collect the necessary data, we conducted an experiment that simulated the decision-making process of firm owners when exporting goods. To keep the experiment as plausible as possible, we simplified the setting by using only two possible means of transportation: trains and trucks.

The experiment was designed to simulate the export of goods from Trentino Alto Adige to Austria after the planned opening of the Brenner Base Tunnel (BBT) in 2028. Specifically, it will be possible

to load trucks onto trains. This will significantly reduce the time required to send goods and also have positive impacts on local pollution and the working conditions of drivers.

Our aim is to assess the effectiveness of a default bias-based policy and determine whether the default bias can influence repeated choices and whether certain features can affect its effectiveness. We also administered a questionnaire to gather additional information on the participants' understanding of the topic and their thoughts on related features.

Our results indicate that a default option can nudge firms to adopt more ecologically sustainable export strategies. Furthermore, we found that ethical considerations play a significant role in the effectiveness of the policy. The questionnaire results suggest that the policy promotes greater awareness of the issue among participants.

This paper is structured as follows:

1. Literature review
2. Material and methods
3. Analysis
4. Conclusion

2. Literature review:

2.1 Default effect:

The default effect is a cognitive bias that may influence an individual's decision-making process by causing them to conform to an existing or proposed status quo. The origins of this bias may be attributed to various factors, which could include social norms, cognitive load, or the preference for familiar options. Here is a short list of the possible reasons for the occurrence of a default bias:

1. Loss aversion: cognitive bias due to changing the status quo is viewed as a loss (Kahneman & Tversky, 1984)
2. Effort: the absence of additional effort offered by a default option (Samuelson & Zeckhauser, 1988)
3. Implied endorsement: default seen as a recommended option (McKenzie et Al, 2006)
4. Implied endorsement and social norms: default not only the recommended option but also the most chosen by others (Everett et Al, 2015)

The focus of those authors was to determine what could generate the default effect, but the effectiveness of this effect was never directly linked to a difference in ethical terms of the default

option than the other one. Our intuition is that the default effect is significantly influenced by the fact that the default option is usually the most ethical among the feasible options.

2.2 Green economy and default effect:

In recent years, there has been a significant increase in academic literature regarding the promotion of a green and sustainable economy through the utilization of default and status quo biases. These biases have been shown to play a critical role in shaping individuals' behaviour and decision-making processes, particularly in the context of environmental sustainability. By leveraging these biases, policymakers and stakeholders can influence individuals' choices towards more sustainable options, such as energy-efficient products or low-carbon transportation. This growing body of literature highlights the potential of these biases as effective tools for promoting sustainable practices and shaping a more environmentally conscious society.

It appears that the default effect is the only one that has a significant effect (Momsen & Stoerk, 2014), as it is confirmed by other authors. It was shown that default affects positively the specific choice of energy-efficient lamps (Dinner et Al,2011) or also prevents strongly the opt-out (even for a better green option) of a green default option (Chassot et Al, 2013) or induces an increase of the number of green contracts' subscriptions (Grabicki, 2019).

On the other hand, it was also shown that, even if the default is still effective, it could not match the consumers' preferences, for different reasons linked to socioeconomic status (Ghesla et Al,2020).

This was our starting point: if the effectiveness of default can be negatively affected by the not exhaustion of the willingness to pay more for richer agents (essentially, wealthier agents are willing to pay more than the price requested by the option with the lowest cost) (Ghesla et Al,2020) will be the default still effective for managerial choices? Indeed, the literature about the green economy and default effect is in the major part focused on the domestic level, and electricity consumption.

2.3 Default effect and ethical features

In the vast majority of the literature about default and status quo bias, the defaulted option is often the most ethical one among the option proposed, but the effect of this feature is never considered. Indeed, the default "falls" on the most ethical because it is preferred by the architects of experimentations/policies. In their work, Sunstein and Reisch faced the dilemma between the default ethical option and influenced active choice (Sunstein & Reisch, 2014) but did not consider

the ethical features of choice as an affecting variable. Other interesting surveys seem to share our intuition of an increased awareness that leads to the most ethical choice, as proposed in the work of Goldstein and Sharpe (Hershfield et Al, 2011) where to some participants were proposed a digital future image of themselves before a choice between some options including the most ethical of saving for a pension. Even though they didn't exploit the default effect, the intuition behind is quite the same: to increase the awareness of the participants during their decision-making process in order to evaluate how an increased awareness determine the effectiveness of the treatment.

2.4 Default effect and repeated choices.

The great majority of studies and experiments are set to analyze the effect of a default bias in a one-shot game. Indeed, it appears to be hard to exploit a default bias in repeated games (Zlatev et Al, 2017).

Anyway, the default effect remains effective even in several turns. Indeed, in the first choice, the participants have to operate in a situation of complete uncertainty, and the default can occur due to the reasons written before. With repeated choices, participants could underestimate the uncertainty (if the experiment is set to preserve it, as ours) and be less affected by the default. But the default is still effective in the following turns: it seems that by gaining experiences, participants introject the choices made before, and that biases their current decision (Couto et Al, 2020).

3. Material and methods

3.1 Research questions:

The aim of this survey is to fill the following gaps found in the literature:

i. Could a policy based on default nudge firms' owners to eco-sustainable but more expensive strategies?
ii. Without time pressure, could this policy be effective through the years?
iii. Are the ethical features linked to the policy crucial for the success of the policy itself?

Following, we propose the three hypotheses formulated and that were the pillars of our experiment:

Hp1: The default bias affects the decision-making process of export strategy

H2: The default bias persists in repeated choices

H3: The default bias is strengthened if the default option is the most ethical one

It is generally assumed that default bias is not limited to individual or household decision-making but can also be observed in managerial choices. This highlights the potential usefulness of default bias as a tool for policymakers seeking to encourage more sustainable business practices. However, while previous research has explored the causes of default bias and its relationship with time, there has been relatively little investigation into its application to managerial decision-making.

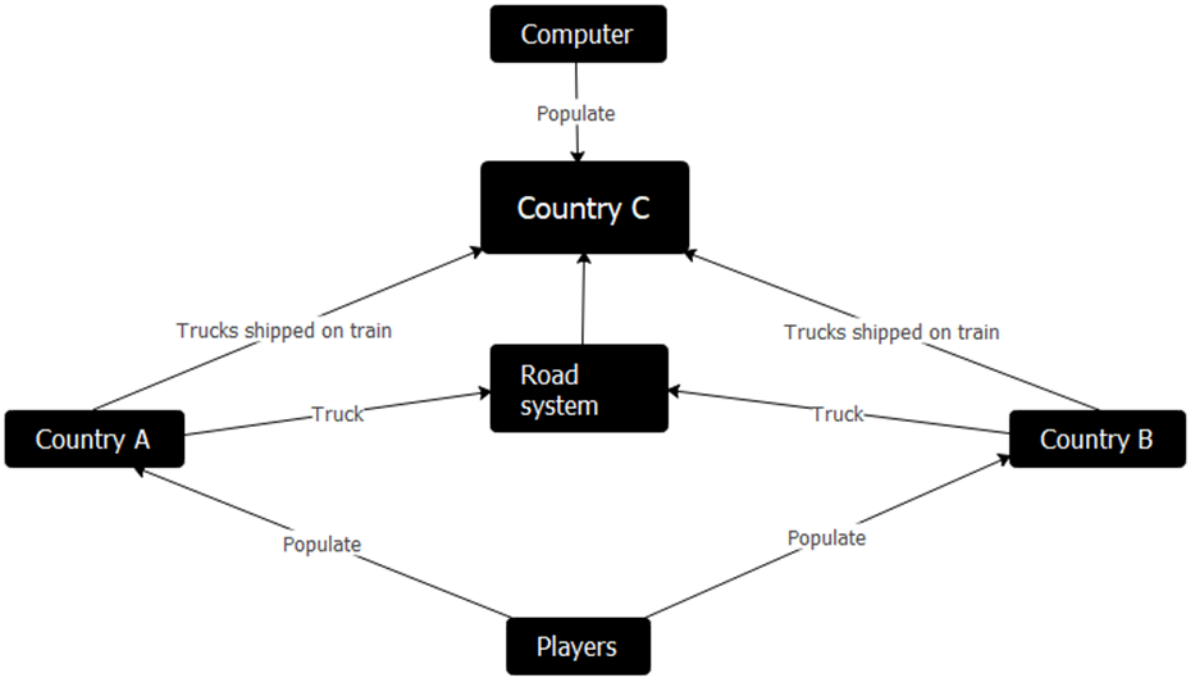
Moreover, an additional hypothesis that remains to be tested is the potential influence of ethical considerations on default bias in managerial decision-making. Although not explicitly considered in the existing literature, ethical considerations are often implicitly present in surveys investigating attitudes toward sustainability and environmentally responsible behaviour. Therefore, there may be a need to examine the potential role of ethical considerations in shaping the impact of default bias on managerial decision-making toward sustainability. By shedding light on this factor, we may gain a more nuanced understanding of the complex interplay between cognitive biases, ethics, and sustainability in the context of business decision-making.

3.2 The experiment

The experiment is a competitive game, where the best output is reached when the player chooses the least chosen option by the sample. Our experiment is based on the well-known El Farol Bar structure (Arthur, 1994).

The “visual” concept of the experiment is the following:

Graphical representation of the experiment



Participants were split equally into two groups: treatment (Country A) and control (Country B). The treatment will be exposed in the next paragraph.

During the instruction phase, it was told to players that they would role as an entrepreneur of a firm that exports their goods to another country (Country C).

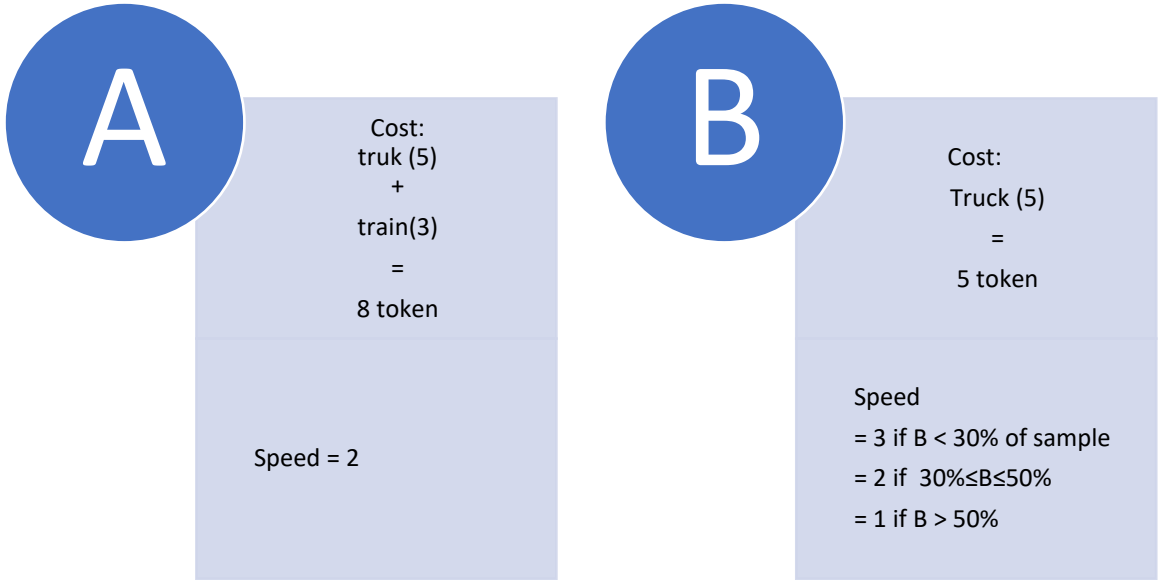
The currency used is the token, and each player will earn 1 euro per 10 tokens at the end of the experiments. Country C's budget for acquiring goods is related to the number of players, and it equals 2 tokens multiplied by the number of players who are participating in the session. Each player starts the experiment with a budget of 50 tokens.

Each turn is composed of two phases: the choice of the strategy and the selling, which is made automatically by the computer. The output of the selling is determined by the choices of the entire sample. The experiment lasts 5 turns, and profits are obtained at the end of each turn.

The gains of each turn are determined by the arrival order between players. The players have two choices, and the speed depends upon their choice: faster players can sell their goods before the slower ones.

The options are proposed to each player as follows:

Feasible options



Choice A: Rent a vehicle (truck) for distribution (at a cost of 5) plus a train ticket (3) for transporting it to country C. The total cost is 80 and the speed is 2, regardless of the choices of the other players.

Choice B: Rent a vehicle and send it through the motorway. The total cost is 5 tokens, and the speed is variable and determined as follows:

- If this option is chosen by less than 30% of the entire sample, the speed will be 3
- Between 30 and 50%, the speed will be 2
- More than 50%, the speed will be 1, due to the severe traffic generated by so many trucks.

As told before, faster players can sell their goods before slower ones. In practical terms, it means that the gross reward obtained by the fastest players is considerably higher than the slowest ones.

Players with the same speed arrive simultaneously. There are three possible outputs related to the speed:

- Fastest: the gross reward is equal to 20 tokens (2 euro)
- Same: gross reward = 10 token
- Slowest: gross reward = 2 token

Due to its structure, during each turn, it is possible to have at maximum only two different speeds, so there will only be one-two echelon (two echelons, fastest and slowest, and one echelon if each player has the same speed.

At the end of each turn, each player received information only about the amount gained in the current turn, so they could try to understand the number of players that have chosen A or B by the amount of token earned, but they couldn't know the precise composition.

Here is a resume table regarding choices, option B chosen by the sample percentual, and related outputs (considering the option's cost, in euro):

Possible outputs

Percentual → The option chosen by player ↓	**B >50%**	**30%≤B≤50%**	**B<30%**
Option A	1,2 euro	0.2 euro	-0.6 euro
Option B	-0.3 euro	0.5 euro	1.5 euro

In order to prevent common strategies that could confuse the data, communication between players was forbidden.

3.3 The treatment

As told before, for this survey were proposed two mirror experiments. The only difference between them is only about the treatment.

The treatment consists of a preselection during the choice of players belonging to Country A.

Participants were assigned to country A through their ID in the session: players with odd IDs belonged to the treatment group. The IDs were assigned randomly, so there wasn't any

manipulation in the composition of the sample. In this way, the groups were composed of the same number of members (at least 1 more for the treatment group).

We performed 8 sessions of this experiment, with 8 different samples recruited through the CEE lab.

In the first four sessions were proposed the preselection of option A (train) with the following flavour test (instead of "Choose between A and B"):

"Due to ecological reasons, in your country, your government decided that the train is the default way to export. Anyway, you could request an exemption by choosing to export through Truck (option B)"

In the other sessions, the treatment consisted of the option B pre-selection, with the same text proposed to the control group.

The different flavour test is proposed to test the HP 2, giving the decision an ethical feature.

3.4 The sample

144 participants were recruited through the CEEL (Cognitive and Experimental Economics Laboratory) of University of Trento. The sessions were run online due to Covid rules prevention. Each player signed up for a specific session, so each session was composed of different numbers of members.

The sample was split as follows:

1. 19 players
2. 21 players
3. 17 players
4. 15 players
5. 19 players
6. 22 players
7. 14 players
8. 18 players

The sample consists primarily of undergraduate economics students but also includes graduate students. The average age falls within the 19-23 range, with a few outliers who are older.

3.5 The questionnaire

At the end of the experiment, a short questionnaire is proposed. After the usual bio part, 5 questions about the green economy and workers' condition features are proposed. Our aim is to understand how much the participants are aware and care about these arguments, in order to understand if these aspects could affect their choices. After the statistical analysis, we will conduct a simple "coherency" test, to evaluate if their choices are, in fact, coherent or not. In any case, it will only be an additional analysis, and it won't influence the statistical analysis, because the questionnaire proposed is not the main part of the data gathering, and the data obtained were not sufficient for a proper analysis. Indeed, the purpose of the survey was another one.

Therefore, we build the experiment avoiding the focus on these themes in order to reduce the analysis only on the treatment, but it's our opinion that by including them, the results could be extremely interesting. Anyway, we proposed the questionnaire to fulfil our curiosity about the thought of our experiments and to understand if, even if these themes weren't directly proposed, they still could affect "subconsciously" the decision-making process of our participants.

The questionnaire is available in the appendix.

4. Analysis

4.1 Logit regression

Logistic regression is a statistical technique commonly used to model the relationship between a binary dependent variable and one or more independent variables. In the context of this study, the dependent variable "Choice" represents the participant's decision to select either option A or option B. The independent variable "Treatment" indicates whether the participant received a particular treatment or not, with a value of 1 denoting treatment and 0 denoting no treatment.

Additionally, the independent variable "turn" refers to the sequential order of decision-making rounds, ranging from 1 to 5. This variable helps capture any potential influence of the decision-making process evolving over time. By including "turn" as an independent variable in the logistic regression analysis, we could explore if there are any systematic changes in decision-making behaviour across different rounds.

Probit regression could be useful too, but in the case of extremely independent variables, such as the discrete dichotomy variable “membership” to the treatment group”, the Logit regression gives the best estimator (Hahn & Soyer, 2005).

To test the first (effect of default bias on managerial decision) and the second (persistency of default bias) *Hp* a logistic regression was conducted on the sample comprising participants of the first four sessions, who received treatment associated with choice A and their control group.

This approach aimed to investigate the effects of the treatment on decision-making processes and assess whether the treatment significantly influenced the likelihood of selecting option A.

The first regression was based on the independent variables *tr* (treatment, binary) and *turn* (turns, discrete, from 1 to 5). The dependent variable is *Choice* (player’s choice, binomial)

The output is the following:

Effect of treatment and turn on choosing A

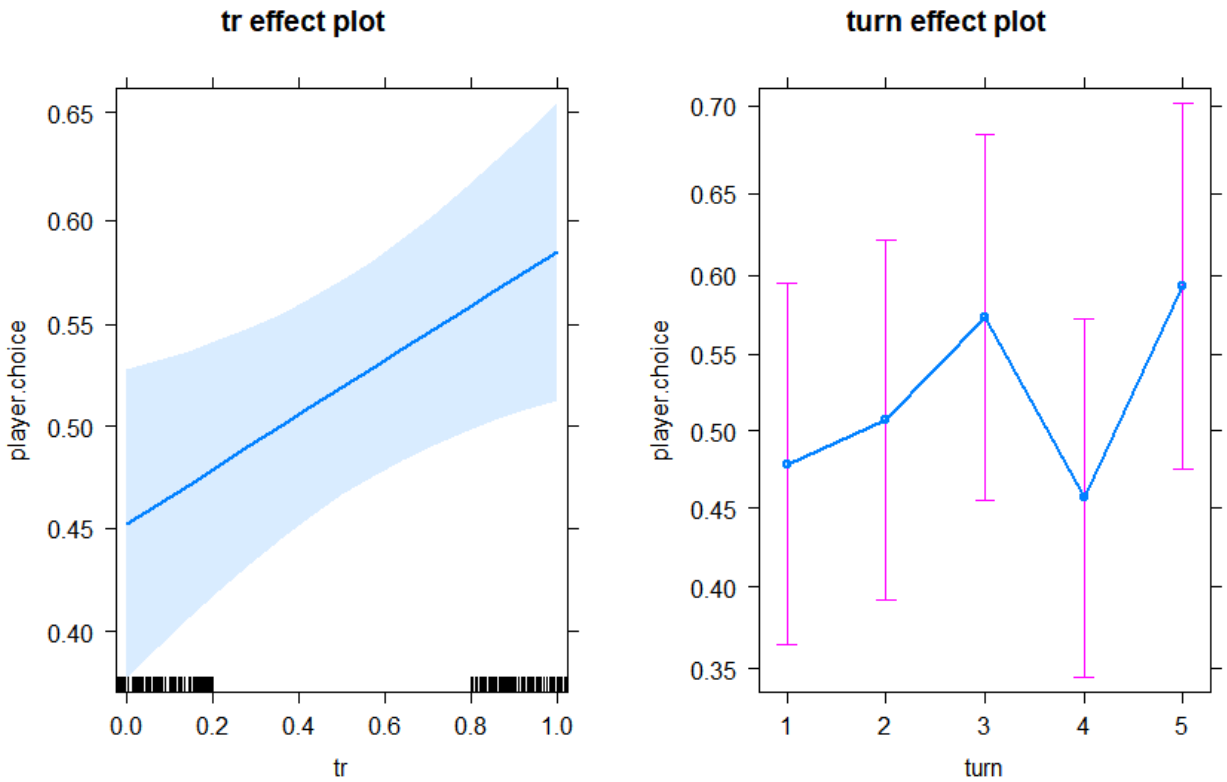


Table 1

Effects of treatment and turn on Variable Choice

COEFFICIENTS	ESTIMATE	STD.	ERROR Z	VALUE PR(>|Z|)
(INTERCEPT)	-0.36537	0.26535	-1.377	0.169
TR	0.53568	0.21578	2.483	0.013 *
TURN2	0.11476	0.33885	0.339	0.735
TURN3	0.38262	0.34186	1.119	0.263
TURN4	-0.08757	0.33823	-0.259	0.796
TURN5	0.46306	0.34177	1.355	0.175

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of the analysis provide support for the first and second hypotheses, indicating that the treatment has a significant effect on the decision-making process, leading to a higher likelihood of choosing option A over option B. However, the analysis also suggests that the impact of "experience" gained through turns is not as effective, nor statistically significant.

To further investigate the relationship between the treatment and decision-making process across different turns, five separate logistic regression analyses were conducted, one for each turn. This approach aimed to examine whether the treatment effect remained consistent throughout the decision-making process, testing the second *Hp*.

The findings of these individual regressions showed that the treatment continued to have a significant effect on the decision-making process at each turn. However, as the analysis was performed on a reduced sample size for each turn, the variable's statistical significance decreased.

The reduction in statistical significance could be attributed to the smaller sample size, which may lead to less precise estimates and wider confidence intervals. It is important to interpret these results cautiously, considering the limitations associated with the reduced sample size.

Overall, the results suggest that the treatment has a significant and consistent impact on the decision-making process across different turns. However, the decreasing statistical significance in the individual regressions may indicate the need for a larger sample size to provide more robust and reliable results.

Here are the results:

Table 2

Effect of treatment in each turn

FIRST TURN

COEFFICIENTS	Estimate	Std.	Error z	value Pr(>|z|)
(INTERCEPT)	-0.4796	0.3529	-1.359	0.174
TR	0.7515	0.4844	1.551	0.121

SECOND TURN

COEFFICIENTS	Estimate	Std.	Error z	value Pr(>|z|)
(INTERCEPT)	4.942e-17	3.430e-01	0.000	1.000
TR	0.7317	4.752e-01	0.114	0.909

THIRD TURN

COEFFICIENTS	Estimate	Std.	Error z	value Pr(>|z|)
(INTERCEPT)	-0.1178	0.3436	-0.343	0.732
TR	0.7309	0.4865	1.502	0.133

FOURTH TURN

COEFFICIENTS	Estimate	Std.	Error z	value Pr(>|z|)
(INTERCEPT)	-0.4796	0.3529	-1.359	0.174
TR	0.6421	0.4831	1.329	0.184

FIFTH TURN

COEFFICIENTS	Estimate	Std.	Error z	value Pr(>|z|)
(INTERCEPT)	0.1178	0.3436	0.343	0.732
TR	0.4953	0.4865	1.018	0.309

The findings of the additional analyses provide further confirmation of the second hypothesis, indicating that the treatment has a significant impact on the decision-making process throughout the entire experiment. However, it is important to note that the degree of the treatment's influence gradually diminishes as the experiment progresses from one turn to the next.

By considering the results from the interaction effects analysis, it was possible to explore the nuanced relationship between the treatment variable and other relevant independent variables. This analysis helps shed light on how different factors may moderate the effect of the treatment on the decision-making process.

Furthermore, examining the influence of the treatment across different turns allowed for a more comprehensive understanding of the dynamics involved in decision-making over time. The observed decrease in the treatment's effect as the experiment progresses suggests that participants may become less responsive to the treatment or that other factors come into play as the decision-making process evolves.

These findings imply that the treatment initially has a strong impact on participants' decision-making, but its effectiveness gradually diminishes over subsequent turns. It is important to

consider potential explanations for this decrease, such as habituation, learning effects, or the influence of external factors that may arise over time.

Overall, these results contribute to a deeper understanding of the second hypothesis, highlighting the complex dynamics of the treatment's influence on decision-making throughout the experiment. Further research could delve into the underlying mechanisms driving these findings and explore strategies to sustain the treatment's effectiveness over time.

The same regression was conducted on the sample composed of participants of the second half sessions. In this case the treatment was the opposite (preselected choice = B), but the variable *Choice* is considered in the same way as before (A =1, B = 0). Even in this case the independent variables were *tr* and *turn*. This regression was conducted to test the third *Hp*: the ethical feature of the choice strengthens the entity of the default effect.

Here is the result:

Effect of treatment and turn on choosing A (Treatment on option B)

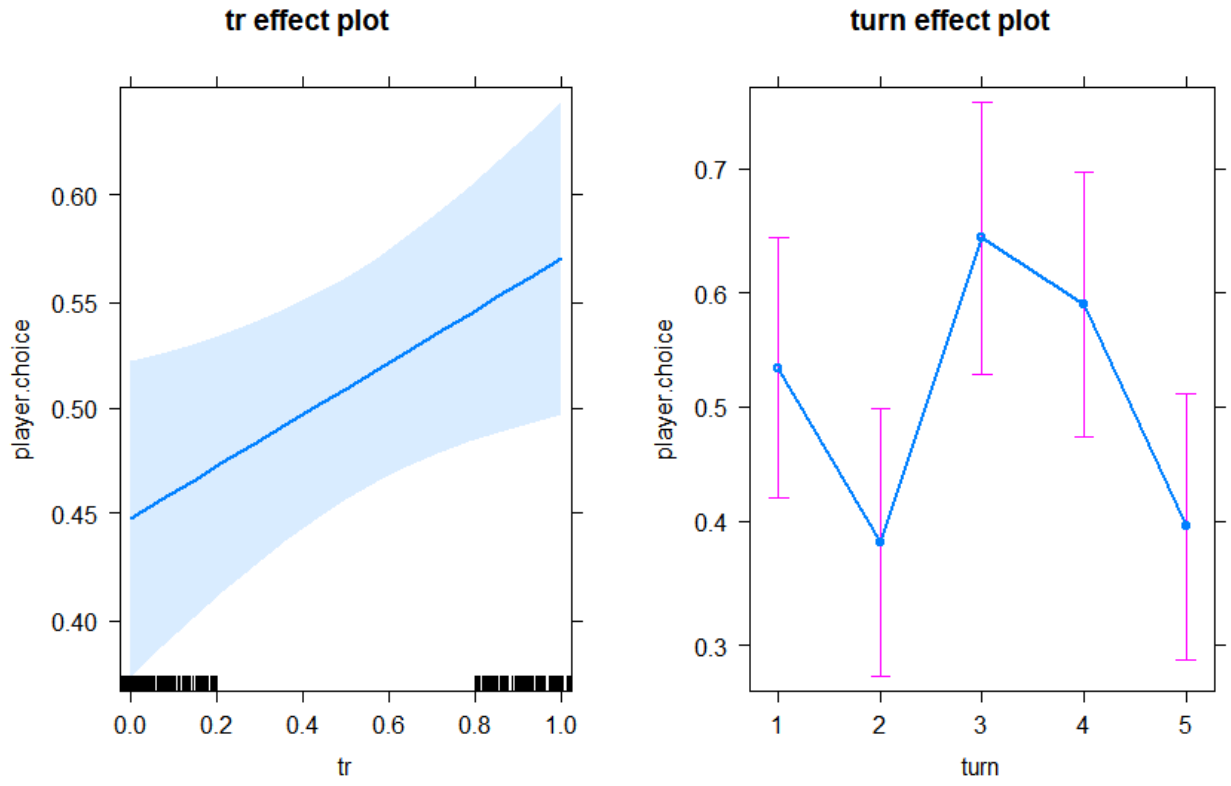


Table 3

Effect of treatment (option B) and turn on variable Choice

COEFFICIENTS	ESTIMATE	STD. ERROR	Z VALUE	PR(>|Z|)
(INTERCEPT)	-0.1112	0.2598	-0.428	0.6685
TR	0.4943	0.2159	2.289	0.0221 *
TURN2	-0.6209	0.3387	-1.833	0.0668 .
TURN3	0.4616	0.3413	1.352	0.1763
TURN4	0.2262	0.3366	0.672	0.5017
TURN5	-0.5625	0.3376	-1.666	0.0957 .

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The findings of the regression analysis further support the idea that the treatment has a positive effect in choosing A, contrary to what is typically expected in the literature, due to the default being the other choice. This aligns with the third hypothesis, suggesting that an ethical feature, such as the green sustainability of the option, enhances the likelihood of choosing option A (findings of the first regression) and the absence of an ethical feature of the preselected choice nullifies the occurrence of the default bias, as it is highlighted with this regression.

To confirm these results, provide additional evidence and testing directly the third *Hp*, a variable called CB (choice B) was created, which is the opposite of the Player.choice variable. In this case, B is assigned a value of 1 and A is assigned a value of 0. By analysing the relationship between this new variable and the treatment, it becomes evident that the treatment has a positive effect on the choice of option A and a negative effect on the choice of option B.

Not surprisingly, the results are the opposite of the previous one:

Effect of treatment (option B) and turn on choosing B

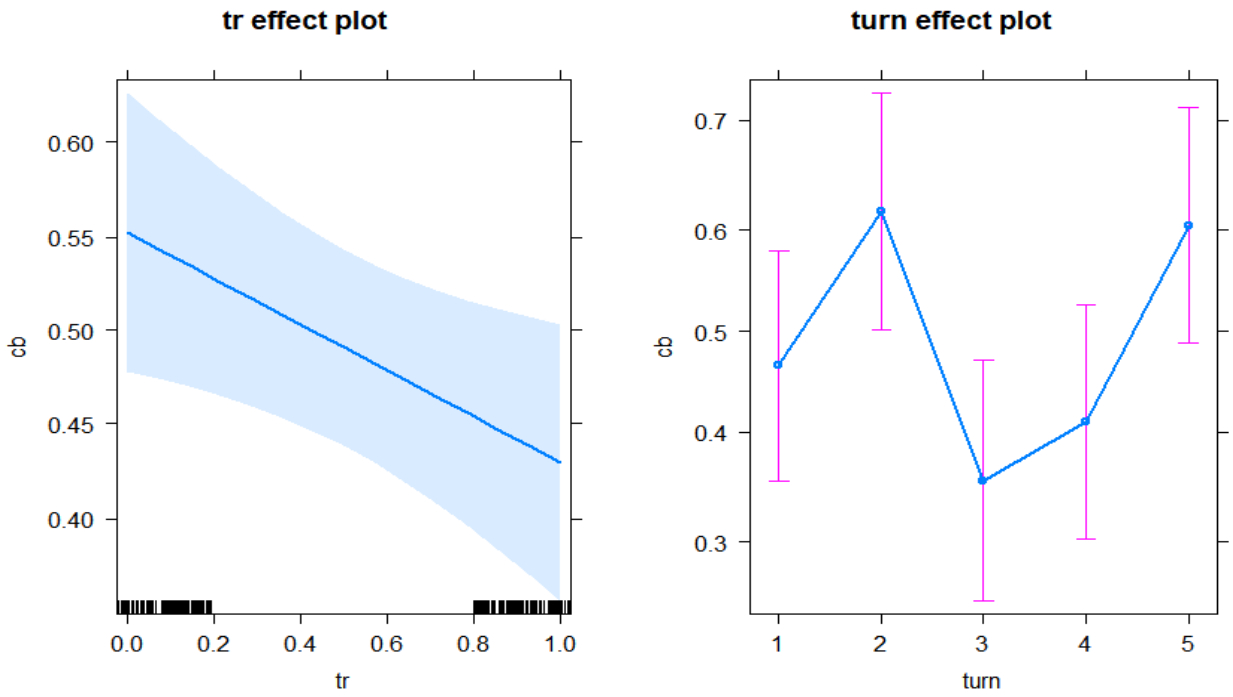


Table 4

Effect of Treatment (option B) and turn on
Variabile choice CB (inverse)

COEFFICIENTS	ESTIMATE	STD. ERROR	Z VALUE	PR(>|Z|)
(INTERCEPT)	0.1112	0.2598	0.428	0.6685
TR	-0.4943	0.2159	-2.289	0.0221 *
TURN2	0.6209	0.3387	1.833	0.0668 .
TURN3	-0.4616	0.3413	-1.352	0.1763
TURN4	-0.2262	0.3366	-0.672	0.5017
TURN5	0.5625	0.3376	1.666	0.0957 .

The confirmation of the hypothesis regarding the enhancement of the treatment effect due to ethical reasons opens a range of possible explanations for the observed results. One potential explanation is that without the ethical feature, the decision-making process is perceived as purely economic. In such a case, participants may not be significantly influenced by the treatment or may even perceive it as a trap, despite option B being the more financially advantageous choice.

This finding suggests that the ethical framing of the decision-making context plays a crucial role in shaping participants' choices. When the decision is presented in an ethical framework, participants are more likely to be influenced by the treatment and inclined to choose option A, even if it is not the most financially rewarding choice.

Even for the second sample were conducted regressions dividing the sample for each turn:

Table 5

Effect of Treatment (option B) in each turn

FIRST TURN

COEFFICIENT	Estimate	Std. Error	z value	Pr(>|z|)
(INTERCEPT)	3.655e-16	3.333e-01	0.000	1.000
TR	-2.719e-01	4.703e-01	-0.578	0.563

SECOND TURN

COEFFICIENT	Estimate	Std. Error	z value	Pr(>|z|)
(INTERCEPT)	0.45199	0.34188	1.322	0.186
TR	0.04445	0.48145	0.092	0.926

THIRD TURN

COEFFICIENT	Estimate	Std. Error	z value	Pr(>|z|)
(INTERCEPT)	-7.955e-16	3.333e-01	0.000	1.0000
TR	-1.288e+00	5.202e-01	-2.476	0.0133 *

FOURTH TURN

COEFFICIENT	Estimate	Std. Error	z value	Pr(>|z|)
(INTERCEPT)	0.1112	0.3338	0.333	0.7390
TR	-0.9714	0.4907	-1.980	0.0478 *

FIFTH TURN

COEFFICIENT	Estimate	Std. Error	z value	Pr(>|z|)
(INTERCEPT)	0.45199	0.34188	1.322	0.186
TR	-0.06899	0.47854	-0.144	0.885

The observation that the treatment variable does not exhibit a linear relationship across turns, unlike the other variables, suggests several possibilities regarding its effect on participants. On one hand, it may indicate that the treatment has no overall effect on decision-making. On the other hand, it could imply that the treatment only affects participants in specific situations, such as after experiencing repeated losses in previous turns.

These findings further reinforce the argument that the ethical features introduced in the experiment play a critical role in influencing participants' choices. The results suggest that ethical framing has a stronger impact on participants' decision-making than previously assumed, emphasizing its significance in shaping individuals' preferences and behaviours.

In this case, the dependent variable CB (choice B) was used for the regressions. Analysing the relationship between the treatment variable and CB provides additional evidence that the ethical features are more relevant than typically believed.

These results support the notion that the presence or absence of ethical considerations can significantly impact decision-making processes. The ethical features introduced in the second experiment seem to have a substantial influence on participants' choices, highlighting the importance of considering ethical framing when analysing decision-making outcomes.

In summary, the non-linear relationship between the treatment variable and the dependent variable CB suggests that the treatment may have specific effects in certain situations, such as after experiencing repeated losses. These results reinforce the argument that the ethical features introduced in the experiment have a significant impact on decision-making and are more relevant than commonly thought.

Robustness test

One of the main concerns was the potential presence of multicollinearity among the variables, as the outputs are the result of repeated choices. For this reason, we execute the VIF (Variance Inflation Factor), here is the result for the first sample:

```
         GVIF Df GVIF^(1/(2*Df))
tr   1.001206  1        1.000603
turn 1.001206  4        1.000151
```

Even though the index is slightly higher than 1 (presence of multicollinearity) it doesn't reach the warning level of 5 (Sarsted, 2019).

The second robust test was the Breuch-Pagan test. Here is the result:

```
BP = 2.1294, df = 5, p-value = 0.831
```
The null hypothesis is not rejected, meaning that the variance is not heteroscedastic.

The third test is the Chi-Squared test. Here is the result:

```
Chi-squared test:
X2 = 10.3, df = 6, P(> X2) = 0.11
```
The model is not significant at the 10% level, but it is extremely near to it.

For the second sample we run the same test, here are the results:

```
         GVIF Df GVIF^(1/(2*Df))
tr   1.002622  1        1.001310
turn 1.002622  4        1.000327
BP = 8.0441, df = 5, p-value = 0.1538
Chi-squared test:
X2 = 20.0, df = 6, P(> X2) = 0.0028
```

4.2 Additional analysis

In order to enhance the robustness of our findings, we conducted additional analyses leveraging the data collected through the questionnaire. In the second part of the questionnaire, participants were asked to rate their level of concern regarding the topic at hand using a scale of 1 to 10. For each experiment, we computed the mean and variance of the sum of these ratings.

For the first experiment, the mean rating was 39.22, with a variance of 23.25. In the second experiment, the mean rating was 37.34, with a variance of 31.6. These differences, particularly the discrepancy in variances, indicate that participants in the first sample were more invested in the topic than those in the second sample. While this is mathematically accurate, it may also suggest that the ethical components of the first treatment prompted participants to contemplate these issues. Indeed, not only did the first group have a higher sum of ratings, but their lower variance suggests that participants in this sample were more consistent in their ratings compared to the second sample.

Additionally, we conducted another analysis, termed the “Coherence” analysis. We determined that a rating of 5.5 (the average rating) indicates indifference toward the topic, with scores above this threshold indicating a higher level of concern. We summed the five ratings for each participant and subtracted 27.5 (5.5 multiplied by 5), resulting in only positive or negative values (integer ratings were mandatory). We then multiplied these values by another variable that

reflects the participants' choices: a value of 1 was assigned for selecting option A (a more cautious choice), while a value of -1 was assigned for selecting option B. This allowed us to identify participants who were consistent in their ratings and choices, despite any distortions caused by the game's mechanics.

Our goal was to adjust the mean and variance based on participants' choices, as they may have been influenced by various factors, such as convenience or repeated losses. With these adjustments, we were able to test whether participants' choices were coherent with their beliefs, which may have been impacted by the ethical features of the treatment. Our results confirmed this hypothesis: for the first sample, the mean and variance were 0.59 and 160.43, respectively, while for the second sample, the mean and variance were 0.44 and 134.15, respectively. Thus, participants in the first sample were more coherent than those in the second sample.

However, we still need to address the question of why the variance was higher in the first sample. Our interpretation (assuming no bias) is as follows: the treatment likely prompted participants to select option A more frequently, thus increasing the values obtained from the multiplication. However, in instances where a "careful" participant opted for option B (which can occur due to exploratory behaviour), the higher values resulted in a more significant subtraction during computation. We are able to formulate this interpretation based on our knowledge that option A was selected more frequently in the first experiment. The average rate (and variance) of the proportion of option A chosen in the first experiment was 0.52 and 0.02, respectively, compared to 0.50 and 0.03 for the second experiment.

5. Conclusion and future developments

Based on the analysis of the data, it can be concluded that all three hypotheses put forth have been proven. Through a simulation of an export strategy decision, a default bias has been reinforced by an ethical feature that nudges decision-makers towards a more eco-sustainable option. It would be interesting to investigate if administering the questionnaire prior to the decision-making process would further strengthen the ethical features of the simulation.

It was observed that option A is safer but more expensive than option B. In a competitive game like the one proposed, the less popular option becomes the best option. Therefore, if players perceive option A to be the best option, they would choose option B based on their expectations.

This was evidenced by the fact that there were several turns where option B was chosen more than option A, despite it not being remunerative the turn before.

In the analysis, the variable of experience was also included to determine if it had any effect on the decision-making process. While the results were not statistically significant, it cannot be ruled out that experience may play an important role in the choice. With a larger sample, it would be easier to detect this effect. However, the main factor affecting the choice remains the treatment, which was designed to create complete uncertainty. Therefore, after a few turns, players should have understood this and the choice becomes either to follow the treatment or bet on the other option, expecting that other players will follow the preselection. Further experimentation could be conducted to test this hypothesis, but too many turns could bore players, leading to indifferent choices.

This study possesses certain potential limitations that should be acknowledged. Notably, the examination of the third hypothesis necessitated the division of participants obtained through the CEEL into two interconnected yet distinct experiments. However, these experiments employed statistically opposing analyses, which resulted in diminished statistical validity due to reduced sample sizes within the respective populations.

Another noteworthy limitation lies in the fact that participants were required to assume roles that did not reflect their actual identities while making choices during the study. This aspect introduces an element of artificiality, raising the possibility that outcomes might differ significantly if the experiment were replicated with real entrepreneurs embodying their genuine roles and perspectives.

Despite these potential internal threats to the study's internal validity, it is crucial to highlight that the findings pertaining to the second and third hypotheses remain robust. This resilience stems from the theoretical grounding of these hypotheses on common human behaviour, which transcends the specific experimental context. Hence, the conclusions drawn from these aspects of the study retain their validity and contribute valuable insights to our understanding of the phenomena under investigation. Nevertheless, it is essential to exercise caution in generalizing the results to real-world settings with authentic entrepreneurs, as the artificial role-playing conditions may not fully reflect the complexities and intricacies of actual entrepreneurial decision-making

behaviour. Further research involving genuine entrepreneurial participants is warranted to ascertain the generalizability of the findings in real-life entrepreneurial scenarios.

Another possible alternative to consider is to reverse the order of the experiment. Administering the questionnaire before the experimental tasks could influence participants' decision-making processes in both the treatment and control groups. This change might lead the control group participants to make choices more similar to the treatment group, as the questionnaire could increase their awareness of the study's topics.

The findings of this study provide valuable insights for applied economics and policymaking. Governments could consider providing incentives for exporting by train or even setting it as the default option, as proposed in the experiment. This would lead to significant improvements in terms of quality of life and benefits for employees and firm owners. Additionally, pollution and energy usage would be greatly reduced.

In conclusion, it can be asserted that the default bias is reinforced by ethical features and sustained by increased awareness among people about them. Therefore, it is imperative to make individuals aware of these features and nudge them towards the desired solution.

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Appendix I

Here is the result of four sessions of the first version of the experiment (treatment on option A)

session.la	participan	player.ch	turn	tr	session.la	participan	player.ch	turn	tr	session.la	participan	player.ch	turn	tr	session.la	participan	player.ch	turn	tr
T1	1	1	1	1	T2	1	1	1	1	T3	1	0	1	1	T4	1	0	1	1
T1	2	0	1	0	T2	2	1	1	0	T3	2	0	1	0	T4	2	1	1	0
T1	3	0	1	1	T2	3	1	1	1	T3	3	1	1	1	T4	3	0	1	1
T1	4	1	1	0	T2	4	1	1	0	T3	4	0	1	0	T4	4	0	1	0
T1	5	0	1	1	T2	5	0	1	1	T3	5	0	1	1	T4	5	0	1	1
T1	6	1	1	0	T2	6	0	1	0	T3	6	0	1	0	T4	6	0	1	0
T1	7	1	1	1	T2	7	1	1	1	T3	7	1	1	1	T4	7	1	1	1
T1	8	1	1	0	T2	8	0	1	0	T3	8	0	1	0	T4	8	0	1	0
T1	9	0	1	1	T2	9	1	1	1	T3	9	0	1	1	T4	9	1	1	1
T1	10	1	1	0	T2	10	0	1	0	T3	10	0	1	0	T4	10	0	1	0
T1	11	1	1	1	T2	11	1	1	1	T3	11	0	1	1	T4	11	0	1	1
T1	12	0	1	0	T2	12	0	1	0	T3	12	1	1	0	T4	12	0	1	0
T1	13	1	1	1	T2	13	1	1	1	T3	13	1	1	1	T4	13	1	1	1
T1	14	0	1	0	T2	14	1	1	0	T3	14	0	1	0	T4	14	1	1	0
T1	15	1	1	1	T2	15	0	1	1	T3	15	1	1	1	T4	15	0	1	1
T1	16	0	1	0	T2	16	0	1	0	T3	16	1	1	0	T4	1	0	2	1
T1	17	0	1	1	T2	17	1	1	1	T3	1	1	2	1	T4	2	0	2	0
T1	18	1	1	0	T2	18	1	1	0	T3	2	1	2	0	T4	3	1	2	1
T1	19	1	1	1	T2	19	0	1	1	T3	3	0	2	1	T4	4	0	2	0
T1	1	1	2	1	T2	20	0	1	0	T3	4	1	2	0	T4	5	1	2	1
T1	2	1	2	0	T2	21	1	1	1	T3	5	1	2	1	T4	6	0	2	0
T1	3	1	2	1	T2	1	1	2	1	T3	6	0	2	0	T4	7	1	2	1
T1	4	1	2	0	T2	2	1	2	0	T3	7	0	2	1	T4	8	0	2	0
T1	5	0	2	1	T2	3	1	2	1	T3	8	1	2	0	T4	9	0	2	1
T1	6	0	2	0	T2	4	0	2	0	T3	9	1	2	1	T4	10	1	2	0
T1	7	1	2	1	T2	5	1	2	1	T3	10	0	2	0	T4	11	1	2	1
T1	8	0	2	0	T2	6	0	2	0	T3	11	0	2	1	T4	12	1	2	0
T1	9	0	2	1	T2	7	0	2	1	T3	12	0	2	0	T4	13	1	2	1
T1	10	1	2	0	T2	8	0	2	0	T3	13	1	2	1	T4	14	0	2	0
T1	11	1	2	1	T2	9	0	2	1	T3	14	0	2	0	T4	15	0	2	1
T1	12	1	2	0	T2	10	1	2	0	T3	15	0	2	1	T4	1	1	3	1
T1	13	0	2	1	T2	11	0	2	1	T3	16	1	2	0	T4	2	0	3	0
T1	14	1	2	0	T2	12	0	2	0	T3	1	1	3	1	T4	3	1	3	1
T1	15	1	2	1	T2	13	0	2	1	T3	2	0	3	0	T4	4	0	3	0
T1	16	1	2	0	T2	14	1	2	0	T3	3	0	3	1	T4	5	1	3	1
T1	17	0	2	1	T2	15	0	2	1	T3	4	1	3	0	T4	6	0	3	0
T1	18	1	2	0	T2	16	0	2	0	T3	5	0	3	1	T4	7	1	3	1
T1	19	0	2	1	T2	17	1	2	1	T3	6	1	3	0	T4	8	1	3	0
T1	1	0	3	1	T2	18	1	2	0	T3	7	1	3	1	T4	9	1	3	1
T1	2	0	3	0	T2	19	0	2	1	T3	8	1	3	0	T4	10	1	3	0
T1	3	1	3	1	T2	20	0	2	0	T3	9	1	3	1	T4	11	1	3	1
T1	4	1	3	0	T2	21	1	2	1	T3	10	1	3	0	T4	12	1	3	0
T1	5	0	3	1	T2	1	0	3	1	T3	11	0	3	1	T4	13	1	3	1
T1	6	0	3	0	T2	2	1	3	0	T3	12	1	3	0	T4	14	1	3	0
T1	7	1	3	1	T2	3	0	3	1	T3	13	1	3	1	T4	15	1	3	1
T1	8	0	3	0	T2	4	0	3	0	T3	14	1	3	0	T4	1	1	4	1
T1	9	0	3	1	T2	5	1	3	1	T3	15	1	3	1	T4	2	1	4	0
T1	10	1	3	0	T2	6	0	3	0	T3	16	0	3	0	T4	3	1	4	1
T1	11	0	3	1	T2	7	0	3	1	T3	1	0	4	1	T4	4	1	4	0
T1	12	0	3	0	T2	8	1	3	0	T3	2	0	4	0	T4	5	0	4	1
T1	13	1	3	1	T2	9	0	3	1	T3	3	1	4	1	T4	6	1	4	0
T1	14	0	3	0	T2	10	1	3	0	T3	4	1	4	0	T4	7	1	4	1
T1	15	0	3	1	T2	11	1	3	1	T3	5	0	4	1	T4	8	1	4	0
T1	16	1	3	0	T2	12	0	3	0	T3	6	0	4	0	T4	9	1	4	1
T1	17	1	3	1	T2	13	1	3	1	T3	7	1	4	1	T4	10	0	4	0
T1	18	0	3	0	T2	14	0	3	0	T3	8	0	4	0	T4	11	0	4	1
T1	19	0	4	1	T2	15	1	3	1	T3	9	0	4	1	T4	12	1	4	0
T1	1	1	4	1	T2	16	0	3	0	T3	10	0	4	0	T4	13	0	4	1
T1	2	0	4	0	T2	17	1	3	1	T3	11	0	4	1	T4	14	0	4	0
T1	3	1	4	1	T2	18	0	3	0	T3	12	0	4	0	T4	15	0	4	1
T1	4	1	4	0	T2	19	1	3	1	T3	13	1	4	1	T4	1	1	5	1
T1	5	0	4	1	T2	20	0	3	0	T3	14	0	4	0	T4	2	0	5	0
T1	6	1	4	0	T2	21	1	3	1	T3	15	1	4	1	T4	3	0	5	1
T1	7	1	4	1	T2	1	1	4	1	T3	16	0	4	0	T4	4	0	5	0
T1	8	0	4	0	T2	2	1	4	0	T3	1	1	5	1	T4	5	0	5	1
T1	9	1	4	1	T2	3	1	4	1	T3	2	1	5	0	T4	6	0	5	0
T1	10	1	4	0	T2	4	1	4	0	T3	3	1	5	1	T4	7	0	5	1
T1	11	0	4	1	T2	5	0	4	1	T3	4	1	5	0	T4	8	1	5	0
T1	12	0	4	0	T2	6	0	4	0	T3	5	1	5	1	T4	9	0	5	1
T1	13	0	4	1	T2	7	1	4	1	T3	6	1	5	0	T4	10	1	5	0
T1	14	0	4	0	T2	8	1	4	0	T3	7	1	5	1	T4	11	0	5	1
T1	15	0	4	1	T2	9	0	4	1	T3	8	1	5	0	T4	12	0	5	0
T1	16	0	4	0	T2	10	0	4	0	T3	9	1	5	1	T4	13	1	5	1
T1	17	1	4	1	T2	11	1	4	1	T3	10	1	5	0	T4	14	0	5	0
T1	18	1	4	0	T2	12	0	4	0	T3	11	0	5	1	T4	15	1	5	1
T1	19	0	4	1	T2	13	1	4	1	T3	12	0	5	0					
T1	1	1	5	1	T2	14	0	4	0	T3	13	1	5	1					
T1	2	1	5	0	T2	15	0	4	1	T3	14	1	5	0					
T1	3	1	5	1	T2	16	0	4	0	T3	15	0	5	1					
T1	4	0	5	0	T2	17	1	4	1	T3	16	1	5	0					
T1	5	0	5	1	T2	18	0	4	0										
T1	6	1	5	0	T2	19	1	4	1										
T1	7	1	5	1	T2	20	0	4	0										
T1	8	0	5	0	T2	21	0	4	1										
T1	9	1	5	1	T2	1	1	5	1										
T1	10	1	5	0	T2	2	0	5	0										
T1	11	1	5	1	T2	3	1	5	1										
T1	12	0	5	0	T2	4	1	5	0										
T1	13	1	5	1	T2	5	1	5	1										
T1	14	1	5	0	T2	6	1	5	0										
T1	15	0	5	1	T2	7	1	5	1										
T1	16	0	5	0	T2	8	1	5	0										
T1	17	1	5	1	T2	9	1	5	1										
T1	18	0	5	0	T2	10	1	5	0										
T1	19	0	5	1	T2	11	1	5	1										
					T2	12	0	5	0										
					T2	13	1	5	1										
					T2	14	0	5	0										
					T2	15	0	5	1										
					T2	16	1	5	0										
					T2	17	0	5	1										
					T2	18	0	5	0										
					T2	19	1	5	1										
					T2	20	0	5	0										
					T2	21	0	5	1										

Here is the result of the second version of the experiment (treatment on option B)

session.la	participan	player.ch	turn	tr	session.la	participan	player.ch	turn	tr	session.la	participan	player.ch	turn	tr	session.la	participan	player.ch	turn	tr
T5	1	1	1	1	T6	1	1	1	1	T7	1	1	1	1	T8	1	0	1	1
T5	2	0	1	0	T6	2	1	1	0	T7	2	1	1	0	T8	2	1	1	0
T5	3	0	1	1	T6	3	1	1	1	T7	3	0	1	1	T8	3	0	1	1
T5	4	0	1	0	T6	4	1	1	0	T7	4	1	1	0	T8	4	1	1	0
T5	5	1	1	1	T6	5	1	1	1	T7	5	1	1	1	T8	5	1	1	1
T5	6	1	1	0	T6	6	0	1	0	T7	6	0	1	0	T8	6	1	1	0
T5	7	1	1	1	T6	7	1	1	1	T7	7	1	1	1	T8	7	1	1	1
T5	8	0	1	0	T6	8	0	1	0	T7	8	0	1	0	T8	8	1	1	0
T5	9	0	1	1	T6	9	0	1	1	T7	9	1	1	1	T8	9	0	1	1
T5	10	1	1	0	T6	10	0	1	0	T7	10	0	1	0	T8	10	0	1	0
T5	11	0	1	1	T6	11	1	1	1	T7	11	1	1	1	T8	11	1	1	1
T5	12	0	1	0	T6	12	0	1	0	T7	12	1	1	0	T8	12	1	1	0
T5	13	0	1	1	T6	13	0	1	1	T7	13	1	1	1	T8	13	1	1	1
T5	14	0	1	0	T6	14	0	1	0	T7	14	0	1	0	T8	14	1	1	0
T5	15	0	1	1	T6	15	1	1	1	T7	1	1	2	1	T8	15	0	1	1
T5	16	0	1	0	T6	16	1	1	0	T7	2	0	2	0	T8	16	1	1	0
T5	17	0	1	1	T6	17	1	1	1	T7	3	1	2	1	T8	17	0	1	1
T5	18	1	1	0	T6	18	1	1	0	T7	4	0	2	0	T8	18	1	1	0
T5	19	0	1	1	T6	19	0	1	1	T7	5	0	2	1	T8	1	1	2	1
T5	1	0	2	1	T6	20	0	1	0	T7	6	1	2	0	T8	2	1	2	0
T5	2	0	2	0	T6	21	1	1	1	T7	7	0	2	1	T8	3	0	2	1
T5	3	0	2	1	T6	22	0	1	0	T7	8	0	2	0	T8	4	1	2	0
T5	4	0	2	0	T6	1	0	2	1	T7	9	1	2	1	T8	5	1	2	1
T5	5	1	2	1	T6	2	0	2	0	T7	10	1	2	0	T8	6	1	2	0
T5	6	1	2	0	T6	3	0	2	1	T7	11	1	2	1	T8	7	0	2	1
T5	7	0	2	1	T6	4	1	2	0	T7	12	0	2	0	T8	8	0	2	0
T5	8	0	2	0	T6	5	1	2	1	T7	13	0	2	1	T8	9	0	2	1
T5	9	0	2	1	T6	6	0	2	0	T7	14	1	2	0	T8	10	0	2	0
T5	10	1	2	0	T6	7	0	2	1	T7	1	1	3	1	T8	11	1	2	1
T5	11	0	2	1	T6	8	0	2	0	T7	2	0	3	0	T8	12	1	2	0
T5	12	1	2	0	T6	9	0	2	1	T7	3	1	3	1	T8	13	1	2	1
T5	13	1	2	1	T6	10	1	2	0	T7	4	1	3	0	T8	14	0	2	0
T5	14	0	2	0	T6	11	0	2	1	T7	5	1	3	1	T8	15	1	2	1
T5	15	0	2	1	T6	12	0	2	0	T7	6	0	3	0	T8	16	1	2	0
T5	16	0	2	0	T6	13	0	2	1	T7	7	1	3	1	T8	17	0	2	1
T5	17	1	2	1	T6	14	0	2	0	T7	8	0	3	0	T8	18	0	2	0
T5	18	1	2	0	T6	15	0	2	1	T7	9	0	3	1	T8	1	0	3	1
T5	19	0	2	1	T6	16	0	2	0	T7	10	1	3	0	T8	2	0	3	0
T5	1	1	3	1	T6	17	0	2	1	T7	11	1	3	1	T8	3	1	3	1
T5	2	0	3	0	T6	18	0	2	0	T7	12	0	3	0	T8	4	0	3	0
T5	3	1	3	1	T6	19	1	2	1	T7	13	1	3	1	T8	5	0	3	1
T5	4	1	3	0	T6	20	0	2	0	T7	14	1	3	0	T8	6	1	3	0
T5	5	1	3	1	T6	21	0	2	1	T7	1	1	4	1	T8	7	0	3	1
T5	6	1	3	0	T6	22	0	2	0	T7	2	1	4	0	T8	8	0	3	0
T5	7	1	3	1	T6	1	1	3	1	T7	3	1	4	1	T8	9	1	3	1
T5	8	0	3	0	T6	2	0	3	0	T7	4	1	4	0	T8	10	0	3	0
T5	9	1	3	1	T6	3	1	3	1	T7	5	1	4	1	T8	11	1	3	1
T5	10	1	3	0	T6	4	1	3	0	T7	6	0	4	0	T8	12	0	3	0
T5	11	1	3	1	T6	5	1	3	1	T7	7	0	4	1	T8	13	1	3	1
T5	12	1	3	0	T6	6	0	3	0	T7	8	0	4	0	T8	14	0	3	0
T5	13	1	3	1	T6	7	1	3	1	T7	9	1	4	1	T8	15	0	3	1
T5	14	1	3	0	T6	8	1	3	0	T7	10	0	4	0	T8	16	0	3	0
T5	15	1	3	1	T6	9	1	3	1	T7	11	0	4	1	T8	17	1	3	1
T5	16	1	3	0	T6	10	0	3	0	T7	12	0	4	0	T8	18	1	3	0
T5	17	1	3	1	T6	11	1	3	1	T7	13	1	4	1	T8	1	1	4	1
T5	18	0	3	0	T6	12	1	3	0	T7	14	0	4	0	T8	2	1	4	0
T5	19	0	3	1	T6	13	0	3	1	T7	1	1	5	1	T8	3	1	4	1
T5	1	1	4	1	T6	14	1	3	0	T7	2	0	5	0	T8	4	1	4	0
T5	2	1	4	0	T6	15	1	3	1	T7	3	0	5	1	T8	5	1	4	1
T5	3	1	4	1	T6	16	0	3	0	T7	4	1	5	0	T8	6	0	4	0
T5	4	0	4	0	T6	17	1	3	1	T7	5	1	5	1	T8	7	0	4	1
T5	5	1	4	1	T6	18	1	3	0	T7	6	0	5	0	T8	8	0	4	0
T5	6	1	4	0	T6	19	1	3	1	T7	7	1	5	1	T8	9	1	4	1
T5	7	1	4	1	T6	20	1	3	0	T7	8	0	5	0	T8	10	0	4	0
T5	8	1	4	0	T6	21	0	3	1	T7	9	1	5	1	T8	11	1	4	1
T5	9	1	4	1	T6	22	1	3	0	T7	10	1	5	0	T8	12	1	4	0
T5	10	1	4	0	T6	1	1	4	1	T7	11	1	5	1	T8	13	1	4	1
T5	11	1	4	1	T6	2	0	4	0	T7	12	1	5	0	T8	14	0	4	0
T5	12	0	4	0	T6	3	1	4	1	T7	13	0	5	1	T8	15	0	4	1
T5	13	0	4	1	T6	4	1	4	0	T7	14	0	5	0	T8	16	1	4	0
T5	14	1	4	0	T6	5	1	4	1						T8	17	1	4	1
T5	15	0	4	1	T6	6	1	4	0						T8	18	0	4	0
T5	16	1	4	0	T6	7	1	4	1						T8	1	0	5	1
T5	17	0	4	1	T6	8	0	4	0						T8	2	1	5	0
T5	18	0	4	0	T6	9	1	4	1						T8	3	1	5	1
T5	19	0	4	1	T6	10	1	4	0						T8	4	0	5	0
T5	1	1	5	1	T6	11	1	4	1						T8	5	0	5	1
T5	2	0	5	0	T6	12	0	4	0						T8	6	1	5	0
T5	3	0	5	1	T6	13	0	4	1						T8	7	0	5	1
T5	4	0	5	0	T6	14	0	4	0						T8	8	0	5	0
T5	5	1	5	1	T6	15	0	4	1						T8	9	0	5	1
T5	6	0	5	0	T6	16	1	4	0						T8	10	0	5	0
T5	7	0	5	1	T6	17	1	4	1						T8	11	1	5	1
T5	8	1	5	0	T6	18	1	4	0						T8	12	1	5	0
T5	9	1	5	1	T6	19	1	4	1						T8	13	1	5	1
T5	10	0	5	0	T6	20	0	4	0						T8	14	1	5	0
T5	11	1	5	1	T6	21	0	4	1						T8	15	0	5	1
T5	12	1	5	0	T6	22	0	4	0						T8	16	1	5	0
T5	13	0	5	1	T6	1	1	5	1						T8	17	0	5	1
T5	14	0	5	0	T6	2	0	5	0						T8	18	0	5	0
T5	15	0	5	1	T6	3	0	5	1										
T5	16	1	5	0	T6	4	0	5	0										
T5	17	0	5	1	T6	5	0	5	1										
T5	18	1	5	0	T6	6	0	5	0										
T5	19	0	5	1	T6	7	1	5	1										
					T6	8	0	5	0										
					T6	9	0	5	1										
					T6	10	0	5	0										
					T6	11	1	5	1										
					T6	12	0	5	0										
					T6	13	0	5	1										
					T6	14	0	5	0										
					T6	15	0	5	1										
					T6	16	0	5	0										
					T6	17	0	5	1										
					T6	18	1	5	0										
					T6	19	0	5	1										
					T6	20	1	5	0										
					T6	21	0	5	1										
					T6	22	0	5	0										

Appendix II

Here the questionnaire was proposed to participants at the end of the experiment.

First part: Demographics

- What is your age?
- What gender do you identify as?
- What is your current occupation?
- What is the highest degree or level of education you have completed?

Second part: ethical traits of the choice

Values between 1 (not influent) and 10 (extremely important)

- How much would affect your decision between train and truck the eco-sustainability of the first option?
- How much do you evaluate would be the benefit for the company's image for choosing a green strategy for export?
- How much do you evaluate the possible impact of using trucks on the local environment?
- How much would affect on your decision the different conditions for your employees offered by the two options?
- How much would affect on your decision the presence of incentives as tax reduction?

The potential impact of Brenner Basis Tunnel: an empirical simulation

Abstract

It is widely recognized that the introduction of new transportation routes has a significant impact on the local economies of the affected regions. This paper presents a simulation study focused on investigating the potential effects of the Brennero Basis Tunnel (BBT) opening on the economies of Bozen, Trento, and Innsbruck provinces. Through our simulation, applying the model proposed by Monte et Al (2018), we examine the potential outcomes of this infrastructure development. Our findings strongly suggest that the opening of the BBT will have substantial effects on these provinces. Specifically, it is expected to stimulate commuting activities, leading to changes in housing prices, particularly in the Bozen region. Additionally, the overall welfare of the studied regions is projected to experience positive growth as a result of this transportation project. This research provides valuable insights into the anticipated economic consequences of the BBT opening for the provinces under consideration.

1. Introduction

In 2028, the opening of the tunnel beneath the Brenner Pass is planned, connecting the city of Bolzano to the high-speed rail line that, passing through Innsbruck, terminates in the city of Munich. It is anticipated that the opening of the Brenner Base Tunnel (BBT) will bring about significant changes in local economies, such as those of Trentino and South Tyrol. The objective of this paper, through simulation, is to quantify the impact of this opening.

Several authors have engaged in a comprehensive academic discourse concerning the role of infrastructure in economic growth, resulting in a substantial body of literature. Aschauer's seminal work (Aschauer,1989a, 1989b) explores the relationship between public investment and economic growth, affirming a high return on infrastructure investments. Furthermore, Eberts' foundational research (Ebert, 1990) elucidates the impact of public infrastructure on regional economic development. Since 1990, the literature has expanded, delving into various dimensions of the relationship between infrastructure and economic development. A well-designed infrastructure exerts a positive influence on long-term economic growth (Farhadi, 2015), worker productivity, labour markets (by generating employment opportunities in construction and maintenance sectors), education, health, and the revitalization of underdeveloped or impoverished areas (Palei, 2015).

Furthermore, a robust body of literature exists on the relationship between railway infrastructure and economic growth. Donaldson has made significant contributions by analyzing the impact of railroads on economic growth, utilizing historical data from the United States (Donaldson, 2016)

and introducing a novel approach distinct from Fogel (Fogel, 1964) as well as examining historical data from India (Donaldson, 2018).

Numerous authors have expanded the literature by approaching the topic from different angles and exploring various aspects. Studies have examined the link between high-speed rail and the growth of city systems (Kobayashi et al, 1997) as well as the transformative effects of such rail systems on regional economies (Vickerman, 2018). Additionally, the literature has highlighted the positive effects of high-speed rail on passengers (e.g. Lingatis et Al, 2014).

Empirical studies on different countries have also contributed to the literature. Examples include research conducted on Italy (Cascetta et Al, 2020), on China (Shi, 2018), and Sweden (Fröidh, 2005). Despite the differing approaches and focuses of these studies, each one supports the notion of a positive impact of high-speed rail on economic growth.

In this paper, we aim to replicate the analysis conducted by Monte et al. (Monte et Al, 2018). While their study focused on an extensive sample of 123 regions and 3,111 provinces, our objective is to narrow our scope to three specific provinces: Bozen, Innsbruck, and Trento. We seek to simulate the potential effects of the opening of the Brenner Base Tunnel (BBT) railway on these provinces. The BBT is designed to facilitate both the transportation of goods and the movement of people. Currently, both Innsbruck and Trentino Alto Adige boast thriving manufacturing economies, and there is already a substantial volume of trade between them. It is therefore of great interest to explore how this connection could be further influenced by a faster and more efficient transportation link.

Furthermore, despite the existing travel time required to reach Innsbruck, commuting from Bozen remains significant. Hence, it is crucial to examine how the implementation of the BBT could impact this commuting pattern.

In contrast to the approach taken by the authors, our study considers distances between provinces in terms of travel time rather than kilometres. This alternative perspective allows us to conceptualize a reduction in travel time as a reduction in distances. By doing so, we can capture the impact of time savings on trading and commuting costs. Additionally, focusing on a smaller sample of provinces, we have refined the methodology employed by the authors by assigning specific reduction values to each route (such as Bozen-Innsbruck) within the matrix. This approach

enables us to generate varying levels of effects, with the Bozen-Innsbruck route experiencing the most significant impact and the Trento-Innsbruck route being affected to a lesser extent. Moreover, we also account for the indirect effects on commuting and trade between Trento and Bozen, even if their direct route remains unaffected by technological improvement.

Our findings demonstrate the potential impact of the Brenner Base Tunnel (BBT) opening on the regional economies of the analyzed countries. Specifically, the results indicate a substantial improvement in commuting costs (especially in time required), particularly towards the region with the highest wages (Innsbruck). Additionally, the opening of the BBT stimulates commuting between the other two regions that are not directly served by the new faster route. We also consider other relevant variables, such as welfare, wages, and expected salaries (considering all the possible commuting workplaces), in our analysis.

The model utilized in our study builds upon previous works in the fields of economic geography, factor mobility, and trade in goods. It was built upon the influential contributions of Krugman (Krugman, 1991) as well as the research conducted by Hanson (Hanson,1996; Hanson, 2005), Helpman (Helpman, 1998), Fujita and Krugman (Fujita et Al, 1999) and several other authors (Rossi Hamber,2005; Redding and Sturm, 2008; Kline and Moretti, 2014; Allen et Al, 2014; Caliendo et Al, 2018; Desmet and Rossi-Hamberg, 26). Moreover, the model incorporates insights from the field of urban economics and commuting literature, taking into account the works of Redding (Redding, 2016), Alonso (Alonso, 1964), Mills (Mills, 1967), Muth (Muth, 1969) and other scholars (Lucas and Rossi-Hamberg, 2002; Desmet and Rossi-Hamberg, 2013; Behrens et Al, 2017; Ahlfedt et Al, 2015).

Moreover, the model is based on the quantitative framework for analyzing costly trade in goods developed by Eaton and Kortum (Eaton and Kortum, 2002). However, our contribution lies in the application of this model to examine specific effects, particularly concerning the opening of the Brenner Base Tunnel (BBT) and its implications for the regions under study.
The paper is structured in the following way:

- Model
- Dataset
- Analysis
- Conclusions and further analysis)

2. The model

The model is constructed as a spatial general equilibrium model, encompassing n locations denoted by n (where workers reside) and *i* (where workers are employed). Each location is endowed with a supply of land (H_n) and workers (L_n).

The model links the locations in the following scheme:

- Good market
  - Trade
- Factor market
  - Commuting
  - Migration

In the following paragraphs, the model will be exposed in each "section".

2.1 Preferences and endowment

In order to maximize their utility, each worker ω in our model makes choices regarding their residence and workplace locations. These choices are made taking into account the decisions made by other workers and firms, which are treated as exogenous or given in the analysis.

The formula used is the following:

$$U_{ni\omega} = \frac{b_{ni\omega}}{k_{ni}} \left(\frac{C_{n\omega}}{\alpha}\right)^{\alpha} \left(\frac{H_{n\omega}}{\alpha}\right)^{1-\alpha}$$

Where:

- ω is worker
- $C_{n\omega}$ is the final good consumption
- $H_{n\omega}$ is land use
- n location where the worker lives and consumes
- i location where the worker works
- $b_{ni\omega}$ is an idiosyncratic amenities shock
- k_{ni} ($\in [1,\infty)$)are iceberg commuting costs in terms of utility.

The idiosyncratic amenities in our model are drawn from an independent Fréchet distribution. This distribution is based on the work of Eaton and Kortum (Eaton and Kortum, 2002) and McFadden (McFadden, 1974))

$$G_{ni}(b) = e^{-B_{ni}\, b^{-\epsilon}}$$

$$B_{ni} > 0, \epsilon > 1$$

In our model, B_{ni} represents the average amenities derived from living in location *n* and working in location *i*. The dispersion of amenities is controlled by the shape parameter ϵ. This parameter determines the degree of variation or heterogeneity in the distribution of amenities across different locations.

To isolate the commuting effect in our analysis, the modeling of goods consumption is approached in the following manner:

$$C_n = [\sum_{i \epsilon \mathrm{N}} \int_0^M c_{ni}(j)^{\rho} dj\ ]^{1/\rho}$$

$$\sigma = \frac{1}{1-\rho} > 1$$

Due to utility maximization, to reach general equilibrium in *n*, are implied:

- $c_{ni}(j) = \alpha X_n P_n^{\sigma-1} p_{ni}(j)^{-\sigma}$
- Expenditure on residential land = Income_{ω} (1-α)

With

- X_n is the aggregate expenditure in n
- P_n is the price index
- $P_{ni}(j)$ is the price of variety j produced in *i* and consumed in n

Denoting α as the fraction of the population that works and (1 - α) as the proportion of pure landlords (those who rent property but do not work), the total expenditure on goods consumption can be expressed as follows:

$$P_n\, C_n = \alpha\, \bar{v}_n\, R_n + (1 - \alpha)\, \bar{v}_n R_n = \bar{v}_n R_n$$

- $\bar{v}$ = average labor income of residents
- R_n = measure of residents

The land price (Q_n) is determined using a formula that ensures the clearing of the land market. This formula is derived to achieve equilibrium in the land market:

$$Q_n = (1-\alpha)\frac{\bar{v}_n R_n}{H_n}$$

2.2 Production

Under the assumption of monopolistic competition and increasing returns to scale, the production process is modelled following the framework used in the new economic geography literature. This approach allows us to isolate the commuting effect in the analysis.

The amount of labour required is computed in the following way:

$$l_i(j) = F + \frac{x_i(j)}{A_i}$$

- x unity of good j produced in i
- F is fixed cost
- A_i is productivity in i

The technology production is generalized in order to include intermediate inputs (Krugman and Venables, 1995; Eaton and Kortum, 2002), physical capital and commercial land use.

Due to profit maximization:

- $p_{ni}(j) = (\frac{\sigma}{\sigma-1})\frac{d_{ni}w_i}{A_i}$

With

- w = wage

The equilibrium output for each j is determined by combining it with the condition of zero profit:

$$x_i(j) = A_i F(\sigma - 1)$$

Assuming it with the market labor clearing is implied as follows:

$$M_i = L_i/\sigma F$$

- M_i is the total production
- L_i are the employed workers

2.3 Goods Trade

The gravity equation for bilateral trade is derived from the model. The share of the location n's expenditure on goods produced in location *i* (π) is obtained through the CES (Constant Elasticity of Substitution) expenditure function, considering the measure of firms and the equilibrium pricing rule. This formulation allows us to analyze and quantify the patterns of trade between different locations based on their economic characteristics and relative prices.
The formula is the following:

$$\pi_{ni} = \frac{M_i p_{ni}^{1-\sigma}}{\sum_{k\epsilon N} M_k p_{nk}^{1-\sigma}}$$

That is equal to:

$$\frac{L_i (^{d_{ni} w_i}/_{A_i})^{1-\sigma}}{\sum_{k\epsilon N} L_k (^{d_{nk} w_k}/_{A_k})^{1-\sigma}}$$

- d_{ni} is the bilateral trade cost (bilateral resistance)

Combining zero profit and Revenue = Expenditure, is obtained:

$$w_i L_i = \sum_{n\in N} \pi_{ni} \bar{v}_n R_n$$

The price index, which is dual to the consumption index, is derived by combining the equilibrium pricing conditions with labour market clearing. This approach ensures that prices are set in a manner that achieves a balance between supply and demand in both the goods market and the labour market. By incorporating these factors, is possible to determine the price level that corresponds to the consumption patterns and labour market conditions in the model.

$$P_n = \frac{\sigma}{\sigma - 1}\left(\frac{1}{\sigma F}\right)^{1/1-\sigma}\left[\sum_{i\epsilon N} L_i\left(\frac{d_{ni}w_i}{A_i}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$$

That's equal to:

$$P_n = \frac{\sigma}{\sigma - 1}\left(\frac{L_n}{\sigma F \pi_{nn}}\right)^{\frac{1}{1-\sigma}}\frac{d_{nn}w_n}{A_n}$$

2.4 Labor mobility and commuting

By utilizing the formulas presented in the initial section, the indirect utility function of workers can be derived.

This function captures the relationship between workers' preferences and the various economic variables, allowing us to analyze the utility or satisfaction derived by workers from their consumption and labour choices within the model.

$$U_{ni\omega} = \frac{b_{ni\omega}w_i}{k_{ni}P_n^{\alpha}Q_n^{1-\alpha}}$$

Given the dependency on a variable that follows a Fréchet distribution, the indirect utility function also follows the same distribution. Moreover, the maximum of this distribution, representing the optimal choice, is itself Fréchet distributed.

Therefore, the probability of a worker choosing to work in location *i* and live in location *n* can be expressed as follows:

$$\lambda_{ni} = \frac{B_{ni}(k_{ni}P_n^{\alpha}Q_n^{1-\alpha})^{-\epsilon}w_i^{\epsilon}}{\sum_{r\epsilon N}\sum_{s\epsilon N} B_{rs}(k_{rs}P_r^{\alpha}Q_r^{1-\alpha})^{-\epsilon}w_s^{\epsilon}} \equiv \frac{\Phi_{ni}}{\Phi}$$

The criteria that the workers should apply in their decision should be the following:

- ✓ lowest cost in n (P and Q)
- ✓ highest wage in i (w)
- ✓ more attractive average amenities (B_{ni})
- ✓ lowest commuting cost (k_{ni})

Following these criteria, we can derive the probability of choosing to live in location n by summing the probabilities associated with each possible working location *i*. Similarly, we can obtain the

probability of choosing the working location by summing the probabilities related to each potential living location.

Using *R* to represent the living location and *L* to represent the working location, we can construct the following system:

- $\lambda_n^R = {R_n}/{\bar{L}} = \sum_{i\epsilon N} \lambda_{ni} = \sum_{i\epsilon N} \frac{\Phi_{ni}}{\Phi}$
- $\lambda_i^L = {L_n}/{\bar{L}} = \sum_{n\epsilon N} \lambda_{ni} = \sum_{n\epsilon N} \frac{\Phi_{ni}}{\Phi}$
- National labor market clearing: $\sum_n \lambda_n^R = \sum_i \lambda_i^L = 1$

Furthermore, the probability of each worker's choice is dependent on the conditions of other workers nearby.

This interdependency can be mathematically described as follows:

$$\lambda_{ni|n}^R \equiv \frac{\lambda_{ni}}{\lambda_n^R} = \frac{B_{ni}(w_i/k_{ni})^{\in}}{\sum_{s\in N} B_{ns}(w_s/k_{ns})^{\in}}$$

This equation implies that the commuting function follows a gravity model, with an elasticity parameter related to *k* equal to -∈, consistently with the cited literature (McFadden,1974; Grogger and Hanson,2011). Using this equation, we can establish the labor market clearing condition:

$$L_i = \sum_{n\in N} \lambda_{ni|n}^R R_n$$

Similarly, it can be computed the expected income:

$$\overline{v_n} = \sum_{I\in N} \lambda_{ni|n}^R w_i$$

This condition indicates that the labour market clearing equation is directly proportional to wages and inversely proportional to commuting costs. It captures the trade-off between wages and

commuting expenses in determining the equilibrium allocation of workers across different locations.

Furthermore, due to population mobility, the expected utility is equal for both working and living locations, as well as for the overall economy. This ensures that individuals are making choices that maximize their utility across various locations, taking into account factors such as amenities, wages, and commuting costs.

$$\bar{U} = E[U_{ni\omega}] = \Gamma(\frac{\epsilon - 1}{\epsilon})[\sum_{r \epsilon N} \sum_{s \epsilon N} B_{rs}(k_{rs} P_r^{\alpha} Q_r^{1-\alpha})^{-\epsilon} w_s^{\epsilon}]^{\frac{1}{\epsilon}}$$

- E is the expectations operator
- Γ Gamma function

2.5 General equilibrium

The general equilibrium is achieved through the following system of equations:

- Land market clearing

$$Q_n = (1 - \alpha)\frac{\bar{v}_n R_n}{H_n}$$

- Income equals to expenditure

$$w_i L_i = \sum_{n \in N} \pi_{ni} \bar{v}_n R_n$$

- Prices indices

$$P_n = \frac{\sigma}{\sigma - 1}(\frac{L_n}{\sigma F \pi_{nn}})^{\frac{1}{1-\sigma}} \frac{d_{nn} w_n}{A_n}$$

- Work-place choice probabilities

$$\sum_n \lambda_n^R = 1$$

- Residence choice probabilities

$$\sum_i \lambda_i^L = 1$$

- Average residential income

$$\overline{v_n} = \sum_{I \in N} \lambda_{ni|n}^R w_i$$

In addition, in order to find the scalar $\bar{U}$ is required to satisfy the following condition:

- Labor market clearing

$$\bar{L} = \sum_{n \epsilon N} R_n = \sum_{n \epsilon N} L_n$$

- w_i is wages
- L_i employment
- v_i average residential income
- R_i are residents
- D_i are trade deficits
- σ is the elasticity of substitution
- H_i is the supply of land
- Q_i is the land price
- λ are probabilities related to location (where to live and where to work)
- A_i is the unobserved county productivity.

So, the equilibrium values can be written as a vector of six variables:

$$\{w_n, \overline{v_n}, Q_n, L_n, R_n, P_n\}_{n=1}^{N}$$

and the scalar $\bar{U}$ (Utility across regions).

The utility of the worker that lives in n and works in i:

$$U_{ni\omega} = \frac{b_{ni\omega}}{k_{ni}} \left(\frac{C_{n\omega}}{\alpha}\right)^{\alpha} \left(\frac{H_{n\omega}}{\alpha}\right)^{1-\alpha}$$

- ω is worker
- $C_{n\omega}$ is the final good consumption
- $H_{n\omega}$ is land use
- n location where the worker lives and consumes
- i location where the worker works
- $b_{ni\omega}$ is an idiosyncratic amenities shock
- k_{ni} are commuting costs.

3. Dataset

For our analysis, we constructed a dataset by gathering data from various sources. The list of the required data and their respective sources can be consulted in the Appendix:

Due to the limited availability of data, particularly for the year 2020, it was necessary to rely on data from the year 2019 for our analysis. The data were obtained by cross-referencing information gathered from various sources in order to compensate for any gaps or missing data. This approach allowed us to construct a comprehensive dataset for our study.

For our analysis, we primarily relied on the Eurostat, which serves as the official data provider for the EU. In particular, we focused on using the "N.U.T.S." 2 Region setting of Eurostat, which provided us data specific to regions such as Bozen, Trento, and Innsbruck. The dataset built was well-suited for our research objectives, due to it furnishes data at provinces level, allowing us to gather pertinent information for our analysis.

Unfortunately, the N.U.T.S 2 setting only provides purely “flows” data, such as the number of entering and exiting commuters, without specifying their specific origins and destinations. To address this issue, we utilized data from the Chamber of Commerce of Bozen and Istat, focusing on commuting flows between Italian regions. Istat's dataset provided detailed information on commuting patterns between regions, including the origins and destinations of commuters. With this data, we were able to calculate the exact number of commuters from Bozen and Trento to other European destinations. However, it should be noted that we were unable to exclude commuters travelling to Switzerland from our analysis due to missing data. Nevertheless, we believe that the number of commuters to Switzerland is minimal. Additionally, since the new railway opening will only directly impact commuting between Austria and Italy, omitting these commuters is unlikely to introduce bias into our analysis.

The trade sector posed a challenge in our analysis as the Eurostat's N.U.T.S. 2 regions were not available, and the N.U.T.S. 1 regions represented macro areas that were not suitable for our analysis. To address this issue, we obtained trade data from the OEC website, specifically focusing on import and export activities between Austria and other regions. Drawing from the insights provided by Geng (Geng, 2018), we statistically calculated the trade flows by applying the percentages associated with Trento and Bolzano Provinces. To validate the accuracy of our

estimations, we cross-referenced the data with the export figures provided by the Chamber of Commerce of Bozen and found them to be consistent and in line with our estimations.

To ensure the most accurate replication of Monte et al.'s study, we collected data that closely matched the dataset used in their paper, with one exception: distances.
In our simulation, we chose to use the train travel time between the cities of Innsbruck, Bolzano, and Trento instead of the physical distances between centroids. This decision was based on several reasons. Firstly, it aligns with the toll provided by the model, which focuses on the impact of a shock that reduces trading costs in terms of distances. The primary effect of the opening of the Brenner Base Tunnel (BBT) for commuters and firms in these regions is the reduction in travel time required to reach other cities. Since the BBT is exclusively for train transportation, it is reasonable to exclude other modes of transport, such as cars and trucks, which would not be positively affected by the opening of the tunnel (there are no aeroplane routes between the regions under consideration). Furthermore, the opening of the BBT could potentially lead to a modal shift, reducing the reliance on cars and trucks and promoting the use of trains.

Additionally, the model takes into account commuting flows based on amenities, a variable that is related to travel time too (faster commuting options increase the likelihood of living and working in different regions). In the original paper, the authors approximated commuting distances within the same county by aggregating data from three years. In our case, we do not need to make this approximation. Instead, we calculated the average time required to reach the capital cities of the provinces (Trento, Bozen, Innsbruck). This approach allows us to capture the impact of reduced travel time on commuting patterns more accurately.

As written before, here is a brief explanation of each variable that we gathered, aiming to make them as similar as possible to the variables used by the authors:

3.1 Trade (Bilateral trade, import/export):

The trade data used in our analysis focuses on bilateral trade between the provinces included in our simulation. These trade flows represent the import and export of goods between the

provinces, and they are measured in thousands of euros (k EUR). However, it's important to note that these trade data are approximations due to the lack of detailed data available in Eurostat.

To overcome this limitation, we used a combination of data from official OEC and Istat dataset. By cross-referencing the available data, we were able to estimate the trade flows between the provinces. Additionally, we obtained further confirmation of the accuracy of our estimates through information provided by the Chamber of Commerce of Bozen, which validated the trade data for its province. This confirmation strengthens our confidence in the estimated trade flows for Trento as well, considering the overall trade flows from the entire region.

While the data may be approximations, we have taken measures to ensure the accuracy and reliability of our estimates by using multiple data sources and validating them against available information. This allows us to provide insights into the trade dynamics between the provinces in our analysis.

3.2 Commuting:

As previously mentioned, we computed the commuting flows between regions using the gross data available from NUTS 1 regions. To obtain the commuting flows at a more granular level, we subtracted the data specific to each region provided by Istat. Indeed, the Istat data furnishes the number of workers that commute to the Trentino and Alto Adige provinces from the other Italian regions. Excluding them from the gross data obtained with the NUTS 1 settings, we computed the exact number of commuters among the provinces taken in account.

This approach allowed us to estimate the net commuting flows between the regions in our analysis. Unfortunately, there are missing data about commuting between Innsbruck and Trentino provinces. Anyway, through the process exposed before, we could ensure that, if there is a commuting between those provinces, its entity should be insignificant.

3.3 Employment:

We were able to utilize the data gathered without making any modifications. Similar to the approach taken by the authors, we considered an age range of 15 to 67 years for our analysis. The

employment by residence variable represents the number of residents in each province, and we computed this variable by reversing the commuting flows as done in the original paper.

To ensure the accuracy of the data, we followed the same process as the authors and confirmed the validity of the gathered data. This involved verifying the consistency of the employment by residence figures obtained through the commuting flow reversal method. This involves reintegrating commuters among local workers by simply summing them. This process will also establish the residential wage, which constitutes the weighted average of all salaries earned locally, including those earned abroad. By adhering to the established methodology, we aimed to maintain the integrity and reliability of the data used in our analysis.

3.4 Wage:

In this case, we were able to utilize the exact data that was gathered. The wages variable is expressed in euros, which represents the monetary unit used for measuring and quantifying salaries and income. It's interesting that the highest residential wage (wage earned by citizens including the commuters) is registered in the province of Alto Adige. Anyway, the highest income is the one of the Innsbruck regions, due to it is the most populated.

3.5 Income:

The regional total income is derived by multiplying the number of residents by the residential wage. By doing so, we obtain an estimate of the overall income generated within each region. In our analysis, we also confirmed the accuracy of the data gathered for residents by province using the same methodology. The regional income is expressed in millions of euros.

3.6 Land:

The geographical extension of the provinces was obtained by referencing maps, sources such as Istat, and other relevant information sources. These data provide an indication of the physical size or area covered by each province. The largest region is the Innsbruck, granting the highest land value endowment among the provinces considered.

4. Results

In order to comply with the transparency regulations of the Journal, the authors provide a complete script of the model and useful tools for data manipulation. These tools allow for the examination of how various variables related to local economies, such as commuting, welfare, housing costs, etc., are impacted by changes in commuting or trading costs. In our case, the tool related to trading costs (which includes both commuting and non-commuting scenarios) aligns well with our objectives. Specifically, the reduction in trading costs is considered as a reduction in distances. Our specific setting, which incorporates time-based distances between centroids rather than traditional kilometres, was purposefully designed to accommodate this requirement.

Via this tool, we intend to simulate a perturbation in commuting prices, inducing a sequence of adjustments culminating in a new equilibrium. The initial variable we foresee undergoing change is commuting itself, with the potential to set off a cascade of variations encompassing salaries, housing costs, prices and welfare.

We made slight modifications to the original script by incorporating a distance reduction matrix for each trade. The multiplier for distance reduction is obtained by dividing the estimated transit time by the currently required time.

This matrix is defined as follows:

Distances reduction (multiplier)	*Bozen*	*Innsbruck*	*Trento*
Bozen	1	0.33	1
Innsbruck	0.33	1	0.53
Trento	1	0.53	1

In our modified script, the rows of the matrix represent the starting locations, while the columns represent the destinations. The fractions in the matrix are computed based on the reduction in time required to travel between the locations. It should be noted that the route between Trento

and Bozen is not affected by the opening of the BBT. While the original script primarily focused on trade, our modified script still takes into account the presence of commuting, ensuring a comprehensive analysis. Complete information regarding the outcomes can be found in the appendix section.

Our simulation indicates that the introduction of the BBT leads to a discernible increase in welfare in all regions, amounting to approximately 0.22% (for detailed figures, please refer to the extended digit in the appendix). The overall effect of the BBT opening is anticipated to be favourable for the local economies. The enhanced mobility of workers and goods, facilitated by the BBT, is expected to foster growth in both the labour market and trade activities.

Due to the opening of the Brenner Base Tunnel (BBT), slight variations in employment are observed in the considered provinces. The most notable change is recorded in the province of Bozen (+0.94%), followed by a slight decline in Innsbruck (-0.54%). The variation in Trento is insignificant (-0.07%), but this can be inferred from the fact that Trento is not directly influenced by the reduction in time costs. The decrease recorded in Innsbruck, despite an increase in commuters, is noteworthy, as detailed in the following paragraph. This phenomenon may have various explanations, such as potential migration of Innsbruck residents to Bolzano or the possibility that many may lose their jobs due to competition from the new commuters.

Therefore, the opening of the BBT has significantly fostered commuting. As anticipated, the most substantial increases in commuting activity are observed for workers travelling to Innsbruck, with a rise of +1532 commuters from Bozen and +2263 commuters from Trento. The combination of higher wages and lower living costs in the neighbouring countries presents a promising opportunity for substantial improvements in individual welfare. Despite the longer distance between Trento and Innsbruck, it is likely that there will be more commuters from Trento than from Bozen, given Trento's current advantage in terms of lower living costs and wages. However, it is important to highlight that the current number of commuters from Trento to Innsbruck is relatively small, and it is unlikely to exceed forty people based on our data. Furthermore, it is crucial to note that the present travel time required to reach Innsbruck from Trento is significantly discouraging, taking approximately 193 minutes per trip, resulting in a total of 6 hours and 23 minutes of travel time per day.

Moreover, there is a notable increase in own commuting, which refers to commuting between the capital of the province and nearby settlements. Despite the significant rise in own commuting, particularly with 509 individuals commuting between Innsbruck province and Innsbruck city, it is important to exercise caution when interpreting these figures. The simulation takes into account all settlements connected through the HSR, considering the reduced travel time. Thus, it is reasonable to assume that the actual number of commuters may be lower than the reported figures. Nevertheless, these values are expected to rise further as facilitated commuting to other regions is likely to spur an increase in work demand. This is due to workers moving towards more lucrative job opportunities in other areas.

The opening of the BBT has varying effects on wages across the three regions. In Trento and Bozen, the impact is positive but nearly to insignificant, with wage increases of +0.17% and +0.04%, respectively. However, in the Innsbruck region, wages experience a reduction of 0.21%. This outcome is not unexpected, as the labour supply in the Innsbruck region is significantly boosted by the influx of new commuters. This increased labour supply creates a situation of heightened competition among workers, prompting local firms to offer lower wages.

Conversely, in Trento and Bozen, there are two opposing effects at play due to this event. The first effect, which positively influences wages, stems from local companies' efforts to retain and attract workers by offering higher salaries. The other effect is akin to what is observed in the Innsbruck region, wherein the increased labour supply resulting from commuters coming from Trento impacts wages. As a result, Trento experiences the highest increase in salaries among the three regions.

It is important to note that the scope of this research only considers migration flows between these three regions. As Trento has the lowest wages, the number of commuters coming into the region is significantly lower compared to those leaving. Thus, the impact of new job offers from other regions is minimal, if not negligible, and is overshadowed by the local companies' efforts to retain their employees. This is because there are no other regions from which to attract new workers in this specific study. Including the Veneto region in the analysis could potentially yield different results.

The notable price surge observed solely in Trentino (+0.15%) is not unexpected, given that it is the region experiencing the highest growth in wages. Conversely, in Alto Adige, prices would see a considerable decrease of -0.10%, even though wages might experience a slight increase. Several factors could account for this trend, including intensified competition from imported goods (due to the model assuming reduced exporting costs). In the case of Innsbruck, prices may experience a not relevant increase (+0.02%), which could be attributed to the increased value of commuters in the region.

On the contrary, the trend in the housing market shows a different pattern. Only Innsbruck housing market appears to be significantly affected experiencing a decline (-0.81%). In the other two provinces the variations appear to be extremely insignificant with a slight stimulation in Bozen (+0.03%) and a smaller decline in Trento (-0.02%). This phenomenon can be attributed to Bozen's advantageous location. Geographically and socio-economically, Bozen occupies a unique position, situated between the other two countries. This makes it an appealing destination for workers from neighbouring regions, as it offers the benefits of central proximity and a lower cost of living compared to Innsbruck. Moreover, Bozen's close proximity to Innsbruck makes it an attractive option for job seekers, leading to an influx of individuals from Trento due to the higher demand for work in the region. This influx contributes to the slight stimulation in Bozen's housing market.

5. Conclusion and future development

The results of our simulation unequivocally demonstrate the profound impact that the opening of the BBT (Brenner Base Tunnel) will have on the economies of the provinces involved. The simulation not only presents a final equilibrium scenario but also reveals several significant changes, including an increase in overall welfare and notable shifts in housing costs. It is reasonable to anticipate that a considerable number of individuals from Innsbruck will opt to relocate to Bolzen due to the lower cost of living, absence of language barriers, and the ability to maintain their current employment with their existing wages, which may be higher than potential wages in Innsbruck.

It is interesting to note that welfare increases despite the reduction in real income for each province. One possible hypothesis is that the increase in the workforce in the province of Bolzano, the decrease in prices, and the rise in commuters lead to a redistribution of wealth and an increase

in activities that collectively contribute to the observed growth in welfare. Explanation about the real income variable is furnished in the appendix.

Although the model employed in this study was not specifically designed to handle shocks specific to each country, such as the one proposed in this survey, the predictions generated by the model align remarkably well with our initial expectations. Moreover, the inclusion of various robustness tests conducted during the analysis serves to validate the consistency and reliability of our results.

This survey presents several promising opportunities for further extension and exploration. One potential avenue for future research is to incorporate additional provinces that are directly linked to the transportation route, in order to examine whether the observed commuting trends, such as the flow from Bolzano to Innsbruck fostering increased commuting from Trento to Bolzano, hold true in those regions as well. Another potential avenue for development is to incorporate behavioural effects, which may be influenced by specific policies, in order to investigate how they impact the decision-making processes of commuters and producers. This aspect is particularly relevant when analyzing the effects of green policies or initiatives aimed at reducing the stress experienced by workers, such as truck drivers.

Furthermore, it would be intriguing to explore the impact of the widespread adoption of remote work (smart working) on commuting patterns. Specifically, it would be valuable to investigate whether the increased mobility facilitated by remote work arrangements influences the decisions of foreign firms in terms of offering national base wages rather than lower wages based on the cost of living in the host country. Such an analysis would shed light on the potential positive or negative effects of smart working on commuting dynamics.

In conclusion, there are numerous avenues for further expansion and enhancement of this survey, which would provide valuable insights into various aspects of commuting, labour markets, and their policy implications.

Appendix I: Results

Here are the outputs of the simulation.

The matrixes are built in the following way: column is the starting province, and rows are the destination. Here is a graphical example:

Starting↓\destination→	Bozen	Innsbruck	Trento
Bozen			
Innsbruck			
Trento			

Commuting:

The following table presents the variations in terms of workers (units) for different country pairs, indicating where the workers live (rows) and where they work (columns). The values in the table represent the changes or differences in the number of workers compared to the current scenario. The rows of countries are where the workers live, columns are where they work.

$\boldsymbol{\lambda}$	*Bozen*	*Innsbruck*	*Trento*
Bozen	206	1532	134
Innsbruck	80	599	52
Trento	305	2263	198

Wages (in %):

	W
Bozen	0,0424
Innsbruck	-0,21441
Trento	0,173006

Expected worker income conditional on living in location n (in %):

	V
Bozen	-0,48214
Innsbruck	-0,43873
Trento	-0,03826

The variable V is equal to the wages in all possible workplaces weighted by the probabilities of commuting to those workplaces conditional on living in n, decreases for each country. This can be attributed to the decrease in wages in Innsbruck, which has the highest current wages and carries significant weight in this variable. The reduction in wages in Innsbruck negatively impacts this variable for workers in other countries. In other words, commuting is currently more economically advantageous compared to after the opening of the BBT if the time required for commuting is not considered. The computation of variable V also includes the case of commuting within the same region (e.g., Innsbruck to Innsbruck), leading to a decrease in its value for Innsbruck as well. On the other hand, the value for Trento does not change significantly due to various factors such as the higher likelihood of working in Bozen counteracted by the lower wages offered by Innsbruck, which makes it a potential commuting destination.

The real income of residents:

	Realin
Bozen	-0,45288
Innsbruck	0,087309
Trento	-0,10706

The variable of real income for residents encompasses not only the wages earned by workers, both commuters and non-commuters. This broader perspective takes into account the overall economic activity and its impact on individuals' financial well-being.

When considering real income, it is important to recognize that the consumption of goods and services is influenced by various factors, one of which is the increased number of commuters. The presence of commuters can have a positive effect on the production process, leading to lower costs for businesses. This, in turn, can potentially result in reduced prices for goods and services, making them more affordable and accessible to consumers.

Therefore, in analyzing the real income of residents, it is necessary to consider not only the direct wages earned by individuals but also the indirect effects of economic factors such as commuting patterns and their influence on the cost of production and consumption.

Variation of employment (in %)

	LM
Bozen	0,941985
Innsbruck	-0,54831
Trento	-0,07028

The LM variable takes into account changes in employment, considering the impact of commuting. The decline observed in Innsbruck, despite the rise in commuting, could be attributed to the migration of Innsbruck residents to Bozen. It is plausible that some individuals from Innsbruck may have lost their jobs or opted to seek alternative employment opportunities in other regions, including Bozen. This migration of workers could result in a reallocation of labour across regions, influencing the economic dynamics and contributing to the changes in Innsbruck's economic indicators.

Variation of employment without commuting (in %)

	LR
Bozen	0,999381
Innsbruck	-0,66823
Trento	0,013544

the variable reflects the total number of employed individuals, regardless of their workplace location. This helps explain why Bozen and Trento exhibit higher values compared to LM, and Innsbruck lower.

House Pricing (in %)

	Q
Bozen	0,035408
Innsbruck	-0,81379
Trento	-0,02523

Prices (in %)

	PH
Bozen	-0,10844
Innsbruck	0,01864
Trento	0,151142

Appendix II: Data sources

⇒ Bilateral trade

a. Chamber of commerce of Bozen

⇒ Commuting flows

a. Eurostats

b. Chamber of commerce of Bozen

c. Istat

⇒ Land area

a. Eurostat

⇒ Labor share in manufacturing

a. Eurostats

b. Chamber of commerce of Bozen

c. Istat

⇒ Employer by residence

a. Eurostats

b. Chamber of commerce of Bozen

⇒ Employer by workplace

a. Eurostats

b. Chamber of commerce of Bozen

⇒ Wage by residence

a. Eurostats

b. Chamber of commerce of Bozen

⇒ Wage by workplace

a. Eurostats

b. Chamber of commerce of Bozen

⇒ Import/Export

a. Eurostats

b. Chamber of commerce of Bozen

⇒ Regional total income

a. Eurostats

Chamber of commerce of Bozen

Appendix III: Data

Here the data used, we used the same nomenclature of the script. The matrixes are built in the following way: column is the starting province, and rows are the destination. Here is a graphical example:

Starting↓\destination→	Bozen	Innsbruck	Trento
Bozen			
Innsbruck			
Trento			

In the case of vector, the order is Bozen, Innsbruck, Trento

Bea_cfs_list:

1,1
2,1
3,1

This table is used to separate the provinces. In the original computation, the first number is referred to the state, and the second to the county. In our case, we considered the provinces as states, due to it doesn't affect the analysis in any case.

Bilateral_cfs_trade

1	54892000	1
876284000	1	876284000
1	1	1

Here is the amount of export in euros. In order to avoid 0 in the denominator, it was used 1.

Commuting_flows

1	2063	1037
78	1	1
2588	1	1

County_names

state_county_code	county_name	state_name	state_fips
1001	Bozen	"Italia"	1
1002	Innsbruck	Austria	1
1003	Trento	"Italia"	1

This table is used only to link the outputs to the provinces, the values are completely arbitrary.

Distance_all_pairs

15	135	58
135	11	193
58	193	12

We considered the distances in minutes required. The diagonal values are computed as the average time required to reach the central station. The computation is considered the time required to reach the capital (Bozen, Innsbruck, Trento) from other settlements, weighted by the number of citizens (16-67).

Distances_onlytrading

15	135	58
135	11	193
58	193	12

In our analysis, these data are equivalent.

Land_area

7398.38
12640.17
6207.12

Geographical land area, in km squares.

Mfg_shares

0.16
0.16
0.24

Shares of workers employed in manufacturing. Our analysis is not required.

ResidentialEmp

242046
369033
344951

Number of workers in the province (adding the commuters that start from the province and removing commuters that arrive from other provinces)

ResidentialWage

58881
56813
33167

The average wage earned in the province (considering the wage earned by commuters)

resIncome

14251,91053
20965,87183
11440,98982

Residential Income

Saiz_price_elasticities

0.23
0.21
0.23

Housing market elasticities, source: the International Monetary Fund (IMF) dataset (Geng, 2018)

WorkplaceEmp

241582
371018
343400

Number of workers in workplaces (computed by multiplying the population 16-67 per the employment rate)

WorkplaceWage

30601
33173
28000

The average wage earned in the province

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Conclusions and future developments

The opening of the Brenner Base Tunnel (BBT) is anticipated to have profound and far-reaching economic implications, not only for the provinces of Trentino and Alto Adige but also for neighbouring regions and even foreign countries. Our research findings have revealed that the effects of this infrastructure project would be multifaceted, impacting various aspects of the economy, including welfare levels, commuting patterns, trade dynamics, and the housing market.

Indeed, while the variations computed from the simulations may not be of excessive magnitude, they are nonetheless promising. This consideration is particularly noteworthy given that no policies were implemented during the simulation. These variations, therefore, represent the direct impact of the tunnel's opening, without leveraging its potential to enhance, for instance, potential trade. The modest yet positive shifts observed underscore the inherent transformative capacity of the tunnel, suggesting that with strategic policy interventions, the economic landscape could experience even more substantial enhancements. The absence of active policies during the simulation implies that the recorded effects are essentially the baseline impact, setting the stage for further exploration of how targeted interventions might shape and amplify these outcomes.

Through our rigorous analysis, we have successfully applied the Monte et al. model to examine the specific route of the BBT and assess its potential impact. The results of our study have demonstrated the robustness and accuracy of the model in capturing the complex interactions and dynamics associated with the opening of such a significant transportation link. Given the success of our approach, expanding the analysis to include other regions would not only be feasible but also enhance the precision and reliability of our findings. For instance, extending the investigation to incorporate the increased commuting flows from other Italian regions, such as Veneto, Lombardy, and Emilia Romagna, to Trentino Alto Adige would provide valuable insights into the indirect consequences and broader ripple effects of the enhanced connectivity to the Innsbruck province. Additionally, exploring the potential impacts on employment opportunities within the affected provinces would deepen our understanding of the regional labour market dynamics.

Nevertheless, as written before, it is essential to acknowledge that our simulation, as presented in the third paper, does not account for the full range of policy interventions that local governments

could potentially implement in response to the opening of the BBT. While the findings of the second paper, proposing a policy to incentivize firms' owners to utilize the train for exports, may appear simplistic at first glance, they offer promising insights that warrant further investigation. Incorporating these findings into a new model, as originally intended, would not only address practical choices faced by businesses but also shed light on the region's commitment to addressing social issues such as environmental sustainability and improving working conditions.

In conclusion, this thesis provides valuable and comprehensive insights into the potential effects of the BBT, laying the groundwork for further exploration of its broader implications and potential omitted effects. It underscores the need to consider various policy interventions to maximize the benefits and mitigate potential challenges associated with this transformative infrastructure project. Furthermore, the newfound connectivity with Europe through the BBT opens up numerous avenues for future exploration and exploitation of this vital transportation link, which will undoubtedly shape the economic landscape of the regions involved for years to come.