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Transportation Infrastructure Transition and Structural Transformation at the Subdistrict[1] Level: The Impact on Argentine Agriculture between 1960 and 1988.

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Abstract | Resume

The academic consensus on the positive impact of the expansion of the Argentine railway network on its agriculture led economic development between 1890 and late 1910s is broad. After this network reached its peak in the 1950s, a transition in transportation infrastructure began, reducing the rail network and substantially expanding paved roadways. This paper estimates the impact of this transition at a subdistrict level for specific but comprehensive variables of the Argentine agricultural sector between the early 60s and the late 80s. Since the treatments involved in the work are two, the empirical strategy relies on a modified **fixed effects differences-in-differences model.** Then, to achieve more solid conclusions, mean differences tests were run between groups with different characteristics, achieving closer comparisons to the traditional treatment-control contrast. The main findings reveals that, for the variables of interest, there is an enhancing effect in the presence of the two treatments (railways and paved roads) performing simultaneously in the subdistricts; likewise, eliminating a treatment from places that used to have both of them and contrasting these to districts that maintained both over time provides negative and robust results, giving greater power to the enhancing effect hypothesis. In another aspect, the results do not reveal the existance of any significant effect in subdistrict agriculture from the treatment of deploying paved roads to places that previously did not have any means of transportation.

[1] ***"Subdistrict"*** is interpreted as a minor division of the Argentine provinces, internally called ***"departamentos"*** or ***"partidos"***.

1 | Introduction

1.1 | Background and Topic Relevance

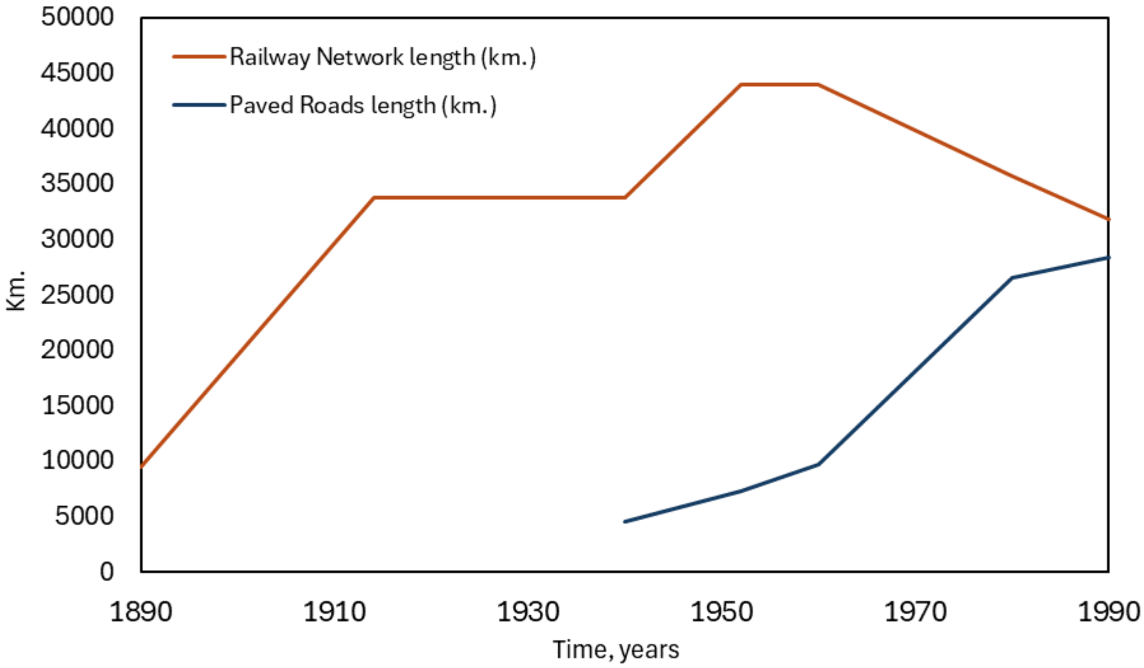
Economic development and transportation infrastructure are strongly connected in a wide range of countries. From one perspective, there are several authors who strengthened a theoretical link between the reduction in transportation costs and economic development. For instance, Dornbusch, Fischer & Samuelson (1997), through a theoretical development, proved that transportation costs act negatively on productivity, generating non-tradable goods and forcing places without access to adequate transportation infrastructure to reduce their well-being. In the same way, Deardoff (2013) showed that, if transportation infrastructure is weak and its costs are high, numerous sufficiently productive markets would be left without supplying the rest given their prohibitive transportation costs.

From another perspective, the empirical literature that supports this link is vast. Firstly, Fogel (1962) provided a quantitative approach to the significant boost that the "railroad revolution" gave to the american agriculture and industry growth. Furthermore, Fremdling (2010) proved that German railroads growth was not only beneficial for the country's economy but also produced benefits in the British iron industry, which supplied materials to Germany. Similarly, Llach (2013) supported an analogous hypothesis for the Argentine Republic expressing the link between the railway and the economic output as a core element in the process.

As Llach relates, in the argentine case long range transportation network was a key element for the social and economic boom during the first half of the 20th century; the great deployment of railway branches during 1890 and 1920 led to a virtuous agro-industrial model with enormous export potential, allowing the country to become one of the wealthiest nations in the world (Della Paolera & Taylor, 2001).

Later, after the railway network reached its peak in the 1940s, the country began a period of structural reforms in which transportation was not exempt. In the late 1950s, President Frondizi requested engineer Thomas B. Larkin to develop a major plan for reforming the national transportation structure, calling this project *"Transportes argentinos: plan de largo alcance"*, or better known as *"Plan Larkin"*. The main goals of this initiative were to substantially reduce the railway network, along with a significant expansion of the paved road network. Historical sources indicate that, due to Frondizi's overthrow in 1962, the project was barely applied; nevertheless, Larkin's central ideas were generously deployed in subsequent decades, closing around 10,000km of railway networks[1] and deploying more than 15,000km of paved roads[2]. This transition is reflected in Figure 1, that shows the evolution of the Argentine transportation infrastructure, considering paved roads and railways.

Figure 1: Extension of the Argentine transport infrastructure network between 1890 and 1990.



Source: Benedetti (2016) & Delgado (1998).

On one hand, regarding the study of the economical impact led by the transportation structure expansion during the first two decades of 20th century the literature is vast. In first place, Fajgelbaum & Redding (2018) provided evidence about structural transformation in argentina subdistrict[3] economy due to the great export led expansion in the railway network. On the other hand, Maddison (2006) also describes the early 1900s Argentinian case, exposing the relevance of the deployment of railway branches to converge in 2.8% GDP growth rates, surpassing almost all the leading economic nations of the time. Likewise, many other authors

[1] Benedetti, A. (2016). Argentina, ¿país sin ferrocarril? La dimensión territorial del proceso de reestructuración del servicio ferroviario. *Transporte y Territorio*, *15*, 68-85.
[2] Delgado, R. (1998). *Inversiones en infraestructura vial: La experiencia argentina*. repositorio.cepal.org.
[3] We define "subdistrict" to a minor division of the Argentine provinces, internally called "departamentos" or "partidos".

contributed to the analysis of the positive macroeconomic impact of public policies related to railway transportation adopted at the time (Cortés Conde, 1960; Prados de la Escosura, 2005).

Then, although there exists some works focused on the period of the transport infrastructure transition, the literature specifically focused on the subdistrict impact of this shift is rather scarce. From one perspective, Benedetti (2016) relates the territorial changes that the railway contraction may have produced. From the other side, Delgado (1998) set his sights on the structural transformation aroused by paved roads expansion after 1990, a period we are not analyzing in this work. Meanwhile, in concern of the specific topic of this research, Belmar & Gentile - Passaro (2021) precisely focuses on the productive transition of transportation infrastructure in the second half of the 20th century using an OLS model with instrumental variables, leaving aside the theory of impact evaluation.

So, given this scenario, the objective of this paper is to estimate the agricultural effect at the Argentinian subdistrict level provided by the transition of the productive means of transport (from the railways to the roads) between the early 60s and the late 80s. For that purpose, we will employ the impact evaluation theory, applying a differences-in-differences model; nevertheless, since we are dealing with two treatments (railways and paved roads) it is important to highlight that this is not the traditional dif-in-dif application and specific modifications have been made in order to make it applicable for this case.

Regarding the methodological aspects the obstacles were several. In first place, the specific beginning and ending years of this work, 1960 and 1988, have a reason that lies in the existence of the National Agricultural Census, a key source for the provision of reliable data. Furthermore, Argentinian subsdistricts have changed their shape and size within the analysis period, forcing geographical unions between them to guarantee an intertemporal comparison without bias. In other methodological topics, official and reliable maps were used to build up the railways and paved roads series and their variation. It should be noted that there will be a certain time lag between the maps used for the second period (1978 - 1980) and the second agricultural census data (1988).

The main findings of the impact evaluation analysis prove the existence of significant opposite effects in the adverse treatments of adding road and removing railway. From one perspective, the fact of incorporating paved roads on the departmental surface may induce a positive impact in the agricultural crops production. Meanwhile, the inverse treatment of removing railway tracks generates a significant retraction in the agricultural crops output. Furthermore, a more significant effect of the same process can be found when the gaze is situated in cereals and oilseeds as a separated variable of interest.

The work structure is quite typical. The following subunit describes the hypothesis in an accurate way, the second chapter displays a more extensive relevant literature review, the third unit poses the procedures and methodology used, the fourth section exposes the results and their interpretation, and in the final chapter a conclusion will be made.

1.2 | Investigation Problem and Hypothesis

The evidence proving the existence of a structural transformation in the argentine subdistricts economy led by a change in its transportation infrastructure during the beginning of the 20th century is robust. However, the same type of evidence for the period between the 60s and 80s is much scarcer, especially at the subdistrict level.

Likewise, the level of consensus on the positive impact of the development of transportation infrastructure on the national economy between 1890 and 1920 is high. Nevertheless, conclusions regarding the effect of the transportation infrastructure transition during the second half of the 20th century are much less consistent.

In this context, the present work seeks to contribute to the evidence on the link between changes in the transportation infrastructure and effects on the economic structure at the departmental level. For this mission, the transition between railway networks and paved roads that occurred in Argentine territory between early 1960s and late 1980s will be evaluated.

We aim to prove that this transition effectively had an impact on the structure of the economies at the subdistrict level, revealing a positive outcome for the subdistricts that incorporated a new means of transportation and a negative one for those that had lost a means of transportation.

2 | Methodology

2.1 | Database Construction

The specific task of this paper is to measure the agricultural subdistrict[4] impact provided by the transition of the productive means of transport (from the railway to the roads) between 1960 and 1988 in Argentina. For this goal, to perform a difference-in-difference model, two specific moments close to the dates of interest with reliable information in relation to subdistrict surface, agricultural crops, population, active railway networks and paved roads are required.

Firstly, the years chosen for the analysis are not casual. On the one hand, it is precisely after 1960 that the railway tracks begin a contraction period (Benedetti, 2016) while the paved roads begin a great expansion. On the other hand, these two years are the ones in which there exists a National Agricultural Census, providing reliable information about argentinian subdistrict agricultural and livestock data. Unfortunately, there are not other continuous and reliable sources for these variables. It is important to note that the 1988 National Agricultural Census uses the same subdistrict shapes and features that the 1991 National Population Census, allowing the work to be capable of holding population data without changes between 1988 and 1991.

Secondly, there is not open, reliable and unified data about the existence of railways and paved roads in argentinian subdistricts for the years of interest. In that aspect, we have decided to use the georeferencing program, QGIS, to merge the railways and paved roads tracks maps to a valid layer based on the official argentinian geographical position and shape (EPSG:5346)[5] defined by the National Geographical Institute (IGN).

Thirdly, it is notorious that several subdistricts are not the same shape and size in 1960 and 1988. In particular, some of them were eliminated, created or modified during this period. For these cases there are two alternatives. One of these is based on ignoring the subsdistrict changes and assuming that they are small, minimizing the bias on the analysis. The other alternative indicates, in a more rigorous procedure, that the districts modified in the period of

[4] We define "subdistrict" to a minor division of the Argentine provinces, internally called "departmentos".

[5] https://epsg.io/5346

interest need to be united with others in such a way that there are no changes in their shape and size over time. For this work we picked the second one, losing some observations but conserving an unbiased subdistrict layout. In particular, the subdistricts that needed unions were the following:

Table 1: Subdistrict unions and modifications needed for 1960 - 1991 period.

Province	Subdistrict Union	Reason of Modification
Buenos Aires	General Pinto & Florentino Ameghino	Previously only General Pinto. Divided into General Pinto and Florentino Ameghino in 1991.
	Coronel Dorrego & Monte Hermoso	Previously only Coronel Dorrego. Divided into Coronel Dorrego and Monte Hermoso in 1983.
	General Lavalle & La Costa	Previously only General Lavalle. Divided into General Lavalle and La Costa in 1983.
	General Mitre & Capitán Sarmiento	Previously only General Mitre. Divided into General Mitre and Capitán Sarmiento in 1961.
	Quilmes & Berazategui	Previously only Quilmes. Divided into Quilmes and Berazategui in 1960.
	General Madariaga, Pinamar & Villa Gesell	Previously only General Madariaga. Divided into General Madariaga, Pinamar and Villa Gesell in 1978.
	Pellegrini, Salliqueló & Tres Lomas	Previously only Pellegrini. Divided into Pellegrini, Salliqueló and Tres Lomas in 1961 and 1986 respectively.
Entre Ríos	Concordia & Federal	Previously only Concordia. Divided into Concordia and Federal in 1973.
	Gualeguaychú & Islas del Ibicuy	Previously only Gualeguaychú. Divided into Gualeguaychú and Islas del Ibicuy in 1984.
Jujuy	General Belgrano & Palpalá	Previously only General Belgrano. Divided into General Belgrano and Palpalá in 1986.
Tucumán	Graneros & La Cocha	Previously only Graneros. Divided into Graneros and La Cocha in 1975.
	Monteros, Chicligasta, Río Chico, Simoca & Alberdi	Previously only Monteros, Chicligasta and Río Chico. These changed their shape and were divided into five in 1976.
	Tafí, Trancas, Lules, Famaillá, Capital & Yerba Buena	Previously only Tafí, Trancas, Famaillá and Capital. These changed their shape and were divided into six in 1976.
Tierra del Fuego	Ushuaia & Bahía Thetis	Previously Ushuaia and Bahía Thetis. The second one was eliminated in 1970, being absorbed by Ushuaia.

Fourthly, the maps used to build up the railway and paved roads networks respond to two different sources. For the railway network, despite the existence of multiple map sources, the decision was made in order to use the one that explicitly showed ***active operational networks*** for the dates considered. For this, the plots were provided by Benedetti (2016) for 1960 and 1980. Meanwhile, for the paved roads, P.H. Randle (1981) was used for 1960 and the *"Red Caminera Principal"* map published by the *Automóvil Club Argentino* (A.C.A) for 1980. In this way, the final map database establishes two points of comparison over time: an initial moment (t=0) for the year 1960 and a second moment (t=1) in the year 1980. Note that there is a time lag of 8 years between the maps used in (t=1) and the data provided by the 1988 National Agricultural Census.

In fifth place, although we analyzed several variables of interest, only two were selected for this work. This is because its characteristics correspond to a more global view of crops in general and do not remain in the specificity of a particular crop. Finally, both variables were evaluated with three identical set ups[6]:

1. **Annual and Perennial Crops**
    a. ln (Annual and Perennial Crops).
    b. ln (Annual and Perennial Crops + 0.01).
    c. Annual and Perennial Crops/Total Area of the Subdistrict.
2. **Cereals and Oilseeds: Wheat, Corn, Soybeans and Sunflower.**
    a. ln (Cereal and Oilseeds).
    b. ln (Cereal and Oilseeds + 0.01).
    c. Cereal and Oilseeds/Total Area of the Subdistrict.

2.2 | Econometric Approach

The chosen model corresponds to a differences in differences case. Nevertheless, given that two treatments are being considered for this work, a different application should be made. Preliminarily, we will introduce the classical model and advance methodologically from there. As we know, the classical differences in differences model with one treatment including fixed effects is defined by

[6] All variables will have the following alternatives: **natural logarithm**, **natural logarithm + 0.01** (to avoid losing observations in case the data was equal to 0), **and their weighting over the total area of the subdistrict**.

$$y_{it} = \alpha + \gamma_i + \delta t + \beta T_i t + \varepsilon_{it} \qquad (1)$$

Being y_{it} the variable of interest, α the constant term, γ_i the individuals fixed effects, t the time dummy, T_i the treatment dummy that assumes value equal to zero if the observation belongs to the non treated control group or a value equal to one if the observation is included in the treated group, and ε_{it} represents the residuals of the equation. The procedures in this elementary case will be presented in table 2.

Table 2: Classic Differences in Differences for one treatment effect.

Groups	**Time**	**Regression**	**First Difference**	**Dif in Dif**
Treatment Group	t = 1	$y_{i1} = \alpha + \gamma_i + \delta t + \beta + \varepsilon_{it}$	$\delta + \beta$	β
	t = 0	$y_{i0} = \alpha + \gamma_i + \varepsilon_{it}$		
Control Group	t = 1	$y_{i1} = \alpha + \gamma_i + \delta t + \varepsilon_{it}$	δ	
	t = 0	$y_{i0} = \alpha + \gamma_i + \varepsilon_{it}$		

Ergo, the purified effect of the treatment after applying first and second differences is summarized by the β coefficient.

Now remind that a treatment effect may have more than one direction. For example, one group may be receiving the treatment effect while another group may be having the considered treatment removed. Likewise, the outcome of adding or removing a treatment does not have to be symmetric. For example, the application of a treatment that results in a 5% positive effect on the variable of interest does not have to mean that the opposite process (removing the treatment) results in a 5% negative effect, Thus, for this case, it is no longer sufficient to define a variable T that only encompasses the treatment and control groups; it is necessary to expand the scope of the variable to four different groups: one corresponding to the observations that receive the treatment, another encompassing those from which the treatment is removed, another that never received the treatment, and a final group that has always had the treatment.

$$y_{it} = \alpha + \gamma_i + \delta t + \sum_{j=N,P,A,E} \beta_j T_{ij} t + \varepsilon_{it} \qquad (2)$$

With T_{ij} assuming a modified treatment dummy role that includes four group possibilities for the observations set: never had treatment (j = N), permanently had the treatment (j = P), treatment added (j = A) and treatment removed or eliminated (j = E). For this case, one group must take the control group role and its coefficient will be necessarily omitted from the equation, reducing the number of dummies from the variable T_{ij} to three. Table 3 presents two exemplary cases of the procedure regarding the differences in differences model presented in equation (2); the first considers the effect of adding a treatment compared to a control group that never received a treatment while the second presents the net impact between the group where the treatment was eliminated contrasted by the group that permanently had the treatment.

Table 3: Particular Application of a Differences in Differences model for multiple treatments setup using equation (2).

Group Comparison	Groups	Time	Regression	First Difference	Dif in Dif
(A vs. N) Treatment added vs. Never had treatment	Treatment Added (A)	t = 1	$y_{i1} = \alpha + \gamma_i + \delta t + \beta_A T_{iA} t + \varepsilon_{it}$	$\delta + \beta_A$	$\beta_A - \beta_N$
		t = 0	$y_{i0} = \alpha + \gamma_i + \varepsilon_{it}$		
	Never had treatment (N)	t = 1	$y_{i1} = \alpha + \gamma_i + \delta t + \beta_N T_{iN} t + \varepsilon_{it}$	$\delta + \beta_N$	
		t = 0	$y_{i0} = \alpha + \gamma_i + \varepsilon_{it}$		
(E vs. P) Treatment eliminated vs. Permanently had treatment	Treatment Eliminated (E)	t = 1	$y_{i1} = \alpha + \gamma_i + \delta t + \beta_E T_{iE} t + \varepsilon_{it}$	$\delta + \beta_E$	$\beta_E - \beta_P$
		t = 0	$y_{i0} = \alpha + \gamma_i + \varepsilon_{it}$		
	Permanently had treatment (P)	t = 1	$y_{i1} = \alpha + \gamma_i + \delta t + \beta_P T_{iP} t + \varepsilon_{it}$	$\delta + \beta_P$	
		t = 0	$y_{i0} = \alpha + \gamma_i + \varepsilon_{it}$		

Although a path similar to that previously described will be taken, that procedure has a particular obstacle: the number of treatments considered in this paper is more than one. On the one hand, negative changes occurred in the national railway length; on the other hand, expansive processes were applied in the road structure. Therefore, a two effect model should be used seeking to capture the opposite effects between both.

Thus, considering these contingencies, we are obliged to disaggregate the variable T_{ij} into different treatments that represent paved roads (R) and the railway network (F). The strategy to achieve this lies in the creation of four groups per treatment:

1. **Paved Roads (denoted by R):**
   a. The subdistrict never had paved roads (NR).
   b. The subdistrict permanently had paved roads (PR).
   c. Roads were added to the subdistrict (AR).
   d. Roads were eliminated from the subdistrict (ER).
2. **Railways (denoted by F):**
   a. The subdistrict never had railways (NF).
   b. The subdistrict permanently had railways (PF).
   c. Railways were added to the subdistrict (AF).
   d. Railways were eliminated from the subdistrict (EF).

To realize this approach it is necessary to establish a base control group for each treatment (R and F). Since the two most frequent processes in the period analyzed were adding paved roads to the subdistricts (AR) and removing railways from them (EF), it has been decided to use the group made up by subdistricts that never had paved roads (NR) and permanently had railways (PF) as the main control group in our evaluation impact model. Likewise, the treatments may have effects of different magnitudes when they interact with each other; for example, the economical impact of adding paved roads to a subdistrict that already had a railroad branch in it may be different from that of another subdistrict that did not have the railroad treatment in the first instance. So, finally, the equation to estimate is the following

$$y_{it} = \alpha + \gamma_i + \delta t + \sum_{j=P,A,E} \beta_j R_{ij} t + \sum_{k=N,A,E} \lambda_k F_{ik} t + \sum_{j=P,A,E} \sum_{k=N,A,E} \omega_{jk} R_{ij} F_{ik} t + \varepsilon_{it} \qquad (3)$$

With R_{ij} being a group of dummy variables that define the presence of (N, P, A or E) for the paved roads, F_{ik} being another group of dummies defining the presence of (N, P, A or E) for an active railway branch, and $R_{ij}F_{ik}$ taking the interactive role of those dummies.

Remind that the (N) group for the paved roads and the (P) group for the railway will take the control group role, so their coefficients will be omitted. Ergo, the total number of dummies analyzed will rise to 16:[7] the time dummy t, three dummies extracted from the group R_{ij}, another three dummies provided by the group F_{ij}, and the final nine dummies obtained from the interaction of groups $R_{ij}F_{ij}$.

Note that equation (3) can be represented by another equivalent equation that synthesizes the net coefficients according to the groups of observations found. This equation will be very useful since it allows us to observe possible comparisons between those groups more clearly.

$$y_{it} = \alpha + \gamma_i + \delta t + \sum_{j=N,P,A,E} \sum_{k=N,P,A,E} \omega_{jk} R_{ij} F_{ik} t + \varepsilon_{it} \qquad (4)$$

Although in this case the four groups (N, P, A, E) are fully included in the sums (including the control groups), the process will be the same as in equation (3): the dummies that involve one of the base control groups, N for the paved roads and P for the railways, will be omitted due to an econometric requirement.

Finally, the fixed effects regression will be taken and the outcome of this model is planned to reveal the coefficients of the remaining pair of groups with respect to the base control group (NR,PF)[8].

[7] We skip the inclusion of the individual's (subsdistricts) variable γ. Nevertheless, the model is estimated including it. So, if the individual's dummy was counted, the dummies analyzed would rise to 17.
[8] As mentioned previously, the group (NR, PF) = (Never Road, Permanently Railway).

3 | Results

As previously mentioned, the work aims to study the impact of changes in transportation infrastructure between railways and paved roads. For this purpose, table 4 presents all possible combinations between subdistricts and the observations available for each. Likewise, it makes no sense to analyze pairs of groups in which elimatings roads (ER) and adding railways (AF) are involved since the number of observations does not exceed three. Finally, it is important to clarify that two pairs of groups will not be analyzed since there are no observations for them: on the one hand, there are no subdistricts in which paved roads had been eliminated (ER) and railway branches had been added (AF); on the other hand, the same situation occurs in the case of subdistricts in which both paved roads and railways were removed (ER and EF). So, in search of more robust results the focus will be on the rest of the existing groups.

Table 4: Number of Observations for each possible combination of variables R and F.

		Railway (F)				
		Never (N)	Permanently (P)	Added (A)	Eliminated (E)	Total
Paved Roads (R)	Never (N)	50	24	2	4	80
	Permanently (P)	8	181	1	9	199
	Added (A)	54	121	1	19	195
	Eliminated (E)	1	3	0	0	4
	Total	113	329	4	32	478

Since the fixed effects regression (3) requires comparing the coefficients to the chosen base control group defined by (NR, PF), then it must be remembered that the interpretation of the results is defined with respect to that base group.

As previously said, the variables will be analyzed in three different setups: natural logarithm, natural logarithm + 0.01 and their weighting over the total area of the subdistrict. It should be noted that results will also be discriminated by three observations set: all observations, no capital subdistricts, and no capitals and conurban districts.

3.1 | Annual and Perennial Crops

Firstly, table 4 will show the results of the equation (3) considering the three variable setups and the three observation sets for ***annual and perennial crops***. These types of crops represent agricultural elements, temporary or permanent, that are not intended for livestock consumption.

Table 5: Fixed effects coefficients results from the regression (3) for annuals and perennials crops.

Variables	ln(Annuals & Perennials)			ln(Annuals & Perennials+0.01)			Annuals & Perennials/Total Area		
	Total Obs.	**No Capitals**	**No Caps. & Conurban**	**Total Obs.**	**No Capitals**	**No Caps. & Conurban**	**Total Obs.**	**No Capitals**	**No Caps. & Conurban**
t	-1.0724**	-1.0724**	-1.1586***	-1.3250***	-1.3250***	-1.4790***	0.0022	0.0022	0.0023
$\Sigma\beta_j R_{ij} t$									
Permanently	0.8473*	0.8737**	1.0941**	1.0786**	1.1011**	1.3511**	0.0156**	0.0188***	0.0226***
Added	0.7385*	0.7354*	0.8570*	0.9921**	0.9890*	1.1782**	-0.0039	-0.0039	-0.0034
Eliminated	1.0651*	1.0651*	1.1513**	-0.2182	-0.2182	-0.0643	-0.0027	-0.0027	-0.0028
$\Sigma\lambda_k F_{ik} t$									
Never	0.1819	0.1819	0.3609	0.1423	0.2629	0.4945	0.0017	0.0018	0.0063
Added	0.1573	0.1573	0.2435	0.4099	0.4099	0.5639	-0.0393*	-0.0393*	-0.0394*
Eliminated	-0.3847	-0.3847	-0.2985	-0.132	-0.132	0.0219	-0.0336***	-0.0336***	-0.0337***
$\Sigma\omega_{jk} R_{ij} F_{ik} t$									
Permanently Roads, Never Railways	-0.1279	-0.1543	-0.4675	-1.0184	-1.1615	-1.4892	-0.0081	-0.0115	-0.0198
Permanently Roads, Added Railways	-0.6492	-0.6757	-0.8960*	-0.8805	-0.903	-1.1531*	-0.1533***	-0.1565***	-0.1603***
Permanently Roads, Eliminated Railways	-0.4803	-0.2261	-0.4464	-0.7115	-0.4534	-0.7035	-0.0158	-0.0276	-0.0314
Added Roads, Never Railways	-0.3389	-0.3357	-0.5502	-0.8011	-0.9186	-1.1855	-0.0036	-0.0037	-0.0088
Added Roads, Added Railways	0.2626	0.2657	0.1442	0.009	0.0121	-0.1771	0.0414*	0.0414*	0.0409*
Added Roads, Eliminated Railways	0.0444	0.1632	0.0417	-0.6228	-0.5401	-0.7292	0.0205	0.0197	0.0192
Eliminated Roads, Never Railways	0.3581	0.3581	0.1791	1.9336	1.813	1.5814	0.0000	-0.0001	-0.0046
Eliminated Roads, Added Railways	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)
Eliminated Roads, Eliminated Railways	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)
α	8.6080***	8.6868***	8.8017***	8.2947***	8.3433***	8.5005***	0.0868***	0.0877***	0.0897***
r2	0.1283	0.1201	0.1192	0.1244	0.1153	0.1172	0.0496	0.06	0.0738
N	457	436	420	478	455	437	478	455	437

Note: The fixed effects regressions were made using robust errors. (*) implies that the coefficient is significant at the 10 percent level, (**) means that the factor is significant at the 5 percent level and (***) implies that the coefficient is significant at the 1 percent level.

Secondly, as mentioned before, the results presented in Table 4 can be summarized in an equivalent but more synthetic table that allows us to clearly observe the effects by group of observations. This approach is executed using equation (4) and its results are presented in table 6.

Table 6: Net coefficients by group using fixed effects results from the regression (4).

Variables	ln(Annuals & Perennials)			ln(Annuals & Perennials+0.01)			Annuals & Perennials/Total Area		
	Total Obs.	No Capitals	No Caps. & Conurban	Total Obs.	No Capitals	No Caps. & Conurban	Total Obs.	No Capitals	No Caps. & Conurban
t	-1.0724**	-1.0724**	-1.1586***	-1.3250***	-1.3250***	-1.4790***	0.0022	0.0022	0.0023
$\Sigma\omega_{jk}R_{ij}F_{ik}t$									
Never Roads, Never Railway	0.1819	0.1819	0.3609	0.1423	0.2629	0.4945	0.0017	0.0018	0.0063
Never Roads, Permanently Railway	0.1573	0.1573	0.2435	0.4099	0.4099	0.5639	-0.0393*	-0.0393*	-0.0394*
Never Road, Eliminated Railway	-0.3847	-0.3847	-0.2985	-0.132	-0.132	0.0219	-0.0336***	-0.0336***	-0.0337***
Permanently Road, Never Railway	0.9013	0.9013	0.9875	0.2025	0.2025	0.3565	0.0092	0.0092	0.0091
Permanently Road, Permanently Railway	0.8473*	0.8737**	1.0941**	1.0786**	1.1011**	1.3511**	0.0156**	0.0188***	0.0226***
Permanently Road, Added Railway	0.3554	0.3554	0.4416	0.608	0.608	0.762	-0.1770***	-0.1770***	-0.1770***
Permanently Road, Eliminated Railway	-0.0176	0.263	0.3492	0.2351	0.5156	0.6696	-0.0338**	-0.0424**	-0.0425**
Added Road, Never Railway	0.5816	0.5816	0.6677	0.3333	0.3333	0.4873	-0.0058	-0.0058	-0.0058
Added Road, Permanently Railway	0.7385*	0.7354*	0.8570*	0.9921**	0.9890*	1.1782**	-0.0039	-0.0039	-0.0034
Added Road, Added Railway	1.1585***	1.1585***	1.2446***	1.4111***	1.4111***	1.5650***	-0.0018	-0.0018	-0.0019
Added Road, Eliminated Railway	0.3982	0.514	0.6001	0.2373	0.3169	0.4709	-0.017	-0.0178	-0.0179
Eliminated Road, Never Railway	1.6051***	1.6051***	1.6913***	1.8577***	1.8577***	2.0117***	-0.001	-0.001	-0.0011
Eliminated Road, Permanently Railway	1.0651*	1.0651*	1.1513**	-0.2182	-0.2182	-0.0643	-0.0027	-0.0027	-0.0028
Eliminated Road, Added Railway	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)
Eliminated Road, Eliminated Railway	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)
α	8.6080***	8.6868***	8.8017***	8.2947***	8.3433***	8.5005***	0.0868***	0.0877***	0.0897***
r2	0.1283	0.1201	0.1192	0.1244	0.1153	0.1172	0.0496	0.06	0.0738
N	457	436	420	478	455	437	478	455	437

Note: The fixed effects regressions were made using robust errors. (*) implies that the coefficient is significant at the 10 percent level, (**) means that the factor is significant at the 5 percent level and (***) implies that the coefficient is significant at the 1 percent level.

Some preliminary inferences could be extracted from tables 5 and 6. Firstly, the dummy time (t) is significantly negative for all the non relative setups, revealing an overall reduction in the implanted annual and perennial crops for all the subdistricts with respect to the base group (NR, PF)[9]. Secondly, as expected, positive and significant coefficients are found when observing the groups where paved roads were added. Thirdly, observations that already had both means of transportation and subdistricts where a second transportation means was added during the analysis period presents also positive and significant coefficients, revealing a possible enhancing effect of the possession of paved roads and railways. Fourthly, the coefficients tend to deepen as the observations corresponding to the subdistrict capitals and the Buenos Aires suburbs (*conurban)*[10] are eliminated; this is an expected result since the population and urban growth in these subdistricts was substantially above the national average, creating the need to occupy spaces that were previously used for agricultural activity and forcing the coefficients associated with the variable of interest (annual and perennial crops) to decrease in value. It is important to note that, given the very limited availability of observations for these, it is not possible to affirm anything conclusive from the group in which paved roads and railways were incorporated simultaneously nor from the categories in which paved roads were eliminated.

Then, to finally achieve an impact evaluation model and realize more robust statements, paired comparisons will be made between different groups, considering that all the compared cases are reasonable and respond to an appropriate treatment-control process. For example, a rational comparison would be to measure a group that never had railways and paved roads were added against another group in which railway and paved roads were never installed; in this way, we would be able to capture the net effect of placing paved roads in subdistricts while keeping the rest of the variables constant. Tables 7, 8 and 9 will show the results from the mean difference tests applied to paired group comparisons for the three different variable setups considered.

[9] Note that the (NR, PF) group is not present in the regressions results. As previously mentioned, this is because it takes the role of the base control group and is unable to be compared to any other group.

[10] The Metropolitan Area of Buenos Aires (AMBA or Conurbano) always represents an agglomeration of special characteristics and it is better not to treat it as common observations [Pagni, C. (2023). *El nudo: por qué el conurbano bonaerense modela la política argentina*. Planeta]. In the case of this work, population growth well above the average of these districts can alter the results and that is why it was decided to carry out one of the regressions without including them.

Table 7: Fixed effects matched groups comparison for *Annual and Perennial Crops* differentiated by total observations set, observations without capitals, and observations without capitals and conurban districts, concerning the first set up: ln(*Annual and Perennial Crops*).

Treatment Type	Matched Groups	ln(Annual and Perennial Crops)		
		All obs.	No capitals obs.	No capitals & conurban obs.
Add Paved Road	(AR,NF) vs. (NR,NF) (Roads Added, Never railways vs. Never Road, Never Railways)	**0.400**	**0.400**	**0.307**
		$n_1, n_2 = (49, 43)$	$n_1, n_2 = (49, 43)$	$n_1, n_2 = (49, 42)$
	(AR,PF) vs. (NR,PF) (Added Roads, Permanently Railways vs. Never Roads, Permanently Railways)	**0.738***	**0.735***	**0.857***
		$n_1, n_2 = (121, 22)$	$n_1, n_2 = (119, 22)$	$n_1, n_2 = (116, 21)$
	(AR,PF) vs. (PR,PF) (Added Roads, Permanently Railways vs. Permanently Roads, Permanently Railways)	**-0.109**	**-0.138**	**-0.237***
		$n_1, n_2 = (121, 178)$	$n_1, n_2 = (119, 162)$	$n_1, n_2 = (116, 151)$
	(AR,NF) vs. (NR,NF) - (AR,PF) vs. (NR,PF)	**-0.339**	**-0.336**	**-0.550**
		-	-	-
Add P. Road & Eliminate Railway	(AR,EF) vs. (NR,PF) (Added Roads, Eliminated Railways vs. Never Roads, Permanently Railways)	**0.398**	**0.514**	**0.600**
		$n_1, n_2 = (17, 22)$	$n_1, n_2 = (16, 22)$	$n_1, n_2 = (16, 21)$
Eliminate Railway	(NR,EF) vs. (NR,PF) (Never Roads, Eliminated Railways vs. Never Roads, Permanently Railways)	**-0.385**	**-0.385**	**-0.299**
		$n_1, n_2 = (4, 22)$	$n_1, n_2 = (4, 22)$	$n_1, n_2 = (4, 21)$
	(PR,EF) vs. (PR,PF) (Permanently Roads, Eliminated Railways vs. Permanently Roads, Permanently Railways)	**-0.865*****	**-0.611***	**-0.745****
		$n_1, n_2 = (9, 178)$	$n_1, n_2 = (7, 162)$	$n_1, n_2 = (7, 151)$
	(NR,EF) vs. (NR,PF) - (PR,EF) vs. (PR,PF)	**0.480**	**0.226**	**0.446**
		-	-	-

Note: The fixed effects regressions were made using robust errors. (*) implies that the coefficient is significant at the 10 percent level, (**) means that the factor is significant at the 5 percent level and (***) implies that the coefficient is significant at the 1 percent level.

As can be seen in the table, to interpret these results the treatment types have been divided in three categories: incorporating paved roads, eliminating railway networks and these two together. In first place, when looking at the paved roads treatment, due to the significant and positive coefficients obtained in all observation sets (all observations, no capitals, and no capitals neither conurban) for the (AR,PF) vs. (NR, PF) test it is possible to conclude the existence of a positive effect in annual and perennial crops by incorporating roads in subdistricts that already had railway networks previously; meanwhile, given that the other paired group comparison are no significant or conclusive, it is possible to affirm that there is a certain multiplier effect for the districts that have both treatments. In second place, by focusing on the groups that perceive the elimination of active railway networks, an expected significant and negative test coefficient is observed for all observation sets when comparing a group with paved roads from which the railway was eliminated to another group that had both treatments (PR,EF) vs. (PR,PF), meaning the existence of a negative effect in annual and perennial crops for removing railways from a subdistricts that used to have both means of transport. Thirdly, the only group comparison that involves both treatments together reveals there is a positive but not significantly different from zero effect for the group of observations in which railways had been removed and paved roads had been added versus the group that own railroads but not paved roads. Finally, it is important to make some clarifications: from one side, some groups involve a really scarce number of observations, making these inapplicable when obtaining valid conclusions; from the other side, neither of the two mean differences tested, (AR,NF) vs. (NR,NF) - (AR,PF) vs. (NR,PF) and (NR,EF) vs. (NR,PF) - (PR,EF) vs. (PR,PF), reveals significant differential effects between pairs of groups, meaning that the presence of a distinctive impact between incorporating a new means of transportation (paved roads or railways) to places that already had the other considered method of transportation and places that never had this one cannot be proven.

Table 8: Fixed effects matched groups comparison for *Annual and Perennial Crops* differentiated by total observations set, observations without capitals, and observations without capitals and conurban districts, concerning the second set up: ln(*Annual and Perennial Crops + 0.01*).

Treatment Type	Matched Groups	ln(Annual and Perennial Crops + 0.01)		
		All obs.	No capitals obs.	No capitals & conurban obs.
	(AR,NF) vs. (NR,NF) (Roads Added, Never Railways vs. Never Road, Never Railways)	**0.191**	**0.070**	**-0.007**
		$n_1, n_2 = (54, 50)$	$n_1, n_2 = (54, 49)$	$n_1, n_2 = (54, 48)$
	(AR,PF) vs. (NR,PF) (Added Roads, Permanently Railways vs. Never Roads,	**0.992****	**0.989***	**1.178****

Add Paved Road	Permanently Railways)	$n_1, n_2 = (121, 24)$	$n_1, n_2 = (119, 24)$	$n_1, n_2 = (116, 22)$
	(AR,PF) vs. (PR,PF) (Added Roads, Permanently Railways vs. Permanently Roads, Permanently Railways)	**-0.086**	**-0.112**	**-0.173**
		$n_1, n_2 = (121, 181)$	$n_1, n_2 = (119, 164$	$n_1, n_2 = (116, 152)$
	(AR,NF) vs. (NR,NF) - (AR,PF) vs. (NR,PF)	**-0.801**	**-0.919**	**-1.185**
		-	-	-
Add P. Road & Eliminate Railway	(AR,EF) vs. (NR,PF) (Added Roads, Eliminated Railways vs. Never Roads, Permanently Railways)	**0.237**	**0.317**	**0.471**
		$n_1, n_2 = (19, 24)$	$n_1, n_2 = (18, 24)$	$n_1, n_2 = (18, 22)$
Eliminate Railway	(NR,EF) vs. (NR,PF) (Never Roads, Eliminated Railways vs. Never Roads, Permanently Railways)	**0.333**	**0.333**	**0.022**
		$n_1, n_2 = (4, 24)$	$n_1, n_2 = (4, 24)$	$n_1, n_2 = (4, 22)$
	(PR,EF) vs. (PR,PF) (Permanently Roads, Eliminated Railways vs. Permanently Roads, Permanently Railways)	**-0.843*****	**-0.585***	**-0.681****
		$n_1, n_2 = (9, 181)$	$n_1, n_2 = (7, 164)$	$n_1, n_2 = (7, 152)$
	(NR,EF) vs. (NR,PF) - (PR,EF) vs. (PR,PF)	**0.711**	**0.453**	**0.703**
		-	-	-

Note: The fixed effects regressions were made using robust errors. (*) implies that the coefficient is significant at the 10 percent level, (**) means that the factor is significant at the 5 percent level and (***) implies that the coefficient is significant at the 1 percent level.

Table 8 reveals that using the second planned configuration with the objective of not losing observations the results are highly consistent with those obtained operating the unmodified setup. Firstly, once again, the paved roads treatment generates a solid positive impact for the particular paired group test comparing the group to which paved roads were added to subdistricts that used to have railway branches permanently against the set that includes subdistricts that permanently had railways branches but had never got paved roads (AR,PF) vs. (NR, PF), inducing the existence of a multiplicative/enhancing phenomenon in the presence of both treatments in a subdistrict since the other tests are inconclusive and insignificant in their results. In second place, the comparison that involves both treatments in opposite directions (AR,EF) vs. (NR, PF) yields a positive but not significant effect; this could be explained by the inability of the positive effect upon the incorporation of one treatment to compensate for the negative effect upon the elimination of another. In third place, for the treatment that involves the railway elimination, the only group comparison that reveals a negative and significant output is the one that contrasts groups in which the railway was eliminated and the paved roads were a permanent transportation tool against the set that permanently had both treatments available (PR,EF) vs. (PR,PF); anew, this could mean there exists an outstanding positive nonlinear effect when both treatments operate simultaneously, and when one of them is eliminated, the loss of the enhancement is reflected to a greater extent. Finally, as in the natural logarithm case, the insignificant coefficients presented in both mean differences tests, (AR,NF) vs. (NR,NF) - (AR,PF) vs. (NR,PF) and (NR,EF) vs. (NR,PF) - (PR,EF) vs. (PR,PF), reveals that differential effects in incorporating new means of transportation to disparate base groups cannot be proved.

Table 9: Fixed effects matched groups comparison for *Annual and Perennial Crops* differentiated by total observations set, observations without capitals, and observations without capitals and conurban districts, concerning the third set up: *Annual and Perennial Crops/District Area (ha.)*.

Treatment Type	Matched Groups	Annual and Perennial Crops/District Area (ha.)		
		All obs.	No capitals obs.	No capitals & conurban obs.
Add Paved Road	(AR,NF) vs. (NR,NF) (Roads Added, Permanently Railways vs. Never Road, Never Railways)	**-0.008**	**-0.008**	**0.012***
		$n_1, n_2 = (54, 50)$	$n_1, n_2 = (54, 49)$	$n_1, n_2 = (54, 48)$
	(AR,PF) vs. (NR,PF) (Added Roads, Never Railways vs. Never Roads, Permanently Railways)	**-0.004**	**-0.004**	**-0.003**
		$n_1, n_2 = (121, 24)$	$n_1, n_2 = (119, 24)$	$n_1, n_2 = (116, 22)$
	(AR,PF) vs. (PR,PF) (Added Roads, Permanently Railways vs. Permanently Roads, Permanently Railways)	**-0.019****	**-0.023****	**-0.026****
		$n_1, n_2 = (121, 181)$	$n_1, n_2 = (119, 164)$	$n_1, n_2 = (116, 152)$
	(AR,NF) vs. (NR,NF) - (AR,PF) vs. (NR,PF)	**-0.004**	**-0.004**	**-0.009**
		-	-	-
Add P. Road & Eliminate Railway	(AR,EF) vs. (NR,PF) (Added Roads, Eliminated Railways vs. Never Roads, Permanently Railways)	**-0.017**	**-0.017**	**-0.018**
		$n_1, n_2 = (19, 24)$	$n_1, n_2 = (18, 24)$	$n_1, n_2 = (18, 22)$
	(NR,EF) vs. (NR,PF) (Never Roads, Eliminated Railways vs. Never Roads,	**-0.034*****	**-0.034*****	**-0.034*****
		$n_1, n_2 = (4, 24)$	$n_1, n_2 = (4, 24)$	$n_1, n_2 = (4, 22)$

	Permanently Railways)			
Eliminate Railway	(PR,EF) vs. (PR,PF) (Permanently Roads, Eliminated Railways vs. Permanently Roads, Permanently Railways)	**-0.049*** **	**-0.061*** **	**-0.065*** **
		$n_1, n_2 = (9, 181)$	$n_1, n_2 = (7, 164)$	$n_1, n_2 = (7, 152)$
	(NR,EF) vs. (NR,PF) - (PR,EF) vs. (PR,PF)	**0.016**	**0.028**	**0.031**
		-	-	-

<u>Note:</u> The fixed effects regressions were made using robust errors. (*) implies that the coefficient is significant at the 10 percent level, (**) means that the factor is significant at the 5 percent level and (***) implies that the coefficient is significant at the 1 percent level.

Ultimately, the last approach to achieve a complete annuals and perennial crops analysis considers the relative weight of them in the total area of the subdistricts and is presented in table 9. For this setup, the results are partially consistent with those obtained in the two previous setups. Firstly, in the opposite direction to the previous cases, for the paved road treatment the only paired group test with a significantly coefficient is the one that compares the group in which paved roads were added and railways connections were permanent with the set that permanently had both treatments (AR,PF) vs. (PR, PF), revealing a negative effect on relative annual and perennial crops when incorporating a second treatment in places where one already existed. In second place, no robust conclusions can be made from the paired group test that involves both treatments performing simultaneously (AR,EF) vs. (NR, PF). Thirdly, as in the cases exposed previously, the significantly negative coefficient presented by the test that evaluates the group in which the railway was eliminated but paved roads were a permanent means of transportation against the set that permanently had both treatments available (PR,EF) vs. (PR,PF) induces that eliminating the railway infrastructure from places that used to have both means of transportation generates the reduction of their multiplicative/enhancing effect. Meanwhile, when focusing on the test that involves the (NR,EF) vs. (NR,PF) groups a negative and significant coefficient is obtained at all observation sets; nevertheless, the number of observations that the first group represents is too small to make solid conclusions. Finally, once again, the mean differences tests, (AR,NF) vs. (NR,NF) - (AR,PF) vs. (NR,PF) and (NR,EF) vs. (NR,PF) - (PR,EF) vs. (PR,PF), are not significant and prevent any type of conjecture.

Table 10: Synthetic Results Board from the three setups used previously for *Annual and Perennial Crops* fixed effects groups comparison.

Matched Groups	Obs. Considered	Variable Setup: *Annual and Perennial Crops*		
		ln	ln + 0.01	relative to area
(AR,NF) vs. (NR,NF) (Roads Added, Never Railways vs. Never Road, Never Railways)	Total Obs.	0.400	0.191	-0.008
	No Capitals.	0.400	0.070	-0.008
	No Capitals & Conurban.	0.307	-0.007	0.012*
(AR,PF) vs. (NR,PF) (Added Roads, Permanently Railways vs. Never Roads, Permanently Railways)	Total Obs.	0.738*	0.992**	-0.004
	No Capitals.	0.735*	0.989*	-0.004
	No Capitals & Conurban.	0.857*	1.178**	-0.003
(AR,PF) vs. (PR,PF) (Added Roads, Permanently Railways vs. Permanently Roads, Permanently Railways)	Total Obs.	-0.109	-0.086	-0.019**
	No Capitals.	-0.138	-0.112	-0.023**
	No Capitals & Conurban.	-0.237*	-0.173	-0.026**
(AR,NF) vs. (NR,NF) - (AR,PF) vs. (NR,PF)	Total Obs.	-0.339	-0.801	-0.004
	No Capitals.	-0.336	-0.919	-0.004
	No Capitals & Conurban.	-0.550	-1.185	-0.009
(AR,EF) vs. (NR,PF) (Added Roads, Eliminated Railways vs. Never Roads, Permanently Railways)	Total Obs.	0.398	0.237	-0.017
	No Capitals.	0.514	0.317	-0.017
	No Capitals & Conurban.	0.600	0.471	-0.018
(NR,EF) vs. (NR,PF) (Never Roads, Eliminated Railways vs. Never Roads, Permanently Railways)	Total Obs.	-0.385	0.333	-0.034***
	No Capitals.	-0.385	0.333	-0.034***
	No Capitals & Conurban.	-0.299	0.022	-0.034***
(PR,EF) vs. (PR,PF) (Permanently Roads, Eliminated Railways vs. Permanently Roads, Permanently Railways)	Total Obs.	-0.865***	-0.843***	-0.049***
	No Capitals.	-0.611*	-0.585*	-0.061***
	No Capitals & Conurban.	-0.745**	-0.681**	-0.065***
(NR,EF) vs. (NR,PF) - (PR,EF) vs. (PR,PF)	Total Obs.	0.480	0.711	0.016
	No Capitals.	0.226	0.453	0.028
	No Capitals & Conurban.	0.446	0.703	0.031

<u>Note:</u> The fixed effects regressions were made using robust errors. (*) implies that the coefficient is significant at the 10 percent level, (**) means that the factor is significant at the 5 percent level and (***) implies that the coefficient is significant at the 1 percent level.

Table 10 presents all the tests previously explained in a more synthetic layout, exposing the coefficients for all setups and observations sets, granting the ability to generate more robust conclusions. First of all, the test that compares the group in which paved roads were added to places where railways were already installed against the set that never had paved roads and permanently got railways (AR,PF) vs. (NR, PF) gives positive and significant coefficients for all sets of observations in the first two setups (ln and ln+0.01), verifying the existence of positive impact regarding the incorporation of a new means of transportation; nevertheless, when observing the variation of annual and perennial crops in relation to the total area of the district, the positive impact disappears. Then, for the same type of treatment, the test that contrasts the group in which roads were added and permanently got railways against the subdistricts that have always had railways and paved roads (AR,PF) vs. (PR,PF) reveals some unexpected negative and significant coefficients at the relative measure of annual and perennial crops; however, this is not robust enough to be confirmed by the other variable setups (ln and ln+0.01). In second place, by focusing on the elimination of railways connections, two main paired group comparisons should be underlined: on the one hand, the test that involves the group that never had paved roads and railways were eliminated against the subdistrict set that have never had roads and have permanently got railways (NR,EF) vs. (NR,PF) gives a significant -3.4% coefficient for all observation sets at the relative measure of annual and perennial crops, inducing an expected negative effect on the agricultural-oriented surface of removing a means of transportation from a subdistrict, however, this conclusion is not verified by the other two setups of the variable of interest (ln and ln+0.01); on the other hand, the statistical evaluation involving the group in which railways were removed and paved roads permanently existed against the subdistricts that have always had both means of transport (PR,EF) vs. (PR,PF) report a significantly negative effect in all setups and observation sets, providing robust evidence on the negative impact of the elimination of transportation means in districts where more than one of them used to coexist (railways and paved roads).

This results synthesis provides some conclusions regarding the proposed hypothesis. On the one hand, in the exercise of sophisticating the analysis by running the paired groups mean differences tests, it is not possible to affirm that there is a generalized effect on annual and perennial crops due to the transformations in the transportation infrastructure experienced between the early 60s and the mid-80s. In this aspect, four of the six tests evaluated provide entirely non-significant coefficients [(AR,NF) vs. (NR,NF) & (AR,EF) vs. (NR,PF)] or very unrobust results [(AR,PF) vs. (PR,PF) & (NR,EF) vs. (NR,PF)] to draw any type of assertion. On the other hand, the two paired group tests that show robust and consistent results involve the application or elimination of a treatment in places where the other treatment of interest was already deployed and did not undergo changes over time [(AR,PF) vs. (NR,PF) & (PR,EF) vs. (PR,PF)], verifying the impact of modifications in transportation infrastructure on annual and perennial crops only if both treatments perform simultaneously, either after the incorporation of a new treatment or before the elimination of an old treatment.

3.2 | Cereals and Oilseeds: Wheat, Corn, Soybeans and Sunflower

As in the previous variable case, for **cereals and oilseeds** the procedure will be the same. Firstly, in table 11 the results of the fixed effects regression in equation (3) are presented.

Table 11: Fixed effects coefficients results from the regression (3) for Cereals and Oilseeds.

Variables	ln(Cereals and Oilseeds)			ln(Cereals and Oilseeds+0.01)			Cereals and Oilseeds/Total Area		
	Total Obs.	No Capitals	No Caps. & Conurban	Total Obs.	No Capitals	No Caps. & Conurban	Total Obs.	No Capitals	No Caps. & Conurban
t	-0.8286**	-0.8286**	-0.9181**	-2.0406***	-2.0406***	-2.2576***	0.0014	0.0014	0.0015
$\Sigma\beta_j R_{ij} t$									
Permanently	0.8885**	0.9351**	1.0757***	1.7248**	1.7295**	2.0341***	0.0629***	0.0673***	0.0633***
Added	0.6809*	0.6737*	0.7855**	1.5842**	1.5722**	1.8759***	0.0293***	0.0298***	0.0307***
Eliminated	0.4141	0.4141	0.5037	1.7643**	1.7643**	1.9813**	-0.0026	-0.0026	-0.0026
$\Sigma\lambda_k F_{ik} t$									
Never	-0.019	-0.019	0.0705	0.8937	0.8703	1.159	-0.0004	-0.0004	-0.0004
Added	0.1457	0.1457	0.2352	1.3593*	1.3593*	1.5764**	-0.0033	-0.0033	-0.0033
Eliminated	-0.1453	-0.1453	-0.0557	1.0668	1.0668	1.2838	-0.0083*	-0.0083*	-0.0083*
$\Sigma\omega_{jk} R_{ij} F_{ik} t$									
Permanently Roads, Never Railways	-0.4793	-0.5259	-0.6665	-2.3146*	-2.2959*	-2.6723**	-0.0663***	-0.0706***	-0.0667***
Permanently Roads, Added Railways	-0.4932	-0.5399	-0.6805	-1.3295*	-1.3343*	-1.6389**	-0.0611***	-0.0655***	-0.0615***
Permanently Roads, Eliminated Railways	-0.7639	-0.6036	-0.7442	-1.5055*	-1.3062	-1.6108*	-0.0568***	-0.0613***	-0.0573***
Added Roads, Never Railways	-0.3779	-0.3707	-0.4825	-1.8904**	-1.8549**	-2.2304**	-0.0300***	-0.0306***	-0.0315***
Added Roads, Added Railways	-1.9386***	-1.9314***	-2.0433***	-2.8433***	-2.8313***	-3.1350***	-0.0279***	-0.0284***	-0.0293***
Added Roads, Eliminated Railways	-0.1452	-0.138	-0.2498	-1.5801*	-1.3048	-1.6086*	-0.0317**	-0.0327**	-0.0336**
Eliminated Roads, Never Railways	(omitted)	(omitted)	(omitted)	-8.4810***	-8.4576***	-8.7464***	0.0014	0.0014	0.0014
Eliminated Roads, Added Railways	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)
Eliminated Roads, Eliminated Railways	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)
α	7.7748***	7.8215***	7.8776***	6.7310***	6.8151***	7.0230***	0.0465***	0.0471***	0.0488***
r2	0.0909	0.0922	0.1007	0.1379	0.137	0.1548	0.137	0.146	0.1885
N	415	396	388	478	455	437	478	455	437

Note: The fixed effects regressions were made using robust errors. (*) implies that the coefficient is significant at the 10 percent level, (**) means that the factor is significant at the 5 percent level and (***) implies that the coefficient is significant at the 1 percent level.

Similarly, the results presented in Table 11 can be summarized in an equivalent but more synthetic table that allows us to observe the net effects by group of observations. This approach is executed using equation (4) and its results are presented in table 12.

Table 12: Net coefficients by group using fixed effects results from the regression (4) for Cereals and Oilseeds.

Variables	ln(Cerelas and Oilseeds)			ln(Cerelas and Oilseeds+0.01)			Cerelas and Oilseeds/Total Area		
	Total Obs.	**No Capitals**	**No Caps. & Conurban**	**Total Obs.**	**No Capitals**	**No Caps. & Conurban**	**Total Obs.**	**No Capitals**	**No Caps. & Conurban**
t	-0.8286**	-0.8286**	-0.9181**	-2.0406***	-2.0406***	-2.2576***	0.0014	0.0014	0.0015
$\Sigma\omega_{jk}R_{ij}F_{ik}t$									
Never Roads, Never Railway	-0.019	-0.019	0.0705	0.8937	0.8703	1.159	-0.0004	-0.0004	-0.0004
Never Roads, Permanently Railway	0.1457	0.1457	0.2352	1.3593*	1.3593*	1.5764**	-0.0033	-0.0033	-0.0033
Never Road, Eliminated Railway	-0.1453	-0.1453	-0.0557	1.0668	1.0668	1.2838	-0.0083*	-0.0083*	-0.0083*
Permanently Road, Never Railway	0.3902	0.3902	0.4798	0.3039	0.3039	0.5209	-0.0037*	-0.0037*	-0.0038*
Permanently Road, Permanently Railway	0.8885**	0.9351**	1.0757***	1.7248**	1.7295**	2.0341***	0.0629***	0.0673***	0.0633***
Permanently Road, Added Railway	0.5409	0.5409	0.6305*	1.7546***	1.7546***	1.9716***	-0.0015	-0.0015	-0.0015
Permanently Road, Eliminated Railway	-0.0207	0.1863	0.2758	1.2860*	1.4901**	1.7071**	-0.0021	-0.0022	-0.0023
Added Road, Never Railway	0.284	0.284	0.3735	0.5875	0.5875	0.8045	-0.0011	-0.0011	-0.0012
Added Road, Permanently Railway	0.6809*	0.6737*	0.7855**	1.5842**	1.5722**	1.8759***	0.0293***	0.0298***	0.0307***
Added Road, Added Railway	-1.1120***	-1.1120***	-1.0225***	0.1002	0.1002	0.3173	-0.0019	-0.0019	-0.0019
Added Road, Eliminated Railway	0.3905	0.3905	0.48	1.0709	1.3341*	1.5511**	-0.0106	-0.0111	-0.0112
Eliminated Road, Never Railway	(omitted)	(omitted)	(omitted)	-5.8230***	-5.8230***	-5.6060***	-0.0016	-0.0016	-0.0017
Eliminated Road, Permanently Railway	0.4141	0.4141	0.5037	1.7643**	1.7643**	1.9813**	-0.0026	-0.0026	-0.0026
Eliminated Road, Added Railway	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)
Eliminated Road, Eliminated Railway	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)
α	7.7748***	7.8215***	7.8776***	6.7310***	6.8151***	7.0230***	0.0465***	0.0471***	0.0488***
r2	0.0909	0.0922	0.1007	0.1379	0.137	0.1548	0.137	0.146	0.1885
N	415	396	388	478	455	437	478	455	437

Note: The fixed effects regressions were made using robust errors. (*) implies that the coefficient is significant at the 10 percent level, (**) means that the factor is significant at the 5 percent level and (***) implies that the coefficient is significant at the 1 percent level.

For the cereals and oilseeds case the results are slightly less consistent, especially when focusing on the group dummies. In first place, once again, the time dummy (t) presents negative and significant coefficients for all non relative cases, inducing a general negative effect of time on cereal and oilseed crops. In second place, only one group presents positive and significant coefficients once they were treated with the addition of paved roads, and this is the situation in which the subdistricts already had previously installed railways, verifying again the enhancing effect of having the two means of transportation simultaneously. Thirdly, when observing the groups that involve only railways or only paved roads (without receiving a treatment in the opposite group), it can be intuited that having only one of these does not guarantee a robust consistent effect on the cereal and oilseed crops of a subdistrict; in particular, the group that have always had railways and have never got paved roads exhibit significantly positive coefficients only for the second setup of the variable (ln + 0.01), meanwhile, the set that have always had paved roads and have never got railways presents significant and negative results only for the relative measure of cereals and oilseeds (relative to the total area of the district). In fourth place, a lack of consistency is also observed by focusing on treatment involving removal of the railroads: on the one hand, the subdistricts that have never had roads and railways were eliminated within the period of analysis present expected negative and significant coefficients only for the relative setup; on the other hand, groups involving the elimination of railways while paved roads were deployed (whether they were added or permanently installed) show positive and significant results only for the second setup (ln + 0.01). Thus, by joining the third and fourth ideas, it is possible to mention that although the effect of having only paved roads without changes over time may be negative, the fact of installing roads in places where railways were eliminated can be compensatory and positive; however, the lack of consistency and robustness in the coefficients prevents solid conclusions from being drawn. Finally, as in the annual and perennial crops case, most of the results tend to increase in magnitude as observations linked to the capital subdistricts or the Buenos Aires suburbs are eliminated, even managing to increase their significance by eliminating the bias of the most urban and densely populated places.

Once again, to achieve a proper impact evaluation model and realize more deeper and robust statements, paired comparisons will be made between different groups, considering that all the compared cases are reasonable and respond to an appropriate treatment-control process.

Tables 13, 14 and 15 will show the results from the mean difference tests applied to paired group comparisons for the three different variable setups considered in the Cereals and Oilseeds variable.

<u>Table 13:</u> Fixed effects matched groups comparison for *Cereals and Oilseeds: Wheat, Corn, Soybeans and Sunflower* differentiated by total observations set, observations without capitals, and observations without capitals and conurban districts, concerning the first set up: ln(*Cereals and Oilseeds: Wheat, Corn, Soybeans and Sunflower*).

Treatment Type	Matched Groups	ln(Cereals and Oilseeds)		
		All obs.	No capitals obs.	No capitals & conurban obs.
Add Paved Road	(AR,NF) vs. (NR,NF) (Roads Added, Never Railways vs. Never Road, Never Railways)	**0.303**	**0.303**	**0.303**
		$n_1, n_2 = (41, 35)$	$n_1, n_2 = (41, 35)$	$n_1, n_2 = (41, 35)$
	(AR,PF) vs. (NR,PF) (Added Roads, Permanently Railways vs. Never Roads, Permanently Railways)	**0.681***	**0.674***	**0.786****
		$n_1, n_2 = (116, 23)$	$n_1, n_2 = (114, 23)$	$n_1, n_2 = (113, 16)$
	(AR,PF) vs. (PR,PF) (Added Roads, Permanently Railways vs. Permanently Roads, Permanently Railways)	**-0.208**	**-0.261***	**-0.290***
		$n_1, n_2 = (116, 166)$	$n_1, n_2 = (114, 151$	$n_1, n_2 = (113, 145)$
	(AR,NF) vs. (NR,NF) - (AR,PF) vs. (NR,PF)	**0.488**	**0.498**	**0.382**
		-	-	-
Add P. Road & Eliminate Railway	(AR,EF) vs. (NR,PF) (Added Roads, Eliminated Railways vs. Never Roads, Permanently Railways)	**0.390**	**0.390**	**0.480**
		$n_1, n_2 = (16, 23)$	$n_1, n_2 = (16, 23)$	$n_1, n_2 = (16, 16)$
Remove Railway	(NR,EF) vs. (NR,PF) (Never Roads, Eliminated Railways vs. Never Roads, Permanently Railways)	**-0.145**	**-0.145**	**-0.056**
		$n_1, n_2 = (4, 18)$	$n_1, n_2 = (4, 18)$	$n_1, n_2 = (4, 16)$
	(PR,EF) vs. (PR,PF) (Permanently Roads, Eliminated Railways vs. Permanently Roads, Permanently Railways)	**-0.909*****	**-0.749****	**-0.800****
		$n_1, n_2 = (8, 166)$	$n_1, n_2 = (6, 151)$	$n_1, n_2 = (6, 145)$
	(NR,EF) vs. (NR,PF) - (PR,EF) vs. (PR,PF)	**0.764**	**0.604**	**0.744**
		-	-	-

Note: The fixed effects regressions were made using robust errors. (*) implies that the coefficient is significant at the 10 percent level, (**) means that the factor is significant at the 5 percent level and (***) implies that the coefficient is significant at the 1 percent level.

Table 14: Fixed effects matched groups comparison for *Annual and Perennial Crops* differentiated by total observations set, observations without capitals, and observations without capitals and conurban districts, concerning the second set up: ln(*Cereals and Oilseeds: Wheat, Corn, Soybeans and Sunflower + 0.01*).

Treatment Type	Matched Groups	ln(Cereals and Oilseeds + 0.01)		
		All obs.	No capitals obs.	No capitals & conurban obs.
Add Paved Road	(AR,NF) vs. (NR,NF) (Roads Added, Never Railways vs. Never Road, Never Railways)	**-0.306**	**-0.283**	**-0.354**
		$n_1, n_2 = (54, 50)$	$n_1, n_2 = (54, 49)$	$n_1, n_2 = (54, 48)$
	(AR,PF) vs. (NR,PF) (Added Roads, Permanently Railways vs. Never Roads, Permanently Railways)	**1.584****	**1.572****	**1.876****
		$n_1, n_2 = (121, 24)$	$n_1, n_2 = (119, 24)$	$n_1, n_2 = (116, 22)$
	(AR,PF) vs. (PR,PF) (Added Roads, Permanently Railways vs. Permanently Roads, Permanently Railways)	**-0.141**	**-0.157**	**-0.158**
		$n_1, n_2 = (121, 181$	$n_1, n_2 = (119, 164$	$n_1, n_2 = (116, 152)$
	(AR,NF) vs. (NR,NF) - (AR,PF) vs. (NR,PF)	**-1.890****	**-1.855****	**-2.230****
		-	-	-
Add P. Road & Eliminate Railway	(AR,EF) vs. (NR,PF) (Added Roads, Eliminated Railways vs. Never Roads, Permanently Railways)	**1.071**	**1.334***	**1.551****
		$n_1, n_2 = (19, 24)$	$n_1, n_2 = (18, 24)$	$n_1, n_2 = (18, 22)$
Remove Railway	(NR,EF) vs. (NR,PF) (Never Roads, Eliminated Railways vs. Never Roads, Permanently Railways)	**1.067**	**1.067**	**1.284**
		$n_1, n_2 = (4, 24)$	$n_1, n_2 = (4, 24)$	$n_1, n_2 = (4, 22)$
	(PR,EF) vs. (PR,PF) (Permanently Roads, Eliminated Railways vs. Permanently Roads, Permanently Railways)	**-0.439**	**-0.239**	**-0.327**
		$n_1, n_2 = (9, 181)$	$n_1, n_2 = (7, 164)$	$n_1, n_2 = (7, 152)$
	(NR,EF) vs. (NR,PF) - (PR,EF) vs. (PR,PF)	**1.506***	**1.306**	**1.611***
		-	-	-

Note: The fixed effects regressions were made using robust errors. (*) implies that the coefficient is significant at the 10 percent level, (**) means that the factor is significant at the 5 percent level and (***) implies that the coefficient is significant at the 1 percent level.

Table 15: Fixed effects matched groups comparison for *Annual and Perennial Crops* differentiated by total observations set, observations without capitals, and observations without capitals and conurban districts, concerning the third set up: *Cereals and Oilseeds: Wheat, Corn, Soybeans and Sunflower/District Area (ha.)*.

Treatment Type	Matched Groups	Cereals and Oilseeds/District Area (ha.)		
		All obs.	No capitals obs.	No capitals & conurban obs.
Add Paved Road	(AR,NF) vs. (NR,NF) (Roads Added, Never Railways vs. Never Road, Never Railways)	**-0.001**	**-0.001**	**-0.0008**
		$n_1, n_2 = (54, 50)$	$n_1, n_2 = (54, 49)$	$n_1, n_2 = (54, 48)$
	(AR,PF) vs. (NR,PF) (Added Roads, Permanently Railways vs. Never Roads, Permanently Railways)	**0.029*** **	**0.030*** **	**0.031*** **
		$n_1, n_2 = (121, 24)$	$n_1, n_2 = (119, 24)$	$n_1, n_2 = (116, 22)$
	(AR,PF) vs. (PR,PF) (Added Roads, Permanently Railways vs. Permanently Roads, Permanently Railways)	**-0.034** **	**-0.037** **	**-0.033** **
		$n_1, n_2 = (121, 181)$	$n_1, n_2 = (119, 164$	$n_1, n_2 = (116, 152)$
	(AR,NF) vs. (NR,NF) - (AR,PF) vs. (NR,PF)	**-0.030*** **	**-0.030*** **	**-0.031*** **
		-	-	-
Add P. Road & Eliminate Railway	(AR,EF) vs. (NR,PF) (Added Roads, Eliminated Railways vs. Never Roads, Permanently Railways)	**-0.011**	**-0.011**	**-0.011**
		$n_1, n_2 = (19, 24)$	$n_1, n_2 = (18, 24)$	$n_1, n_2 = (18, 22)$
Remove Railway	(NR,EF) vs. (NR,PF) (Never Roads, Eliminated Railways vs. Never Roads, Permanently Railways)	**-0.008***	**-0.008***	**-0.008***
		$n_1, n_2 = (4, 24)$	$n_1, n_2 = (4, 24)$	$n_1, n_2 = (4, 22)$
	(PR,EF) vs. (PR,PF) (Permanently Roads, Eliminated Railways vs. Permanently Roads, Permanently Railways)	**-0.065*** **	**-0.070*** **	**-0.066*** **
		$n_1, n_2 = (9, 181)$	$n_1, n_2 = (7, 164)$	$n_1, n_2 = (7, 152)$
	(NR,EF) vs. (NR,PF) - (PR,EF) vs. (PR,PF)	**0.057*** **	**0.061*** **	**0.057*** **
		-	-	-

<u>Note:</u> *The fixed effects regressions were made using robust errors. (*) implies that the coefficient is significant at the 10 percent level, (**) means that the factor is significant at the 5 percent level and (***) implies that the coefficient is significant at the 1 percent level.*

<u>Table 16:</u> Synthetic Results Board from the three setups used previously for *Cereals and Oilseeds: Wheat, Corn, Soybeans and Sunflower* fixed effects groups comparison.

Matched Groups	Obs. Considered	Variable Setup: *Cereals and Oilseeds*		
		ln	ln + 0.01	relative to area
(AR,NF) vs. (NR,NF) (Roads Added, Never Railways vs. Never Road, Never Railways)	Total Obs.	0.303	-0.306	-0.001
	No Capitals.	0.303	-0.283	-0.001
	No Capitals & Conurban.	0.303	-0.354	-0.0008
(AR,PF) vs. (NR,PF) (Added Roads, Permanently Railways vs. Never Roads, Permanently Railways)	Total Obs.	0.681*	1.584**	0.029***
	No Capitals.	0.674*	1.572**	0.030***
	No Capitals & Conurban.	0.786**	1.876***	0.031***
(AR,PF) vs. (PR,PF) (Added Roads, Permanently Railways vs. Permanently Roads, Permanently Railways)	Total Obs.	-0.208	-0.141	-0.034**
	No Capitals.	-0.261*	-0.157	-0.037**
	No Capitals & Conurban.	-0.290*	-0.158	-0.033**
(AR,NF) vs. (NR,NF) - (AR,PF) vs. (NR,PF)	Total Obs.	0.488	-1.890**	-0.030***
	No Capitals.	0.498	-1.855**	-0.030***
	No Capitals & Conurban.	0.382	-2.230**	-0.031***
(AR,EF) vs. (NR,PF) (Added Roads, Eliminated Railways vs. Never Roads, Permanently Railways)	Total Obs.	0.390	1.071	-0.011
	No Capitals.	0.390	1.334*	-0.011
	No Capitals & Conurban.	0.480	1.551**	-0.011
(NR,EF) vs. (NR,PF) (Never Roads, Eliminated Railways vs. Never Roads, Permanently Railways)	Total Obs.	-0.145	1.067	-0.008*
	No Capitals.	-0.145	1.067	-0.008*
	No Capitals & Conurban.	-0.056	1.284	-0.008*
(PR,EF) vs. (PR,PF) (Permanently Roads, Eliminated Railways vs. Permanently Roads,	Total Obs.	-0.909***	-0.439	-0.065***
	No Capitals.	-0.749**	-0.239	-0.070***
	No Capitals & Conurban.	-0.800**	-0.327	-0.066***

Permanently Railways)				
(NR,EF) vs. (NR,PF) - (PR,EF) vs. (PR,PF)	Total Obs.	0.764	1.506*	0.057***
	No Capitals.	0.604	1.306	0.061***
	No Capitals & Conurban.	0.744	1.611*	0.057***

Note: The fixed effects regressions were made using robust errors. (*) implies that the coefficient is significant at the 10 percent level, (**) means that the factor is significant at the 5 percent level and (***) implies that the coefficient is significant at the 1 percent level.

4 | Conclusion

Transportation infrastructure plays an important role in shaping the structure of economies in general. In particular, this work attempts to estimate the structural impact of the transition on the Argentine transportation infrastructure (from the railways to the paved roads) at the subdistrict level, focusing on agricultural variables.

In first place, the main finding extracted from the regressions and the paired group comparisons lies in the presence of an enhancing effect when the two means of transport perform simultaneously. Both at the level of annual and perennial crops as well as cereal and oilseed crops, the simultaneous deployment of railways and paved roads shows positive, significant and robust coefficients in the face of the different configurations in the definition of the variables and sets of observations considered. It is notable that, when observing groups in which the railway is eliminated as a means of transport and contrasting it with districts that still have both means, the negative and significant effect is persistent among the different configurations tested, verifying the negative impact of the dissolution of the enhancing effect provided. by the media acting simultaneously.

In second place, in none of the variables analyzed is there a significant impact on the addition of paved roads in places where there was previously no means of transportation. In particular, the paired group tests that involve the group in which paved roads were added and have never had railways against the set that have never had both means of transports do not reveal a significant coefficient in any case for any configuration. At this point, it is not possible to prove that the deployment of paved roads in places that previously remained without transport connections had a positive effect on their agricultural sector.

5 | Relevant Clarifications for LIX AAEP Meeting

The work is not yet completed. It is possible to note the absence of interpretations for all the tables corresponding to the cereals and oilseeds variable, and the lack of some conclusions not fully developed yet. However, it is possible to affirm that the paper is 85% - 90% complete.