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Natural disasters, growth and institutions: a tale of two earthquakes

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Abstract. We examine the impact of natural disasters on economic growth by applying a synthetic control approach. In contrast to previous literature, we adopt a within-country perspective, which allows us to use richer and more comparable data and to better define the geographic area hit by the disaster. We examine two large-scale earthquakes that occurred in two different Italian regions in 1976 and 1980. According to our findings, the short-term effects are negligible in both regions, though they become negative if we simulate the GDP that would have been observed in absence of financial aid. In the long-term, the two regions show opposite effects on GDP per capita, largely reflecting different patterns of the TFP. These opposing outcomes are consistent with the idea that a quake (and related financial aid) might either increase technical efficiency via a disruptive creation mechanism or reduce it by stimulating corruption, distorting the markets and deteriorating social capital. We show that the latter case is more likely to occur in areas with lower pre-quake institutional quality. Moreover, institutional quality itself changes in response to the shock and these patterns are correlated to those of the TFP. Overall, our evidence suggests that natural disasters are likely to exacerbate regional differences in economic and social development.

Keywords: natural disasters, regional economic growth, aids, corruption, social capital

JEL codes: R11, O40, H84, Q54

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1. Introduction

Large-scale natural disasters regularly affect societies in all corners of the globe. The immediate consequences, thanks to massive media coverage, are clear to all: deaths, displacement of people, damage to physical capital and infrastructure. As time passes, attention diminishes and long-term consequences become less clear. However, understanding a disaster's impact on later economic growth and how local institutions and economic actors react is crucial to better assess the costs of a disaster and to better design financial aid programs.

The available literature regarding the economic impact of natural disasters is still scant and inconclusive. Some studies report negative effects on economic growth, while others indicate no, or even positive, effects.¹ Moreover, many existing studies have a number of limitations that make their conclusions less than convincing. First, the effects of natural disasters are typically geographically concentrated, and the adoption of a cross-country approach (common to all existing studies) may lead, by construction, to an attenuation bias. Moreover, cross-country evidence is based on natural disasters that differ substantially in terms of type (from climatic to geological) and magnitude and that occur across countries exhibiting very different levels of economic development. Data are often not equally comparable across countries, adding further bias to estimates. Finally, the GDP dynamics following a quake can be largely affected by the amount of post-quake financial aid provided, a variable that has been rarely taken into account in existing studies. There are also econometric concerns regarding the difficulty of constructing appropriate counterfactuals. Indeed, rather than simply relying on a before-after analysis, one should compare the path of the GDP with that which would have been observed in the absence of the natural disaster (Cavallo et al., 2012).

Even less is known about *why* we observe heterogeneous long-term effects of natural disasters.² Indeed, in the aftermath of a quake, the local economy typically receives a second large shock – a storm of public transfers – that plays a crucial role in the recovery period because it positively affects the GDP in the short run. However, the long run effects are uncertain and depend on the quality of the outlay. For example, the construction of better infrastructure to replace that which is old and damaged might increase the potential output of the economy. On the other hand, if public resources are

¹ The first attempt to empirically assess the economic effects of natural disasters was by Albala-Bertrand (1993) who used a before-after statistical analysis and found positive effects on the GDP. Similar results have been found using a wider temporal perspective and a larger panel by Skidmore and Toya (2002). Loayza et al. (2009) and Noy (2009) argue that heterogeneous effects, either positive or negative, are observable depending on the type of disaster and the level of socio-economic development of the country. Finally, Cavallo et al. (2012) critically review previous empirical strategies and, by adopting the synthetic control approach, find that disasters do not significantly affect economic growth. See also Cavallo and Noy (2011) for a review of the literature.

² Kahn (2005) argues that “nations with stronger institutions suffer lower national death counts from disasters. Why this is the case requires future research. One possible mechanism is corruption”.

misallocated and diverted due to rent-seeking behaviors, institutions might become weaker and less efficient, decreasing the potential economic output.

The aim of this paper is to examine the economic impact of natural disasters by using, unlike the previous literature, a within-country perspective and a richer dataset. Namely, we investigate the consequences of two almost contemporaneous earthquakes that occurred in Italy (“Friuli” quake in 1976 and “Irpinia” quake in 1980). We compare the observed GDP per capita after the quake (which is an exogenous shock by definition) in each area with that which would have been observed in the absence of the natural disaster. We carry out this comparative analysis using a rigorous counterfactual approach, the synthetic control method, proposed by Abadie and Gardeazabal (2003) and Abadie et al. (2010). Finally, we discuss the role of institutions in mediating the impact of the quake on the local economy.

We do not find significant effects from the quake in the short term. However, this result can be largely attributed to the role of financial aid in the aftermath of the quake. Using a different assumption regarding the magnitude of the fiscal multiplier, we estimate that the yearly GDP per capita growth rate in the five years after the quake, in the absence of financial aid, would have been approximately 0.5-1.0 percentage points lower in Friuli and between 1.1-2.0 points lower in Irpinia. In the long term, we find two opposing results: the quakes yielded positive effect in Friuli and negative in Irpinia. In the former, 20 years after the quake, the GDP per capita was 13 percent higher than in the synthetic control, while in the latter, the GDP per capita experienced a 14 percent drop. After showing that in both cases, the dynamics of the GDP per capita largely mirror that of the TFP, we argue that institutional quality crucially shaped these patterns. Indeed, in Irpinia, the pre-quake institutional quality was significantly lower than that of Friuli. Moreover, in the former case, this social and economic *milieu* favored the diversion of public transfers, flourishing of fraudulent behaviors and a deterioration of social capital, negatively affecting the technical efficiency of the economy. Almost entirely opposite effects were observed in Friuli. Overall, our results suggest that natural disasters may exacerbate regional differences in economic and social development.

This paper adds to existing literature in several ways. Our empirical strategy is similar to that of Cavallo et al. (2012), who studied the economic effects of natural disasters using the synthetic control approach. That study found that even large disasters do not significantly affect the economy unless they are followed by radical political revolutions (as in Iran in 1979 and Nicaragua in 1979). However, we believe that both our data and the adoption of a within-country perspective have some advantages over the work of Cavallo et al. (2012).³ First, we can correctly define the geographical area affected by the quake. For instance, the impact of the Friuli quake – which Cavallo et al. (2012) define as a severe disaster – is significant at the local level (killed people and

³ See Miguel and Roland (2011) for another example of a within-country perspective in a somewhat related field. They investigate the impact of U.S. bombing on later local economic development in Vietnam districts.

homeless represented approximately 18 percent of the regional population) and arguably negligible at the country level (0.4 percent of the national population). Second, the within-country perspective mitigates the role of unobserved confounders that might affect the outcome dynamics between the treated and control units and which cannot be credibly controlled in a cross-country approach. Third, we use data that are much more susceptible to comparison – being drawn from the same national sources – and are much richer than those available in a cross-country context. Indeed, we have data on financial aid that allows us to estimate its impact on the GDP while applying different assumptions regarding the fiscal multiplier. Fourth, the Italian regions are much more comparable to each other than countries in different continents (which have different institutional regimes and are in extremely heterogeneous stages of development) are. This increases the similarity among the treated regions and the set of donors and, therefore, the reliability of the construction of the synthetic control.⁴

Our paper also shares an interest with Kahn (2005), Stromberg (2007) and Noy (2009) in the mediating role of institutions. However, these previous studies consider institutions as given and argue that countries with better institutions suffer fewer deaths from natural disasters and are also better able to withstand the subsequent shock. We show that the institutions themselves may change in response to the quake (and to the flow of financial aid). Indeed, we find that corruption and fraudulent behavior increase and that social capital deteriorates where local institutions are weaker. In this respect, our results mimic those of Rajkumar and Swaroop (2008) – who show that the quality of public spending can be largely explained by the quality of governance – and those of Brollo et al. (2012) – who find that larger transfers may increase corruption and reduce the quality of serving politicians.

The rest of this paper is organized as follows. In Section 2, we sketch a simple model of economic growth in which we frame the impact of an earthquake. In Section 3, we discuss our empirical strategy. In Section 4, we present the data and variables and we describe the two earthquakes. In Section 5, we discuss our results and provide a rich set of robustness checks and refinements. Section 6 concludes the paper.

2. Theoretical framework

We frame the analysis of the economic consequences of earthquakes within a simple neoclassical growth model. The production function is described by a Cobb-Douglas function:

$$Y = AK^\alpha L^{1-\alpha},$$

where Y is the GDP, A is the total factor productivity, K denotes the capital input, L is the labor input and α is the capital's share. We assume that there is no technical progress

⁴ The two seminal papers regarding the synthetic control approach (Abadie et al, 2010, and Abadie and Gardeazabal, 2003) adopt a within-country perspective.

and no population dynamics; that is, both A and L are constant. Consequently L can be normalized to 1.⁵ The capital's dynamics are given by:

$$\dot{K} = sY - \delta K = sAK^\alpha - \delta K$$

where s is the saving rate, δ is the depreciation rate and the dot over a variable indicates its derivative with respect to time. Analogously, it holds that

$$\dot{Y} = \alpha AK^{\alpha-1}\dot{K}$$

In the steady state $\dot{K} = 0$, the equilibrium stock of capital is given by:

$$K^* = \left(\frac{sA}{\delta}\right)^{\frac{1}{1-\alpha}}$$

while the steady state GDP is given by:

$$Y^* = A \left(\frac{sA}{\delta}\right)^{\frac{\alpha}{1-\alpha}}$$

that is, Y^* is an increasing function of A , s , α and a decreasing function of δ .

In this framework, assuming that the economy is in the steady state, we model the natural disaster as an instantaneous destruction of capital stock, which moves from K^* to $K' < K^*$. Significant aid flows occur after a large disaster. We model financial aid g , which is typically temporary and largely financed with external funds and not by local taxes, as a one-shot provision of funds proportional to the damage incurred ($K^* - K'$).

The key feature of the model is that g , beyond its short-term effects in the recovery period, may shape the technical efficiency of the economy (A) in the long term in a way that is a priori ambiguous. On the positive side ($\partial A/\partial g > 0$), we might observe a process of “creative destruction” (Skidmore and Toya, 2002; Cuaresma et al., 2008). Firms may replace old production technologies with new, more productive ones. Local governments, in turn, may adapt public infrastructure to the new needs, such as reconstruction of schools with better equipment and of roads more suited for the productive system.⁶ On the negative side ($\partial A/\partial g < 0$), the windfall transfers might exacerbate corruption that, in turn, may deteriorate productivity and efficiency in the allocation of inputs (e.g., the firm that pays a bribe to a bureaucrat to obtain access to public transfers also imposes externalities onto other firms and distorts the market). Moreover, local governments might misallocate resources based on favoritism and/or rent-seeking rather than public welfare criteria (Tanzi and Davoodi, 1997; Mauro, 1998).

The balance between these two opposing outcomes is assumed to positively depend on the parameter ρ , which measures the quality of local institutions (Acemoglu

⁵ The model can be easily extended to the textbook case, without affecting our predictions.

⁶ One may also expect that the damages from a catastrophic disaster fall more often on older and outdated facilities and equipment than on the new and updated ones, because older capital stock was likely built using weaker structures and following outdated regulations and building codes.

et al., 2005; Rajkumar and Swaroop, 2008). Thus, for high values of ρ the positive effect prevails ($\partial A/\partial g > 0$), while for low values of ρ we obtain the opposite ($\partial A/\partial g < 0$). Moreover, institutions themselves may change over time in response to public spending. For example, if financial aid is spent in education and/or to increase the efficiency of the market, there is a corresponding increase in social capital and a spread of good practices into the economic and political arenas ($\partial \rho/\partial g > 0$). On the other hand, if the resources are misallocated and/or diverted, there is a decrease in civic engagement and an increase in fraudulent behavior among economic and political actors ($\partial \rho/\partial g < 0$). Therefore, the quake and the financial aid might reinforce and exacerbate initial differences in institutional quality.

More formally, after denoting with K^{**} the new steady state stock of capital, which reflects the change in the technical efficiency of the economy, we observe 4 potential scenarios:

- (1) The *benchmark scenario* is devoid of financial aid. It follows that the quake causes destruction in the capital stock from K^* to K' (see Figure 1a), while the steady state of capital continues to be equal to K^* . Consequently, we observe a drop in GDP and a subsequent convergence to the same steady state equilibrium, without long run effects (represented in Figure 2 by the blue line).
- (2) The *good scenario* is characterized by financial aid having a positive effect on the technical efficiency of the economy ($\partial A/\partial g > 0$). In this case, the quake causes destruction in the capital stock from K^* to $K'' > K'$ (see Figure 1b), while the new steady state of capital is equal to $K^{**} > K^*$. Consequently, we observe a drop in GDP (though lesser than in the benchmark scenario) and a subsequent convergence to a higher steady state equilibrium (represented by the green line in Figure 2).
- (3) The *bad scenario* is characterized by financial aid having a negative effect on the technical efficiency of the economy ($\partial A/\partial g < 0$). In this case, the quake causes destruction in the capital stock from K^* to $K'' > K'$ (see Figure 1c), while the new steady state of capital is equal to $K^{**} \in (K'', K^*)$. Consequently, we observe a drop in GDP and a subsequent convergence to a lower steady state (represented by the yellow line in Figure 2).
- (4) The *very bad scenario* is characterized by financial aid having a “large” negative effect on the technical efficiency of the economy ($\partial A/\partial g < 0$). In this case, the quake causes destruction in the capital stock from K^* to $K'' > K'$ (see Figure 1d), while the new steady state of capital is equal to $K^{**} < K'' < K^*$. Consequently, we observe a drop in GDP and a subsequent convergence to a lower steady state, which implies negative growth rates in the short-term (represented by the red line in Figure 2).

In the presence of financial aid, scenario (2) is expected to hold when a quake hits a region with sufficient local institutions. Scenarios (3) and (4) are more likely to occur in the presence of weak local institutions. Moreover, in these latter cases, the model

predicts a negative impact on TFP and a deterioration of institutional quality in the post-quake period. We rely on empirical evidence to examine which scenario prevails in practice and the internal consistency of each scenario.

3. The empirical strategy

We compare the patterns over time in the GDP per capita of regions exposed to the earthquake with that of a control group of unaffected regions. To construct a credible control group, we adopt the synthetic control method for comparative case studies (Abadie and Gardeazabal, 2003; Abadie et al., 2010). Namely, we construct a synthetic counterfactual as a weighted average of potential control regions that replicates the initial conditions and the growth potential of the region of interest before the earthquake.

Following Abadie et al. (2010), there are $J + 1$ regions. Without loss of generality, let the first region be the one exposed to the earthquake. Let y_{it}^1 be the potential GDP per capita in region i ($i = 1, \dots, J + 1$) at time t ($t = 1, \dots, T$) if the region is hit by the earthquake and y_{it}^0 if the region is unexposed to the earthquake. Let T_0 be the number of periods before the earthquake ($1 \leq T_0 < T$). We assume that the earthquake has not any effect on the outcome variable before it occurs so that $y_{it}^0 = y_{it}^1$ for any region i and any time $t < T_0$. This is equivalent to assume that the earthquake is unpredictable so that there are no anticipation effects. Let $\alpha_t = y_{1t}^1 - y_{1t}^0$ be the effect of the earthquake at time $t > T_0$. Let D_t an indicator variable that takes value if $i = 1$ and $t > T_0$. Then the observed per capita GDP in the affected region can be written as $y_{1t} = y_{1t}^0 + \alpha_t D_t$. It follows that for $t > T_0$, $\alpha_t = y_{1t} - y_{1t}^0$ but y_{1t}^0 is not observed and has to be estimated. This is the well-known fundamental problem of causal inference. Abadie et al. (2010) suggests estimating α_t with $\widehat{\alpha}_t = y_{1t} - \sum_{j=2}^J w_j y_{jt}$ for $t > T_0$ where weights w_j are chosen to minimize a certain penalty function that is selected as follows.

Let X_1 be a $(k \times 1)$ vector of GDP per capita predictors for the treated region and, analogously, X_0 be a $(k \times J)$ matrix that contains the same variable for the donor regions. The $(J \times 1)$ vector of optimal weights $W^*(V)$ minimizes the distance:

$$\|X_1 - X_0 W\|_V = [(X_1 - X_0 W)' V (X_1 - X_0 W)]^{\frac{1}{2}}$$

subject to $w_j \geq 0$ for $j = 2, \dots, J$ and $w_1 + w_2 + \dots + w_J = 1$. V is a $(k \times k)$ symmetric and positive definite matrix that contains weights to the variables in X_1 and X_0 according to their predictive power with respect to the outcome. The choice of V is data driven. The optimal matrix V^* is a diagonal positive definite matrix that minimizes the Mean Squared Prediction Error (MPSE) of the outcome variable over some set of the pre-quake period. More formally, let Z_1 be a $(T_p \times 1)$ vector containing the values of the outcome variable for the treated unit and Z_0 be a $(T_p \times J)$ matrix that contains the same variable for the control regions where $(1 \leq T_p \leq T_0)$. Then V^* minimizes:

$$(Z_1 - Z_0W^*(V))'(Z_1 - Z_0W^*(V)).$$

The outcome of interest is the GDP per capita at constant 1985 euro-equivalent prices. The GDP per capita predictors are averaged over a five-year period before the earthquake (1971-1975 as for the Friuli earthquake, 1975-1979 as for the Irpinia one). The MPSE is minimized over the 1951-1975 period (“Friuli”) or the 1951-1979 period (“Irpinia”).

4. Data and descriptive evidence

Our main outcome variable is the real GDP per capita. Following a rather consolidated approach (Abadie and Gardeazabal, 2003; Barro and Sala-i-Martin, 2004), we include among our main predictors the investment-to-GDP ratio, the share of graduates (as proxy for human capital), the population density and sectoral shares of value added. Moreover, in some specifications we enrich the set of GDP per capita predictors by including measures of institutional quality (Acemoglu et al., 2005). See subsection 4.1 for a full description of the data and variables and subsection 4.2 for an examination of the main features of the two earthquake episodes.

4.1 Data and variables

Most of the time-series data at the regional level are drawn from the research institute CRENOS. Specifically, these data include the GDP, labor units, investment, population and sectoral shares of value added in agriculture, industry, construction, market services and non-market services. They cover the 1951-2004 period. Investment and sector breakdowns of the value added are available for 1960 onward. The time-series have been updated through 2009 by using official figures provided by the National Institute of Statistics (Istat). Data on human capital are taken from population censuses conducted by Istat. Censuses are run every 10 years; inter-census data are obtained through interpolation.

Moreover, we use three region-level variables aimed at capturing the quality of local institutions; these variables are relatively new and deserve further description.

The first variable measures the intensity of corruption and fraudulent behavior in the local economy. More specifically, we consider crimes under Statutes 286 through 318 (i.e., embezzlement, bribery, corruption and other infringement of public duties), Statutes 110 through 118 (i.e., different types of frauds and fencing), Statutes 374 through 376 (i.e., bankruptcies). This large set of crimes is arguably better suited to capture the different dimensions of corruption, which exists in both the public and private sectors and is interwoven with different types of fraudulent behavior. Crime data are drawn from the Annals of Judicial Statistics (AJS), a yearly publication by Istat available since the 1970s that contains statistics, at the local level, on the number of crimes detected by Italian law enforcement. The indicator is calculated as a 3-year

moving average (to capture potential delays in the penal procedure) of the number of crimes, normalized with respect to labor units (a proxy for the number of economic transactions at the local level). Our measures clearly reflect only the “revealed” level of corruption and fraud, leaving some corruption and fraud hidden. Nevertheless, the use of objective data from administrative records has advantages over qualitative indicators of corruption, such as the Corruption Perceptions Index (CPI) produced by Transparency International, which is widely used in cross-country analysis.⁷

The second variable, following Guiso et al. (2004), is referenda and European election turnout at the regional level as a proxy for political participation.⁸ There are some reasons that justify this choice. On the one hand, until 1993, it was a legal duty in Italy to participate in general elections but not in referenda. Thus, it is very likely that many Italians went to the polls in general elections, irrespective of their sense of civic duty; the same is not true in the case of referenda. On the other hand, voting in general or local elections can lead to personal patronage benefits, that is, an “exchange” rather than a measure of civic involvement; however, there are no immediate personal benefits in the case of European elections or referenda. Therefore, our measure of electoral participation is not driven by legal or economic incentives, but only by social and internal norms. As explained by Putnam (1993), the primary motivation is a concern for public issues.

The third variable is the diffusion of newspaper readership, drawn from the agency ADS and available since 1980. The claim is that well-informed citizens have better knowledge of public affairs and are more likely to be involved in collective action and public life. Putnam (1993) used this variable as an indicator of citizens’ civic engagement in Italy.

Table 1 shows the descriptive statistics of all these variables.

⁷ The CPI is built using opinion surveys from businessmen and local people. However, the subjective meaning of corruption can vary greatly from one country to another; the types of corrupt activities could be also substantially different in each country, making comparative analyses even more difficult. On the other side, a drawback of our measure is that we count the number of crimes, but do not take into account their severity. Stated differently, in our data a 10 Euro bribe has the same weight as a 100 Euros bribe. However, it is worth noting that after an earthquake, the amount of transfers to the local level increases disproportionately. Thus, if any, our method underestimates the impact of the natural disaster on corruption in the treated region.

⁸ We considered European elections for the following years: 1979, 1984, 1989, 1994, 1999 and 2004 (see <http://elezionistorico.interno.it>). The referendum included in our temporal window concerned the following issues: the choice between republic and monarchy in 1946; divorce legislation in 1974; public security and public financing of parties in 1978; public security, anti-terrorism and abortion legislation in 1981; wage escalator clauses in 1985; nuclear power in 1987; hunting regulation and use of pesticides in agriculture in 1990; political preferences in 1991; drugs, public financing of parties and abolition of certain ministries in 1993; labor unions, television and commercial rules in 1995; abolition of certain ministries, hunting and professions regulation in 1997; electoral rules in 1999; electoral rules, labor unions and professions regulation in 2000. For missing years, political participation was obtained through interpolation. Since those elections were quite heterogeneous in terms of public interest, we normalize the regional figures with the national turnout.

4.2 The two earthquakes

Italy lies directly over the Eurasian and African fault lines, where two tectonic plates meet (Figure 3). The peninsula has suffered many major earthquakes over the centuries and is one of the most earthquake-prone countries in the world. The three largest earthquakes recorded in the last millennium were the Sicily earthquake in 1693 (60,000 deaths), the Calabria earthquake in 1783 (50,000 deaths) and the Messina earthquake in 1908 (120,000 deaths). Regarding more recent events, for which a richer set of data is available, the two most important earthquakes since World War II were the Friuli earthquake in 1976 and the Irpinia earthquake in 1980 (see Figure 4 for a finer localization of these two earthquakes).

The Friuli earthquake took place in the Friuli-Venezia Giulia region (in north-eastern Italy) on May 6, 1976. In the following months, there were aftershocks, the most significant of which occurred on September 15, 1976. The earthquake measured 6.4 on the Richter scale. According to EMDAT data, the earthquake killed 922 people (0.07 percent of the regional population), while the total number of affected people was 218,200 (17.7 per cent of the regional population). It ranked 2nd (according to the total number of affected people) on the list of most relevant Italian earthquakes during the period 1950 to 2012 (the earthquake ranked 84th in a worldwide comparison).

The second earthquake took place in the Irpinia region of Southern Italy on November 23, 1980. The quake measured 6.9 on the Richter scale and damage was spread over a large area, including the Campania and Basilicata regions, which, in the empirical analysis, are jointly considered the treated area.⁹ According to the EMDAT data, this earthquake killed 4,689 people (0.08 percent of the regional population), and affected 407,700 people (6.9 percent of the regional population). It was the most relevant Italian earthquake in the last 60 years (and the 52nd most relevant in a world comparison).

In summary, the two earthquakes occurred almost contemporaneously and had comparable magnitudes. It is also worth noting that the two earthquakes can be unambiguously considered as large disasters in the affected regions, according to the definition given by Cavallo et al. (2012).¹⁰ The two areas affected by the quakes differ in a number of dimensions. In the first half of the 1970s, Friuli's GDP per capita was more than 40 percent higher than that of Irpinia. Friuli also held a slightly larger share of the industry sector (39 percent as opposed to Irpinia's 33 percent) and a smaller share of the nonmarket sector (19 and 22 percent, respectively). The Irpinia region was much more densely populated (345 and 156 people per sq. km, respectively) whereas the fraction of individuals with a university degree was roughly similar in the two areas

⁹ However, it is worth noting that the relative weight of Basilicata in the treated area is relatively small; it equates to about 10 percent both in terms of GDP and population.

¹⁰ They consider the world distribution of the number of people killed (as a share of population) and define large disasters to be those above the 99th percentile—with more than 0.02 percent of the population killed.

(approximately 1.5 percent). The differences in institutional quality were quite large. The corruption and fraud rates in Irpinia were more than double that in Friuli and among the highest in Italy. Moreover, the electoral turnout in Irpinia was 12 points lower and the diffusion of the newspapers readership was less than half that of Friuli (the latter figure refers to 1980, the first available year).¹¹

After the earthquakes, a huge amount of public transfers occurred. The financial aid represented, on average, 5.7 percent of the GDP per year in the first decade after the Irpinia quake. The corresponding figure for the Friuli quake was 3.8 percent. In both cases, a larger amount of resources were concentrated in the aftermath of the quake (Figure 5).

5. Results

Our main findings are reported in subsection 5.1. Robustness checks are carried out in subsection 5.2. We discuss the short-term role of financial aid in subsection 5.3. Finally, a long-term analysis of economic growth, TFP and institutional performance is presented in subsection 5.4.

5.1 Main findings

First, we consider the Friuli quake. The synthetic control method delivers positive weights (see Table 2) for Piedmont (0.002), Tuscany (0.397), Umbria (0.438), Latium (0.065) and Campania (0.097). In Table 3, Panel A, we report the pre-treatment growth determinants of the treated region (Friuli-Venezia Giulia), the synthetic control and the population-weighted average of the entire set of regions in the donor pool. As clearly shown, the synthetic control closely mimics the treated region in all variables considered. In Figure 6, Panel A, we compare the evolution of the GDP per capita in Friuli-Venezia Giulia and in the synthetic control over a period of approximately 50 years. The evolution of GDP in most regions mostly overlaps until 1976, underscoring the credibility of the synthetic control as a counterfactual estimator. In the aftermath of the earthquake, no detectable effect is observed; nevertheless, in the second half of the 1980s, the trend in the treated region (positively) starts to diverge from the control unit. Indeed, in 1996 (20 years after the quake) the GDP per capita in Friuli-Venezia was 13 percent higher than that in the synthetic control.

¹¹ A further important (time-invariant) institutional difference between the two areas is the tradition of political autonomy. The database ISL-University of Parma provides a discrete measure of this variable based on historical observations. Friuli-Venezia Giulia is coded as a region with a long tradition of economic and political autonomy. Moreover, the Italian Constitution recognized a broad amount of autonomy through a special statute. Campania and Basilicata have instead completely different historical legacies because, for centuries, they were part of a broader economic and political system (i.e., foreign dominant and overpowering authorities).

Concerning the Irpinia quake, the synthetic control method delivers positive weights for Liguria (0.101), Molise (0.332) and Calabria (0.566). In Table 3, Panel B, we report the balancing properties of the relevant pre-earthquake variables. Overall, the synthetic control resembles Campania and Basilicata (the two treated regions) more closely than do the entire set of donors, especially with respect to the GDP per capita. As shown in Figure 6, Panel B, in the pre-treatment period the evolution of the GDP per capita in the treated region and in the synthetic control is largely comparable. In the first years after the quake, there is a negative (though almost indistinguishable) effect on the GDP per capita. As time passed, the GDP per capita in the treated area displays weaker dynamics; 10 years after the quake, the GDP per capita in Irpinia was 11 percent lower than that of the synthetic control, and 20 years later was even lower (14 percent lower).

Are these estimates statistically significant? In the comparative case study setting, the standard statistical tests based on the normality assumption are not available. An alternative method to measure significance is running a number of placebo studies. The underlying idea is that if relevant effects are detected in the placebo exercises, as well, one may doubt the credibility of the empirical strategy. Therefore, for each quake we apply the synthetic control method to all other regions that were not exposed to a quake in the same year. We then compute the estimated effect associated with each placebo run. Afterward, we have a distribution of estimated effects for the regions where no treatment took place. Figure 7 shows the results of this test. The black line represents the estimated gap between the treated unit and the synthetic control for Friuli-Venezia Giulia (top graph) and Campania and Basilicata (bottom graph). The grey lines denote the same gap for the placebo runs. In the Friuli case, the estimated effect is, on average, larger with respect to the distribution of the gaps in the potential controls. In contrast, in the case of the Irpinia earthquake, the estimated gap is smaller relative to most of the placebo gaps. Overall, these exercises confirm our baseline findings. In the Friuli case, at the end of the sample period the estimated gap for the treated region ranked 3rd out of 20 tests. This indicates that the probability of estimating a larger effect under a random permutation of the treatment is $2/20 = 10\%$. In a confidence interval setting, we would conclude that the estimate effect for Friuli-Venezia Giulia is positive and significantly different from zero at a 10 percent confidence level. In the Irpinia case, the pseudo p-value is below 1 percent, confirming the significance of the estimated effect.

5.2 Robustness checks

In this subsection, we conduct several robustness checks. First, we exclude from the donor pool those regions that have experienced a large-scale quake within a 10-year window that could bias the estimated effect. In the Friuli case, we exclude Sicily (because of the quake that occurred in 1968 in the “Valle del Belice”, a large area in the western part of the region), Campania and Basilicata (both affected by the Irpinia quake in 1980). In the Irpinia quake case, we exclude the Friuli-Venezia Giulia region. The results are reported in Figure 8, Panel A. In both of our case studies, the results are

largely confirmed. This is clearly because the excluded regions did not enter (or entered with small weights) into the construction of the corresponding synthetic controls.

In a second robustness check, we resort to a cross-validation approach. Namely, we minimize the MPSE up to 5 years before the earthquake: if the synthetic control is a credible counterfactual then we would expect that after the MPSE-minimization-end year and before the treatment, treated and control regions would show similar evolution patterns. Our baseline findings prove to be robust under this check, as well (see Figure 8, Panel B).

According to our results, the estimated effects are delayed. This is consistent with the notion that adjustment to a new steady state requires time. However, from an empirical point of view, it may be difficult to discriminate between the delayed effect of the quake and the immediate effect of a totally different exogenous shock. Therefore, our third robustness check aims to rule out other potentially competing factors. As far as the Friuli case is concerned, we have not been able to find in the local economic history any significant event that might explain the divergent trend in the GDP (compared to the synthetic control) since the second half of the 1980s. However, one might argue that the Friuli-Venezia Giulia is a small and export-oriented region and, consequently, may have benefited from the competitive devaluation that occurred in Italy at the beginning of the 1990s (see Marcellino and Mizon, 2001). Therefore, we check the robustness of our result by restricting the sample of donors to regions with a relatively similar degree of trade openness. In 1995, the first year for which openness statistics at the regional level are available, Friuli-Venezia Giulia ranked 4th among all the Italian regions. In the restricted pool of donors, we include the regions from the first to the seventh position in the ranking (excluding Friuli-Venezia Giulia), which are +3 or -3 positions from the treated region: Piedmont, Veneto, Lombardy, Emilia-Romagna, Tuscany and Marche. The results are reported in Figure 8, Panel C, and are substantially similar to our baseline findings. With regard to the Irpinia quake, Pinotti (2012) noted that starting in the 1970s, there was a sudden increase in organized crime activities in Basilicata (and in Apulia), which have been shown to negatively impact the GDP. To analyze the robustness of our results against this potential confounding factor, we have repeated the synthetic control approach using only Campania as the treated unit. The results are reported in Figure 8, Panel C and again confirm our main findings. This is likely because Basilicata accounts for a very small fraction of the treated region, which includes both Campania and Basilicata.¹²

In our final robustness check, we include, among the predictors of the GDP, some variables aimed at capturing the quality of local institutions. Specifically, we include

¹² A further potential confounding factor concerning Basilicata is the intensive oil production that started in the mid-1990s. Again, this does not represent a concern for us. First, as stated above, Basilicata represents a small part of the outcome of the treated region. Second, and more importantly, the effect of oil extraction on the GDP per capita is positive. This result (available from the authors upon request) has been obtained applying the synthetic control approach to analyze the effect of oil extraction on GDP per capita in Basilicata. Therefore, our estimates for Irpinia (which document a negative effect of the quake) can be thought of as an upper bound.

our measure of the intensity of corruption and fraudulent behavior and electoral turnout, as proxies for social capital and civic engagement.¹³ As noted by Acemoglu et al. (2005), local institutions are good predictors of the growth potential of the economy.¹⁴ In Figure 8, Panel D, we report the results of the synthetic control, after including these proxies for local institutions as predictors of the GDP per capita. Our findings are again confirmed in this case, which becomes our preferred specification in the following sections.

5.3 The role of financial aid

One apparently striking result of our empirical analysis is the absence of any significant negative shock in the short term. Although this finding is not completely new in the literature¹⁵, we believe that accounting for reconstruction fiscal stimulus may provide a better understanding of the macroeconomic impact.

Fortunately, we have data regarding the yearly flow of financial aid from the central government that, as we have observed before, represents a sizeable fraction of the regional GDP. Therefore, we can plot the GDP per capita dynamics and the net financial aid. To do this, it is necessary to make some assumptions regarding the fiscal multiplier. We rely on estimates provided by Acconcia et al. (2013) because they use a setting that is very similar to ours. First, they estimate the fiscal multiplier at the local level in Italy. Second, the within-country perspective allows them to control for national monetary and fiscal policy and to hold the tax burden of local residents constant. Third, they refer to a sharp change in fiscal policy. Acconcia et al. (2013) yielded a preferred estimation of the local fiscal multiplier of 1.2, slightly lower than what has been found in the United States (Nakamura and Steinson, 2013). However, we consider two bounds to these estimates, allowing the true (and unobserved) fiscal multiplier to fluctuate within this interval. As a lower bound, we consider a value of 1, which Acconcia et al. (2013) cannot statistically reject in their preferred estimation. As an upper bound, we consider a value of 1.8, which accounts also for the effects of delayed spending.¹⁶

Figure 9 provides a clear illustration of this exercise. Without financial aid, in the five years after the Friuli quake, the GDP per capita would have been between 2 and 4 percent lower; the yearly GDP per capita growth rate would have been between 0.5 and 1.0 percent lower than the synthetic control. The corresponding figures for Irpinia were

¹³ The diffusion of newspaper readership is not included among the predictors because it is available only from 1980 onward. However, we are still able to plot its dynamics in the post-quake periods for both regions.

¹⁴ The first comprehensive econometric research to assess the (negative) impact of corruption on economic growth is by Mauro (1995).

¹⁵ Albala-Bertrand (1993), in one of the first attempts to empirically describe the macroeconomic dynamics of natural disasters, found a positive (though modest) impact on GDP growth. See Cavallo and Noy (2011) for a thoughtful review of the literature.

¹⁶ In detail, Acconcia et al. (2013) obtain the value of 1.8 by adding up the coefficients on the contemporaneous and one-year delayed spending variable, after having corrected for the impact of the first delay in the value added.

between 6 and 10 percent, in terms of levels, and between 1.1 and 2.0 percent, in terms of growth rates.

5.4 Growth, TFP and institutions

We have documented that these two earthquakes, after taking into account the aid inflows, had negative short-term consequences in the affected areas. In the long-term, however, we detect opposite large-scale effects on the GDP per capita. These findings are consistent with the theoretical framework described in Section 2. In the short-term, public intervention mitigates the negative impact of a quake. In the long-term, the steady state equilibrium may change. Friuli falls into the *good scenario* where the positive effect on the GDP per capita, relative to the synthetic control, is consistent with a positive shift in the technical efficiency of the economy. In contrast, Irpinia falls into the *very bad scenario* because, post-quake, growth is slower and, in the long-term, the GDP per capita is permanently lower compared to the synthetic control, suggesting a negative effect on technical efficiency.

To empirically support these conjectures, we estimate the TFP growth through a traditional growth accounting setting:

$$\frac{\Delta A}{A} = \frac{\Delta Y}{Y} - \alpha \frac{\Delta K}{K} - \beta \frac{\Delta L}{L}$$

where α and β are the factor shares of capital and labor, respectively. According to a standard Cobb-Douglas regression, results of which are recorded in Table 4, we cannot reject the constant-return-to-scale hypothesis and the labor factor share is slightly above 0.7.

Table 5 reports this simple growth accounting exercise, distinguishing between factor accumulation and productivity and comparing the results of the treated area with those of the synthetic control. The exercise encompasses the 20 years after the quake.¹⁷ With regard to Friuli-Venezia Giulia, the difference in the GDP per capita growth translates to an analogous gap in the GDP growth. The latter was largely due to higher TFP growth in the treated area (41 percent, approximately 20 percentage points above the synthetic control), and the accumulation of capital stock was roughly similar. In Irpinia, the difference in the GDP growth was smaller than that in the GDP per capita, and the negative gap with respect to the synthetic control is entirely due to the lower TFP growth (20 percent, nearly 6 points less than in the synthetic control).

In terms of our theoretical background, the *good scenario* is realized when good institutions favor a virtuous reconstruction, thus improving private capital stock, public infrastructure, and less tangible production factors. The *very bad scenario* is more likely to occur where local institutions are weaker. These facts are consistent with the quality

¹⁷ CRENOS reports consistent time-series of regional capital stock (reconstructed through the perpetual inventory method) for the period 1970-1994. We extended this series forward using data regarding the investments and assuming a (data-driven) depreciation rate of 6.5 percent.

of pre-quake institutions in the two areas (see subsection 4.2). Moreover, after an exogenous shock, bad institutions and large financial aid may negatively interact, further deteriorating social capital and, in turn, negatively affecting the technical efficiency of the local economy.¹⁸

Indeed, the data on the patterns of the institutional variables in the two treated regions are consistent with the TFP dynamics.¹⁹ In Friuli, the corruption and fraud rates increased and became progressively closer to those of the synthetic control, although those figures remained remarkably lower compared to national figures (Figure 10, Panel A). The electoral turnout was fairly stable over the years, slightly improving the positive gap with the synthetic control and remaining above national electoral turnout (Figure 10, Panel B). Finally, the diffusion of newspaper readership became greater in later years, increasing the positive gap with respect to the control regions (Figure 10, Panel C). Overall, the Friuli case was characterized by good institutions before the quake and institutional quality did not change significantly in subsequent years.

The overall picture is completely different in Irpinia. The corruption and fraud rates were above the synthetic control and the national mean pre-quake and the gap increased over the years (Figure 10, Panel A).²⁰ The electoral turnout, though smaller than the national mean, was larger than in the synthetic control. However, this positive gap progressively vanished and became negative, suggesting deterioration in political participation (Figure 10, Panel B). Finally, the diffusion of newspaper readership remained lower than the synthetic control (and the national figure) and the gap increased over the years (Figure 10, Panel C). In sum, the three variables used as a proxy for the quality of local institutions performed poorly pre-quake and deteriorated with respect to both the national figures and those of the synthetic control post-quake.

6. Concluding remarks

Natural disasters affect thousands of people each year in every corner of the world. Though the images of destruction attract much attention from the media and the public, we still lack solid empirical evidence regarding the economic consequences of these disasters, mainly due to data limitations. In this paper, we start by illustrating

¹⁸ These conjectures are in line with anecdotal evidence on the reconstructions after the two quakes. See http://www.corriere.it/europeo/cronache/2010/14/europeo-14-sergio-rizzo-professionisti-macerie_d09409de-cfa7-11df-8a5d-00144f02aabe.shtml; <http://ricerca.repubblica.it/repubblica/archivio/repubblica/1989/11/24/il-tesoro-mette-sott-accusa-la-ricostruzione.html>; <http://www.repubblica.it/speciale/irpinia/irpi.html>.

¹⁹ See also Hall and Jones (1999), who state that differences in productivity across countries are mainly driven by differences in institutional and government policies, which they call social infrastructures.

²⁰ The crime rate had an irregular pattern, partly due to a massive anti-corruption investigation, named *Mani pulite* (literally “clean hands”) in the first half of the 1990s in most of the Italian regions. The inquiries revealed a diffuse system of corrupt practices involving entrepreneurs, bureaucrats, judges, and representatives of almost all political parties. It is also widely acknowledged that most of those practices were related to the previous decade. This means that *Mani pulite* revealed a system of corruption that was hidden (at least in the data) during the 1980s.

within a very simple model the basic forces that drive the economy after a quake and the different scenarios that may arise. Then, we use a synthetic control empirical strategy and find that similarly disruptive quakes generated large and opposite long-term effects on the GDP per capita. These outcomes largely reflect differences in the TFP.

We argue that the institutional setting significantly affects these patterns. Better pre-quake institutions might be more capable of withstanding the shock and managing the recovery period. Moreover, when institutions are weaker, the huge inflow of financial aid is more likely to be misallocated and diverted to less productive activities, negatively affecting the technical efficiency of the economy and further deteriorating institutional quality. Our empirical evidence supports this analysis. Overall, in the long-term, the earthquake might exacerbate regional disparities in both economic and social development.

From a policy perspective, we have shown that financial aid plays an important role in the recovery period, favoring immediate reconstruction and attenuating the GDP drop. However, the design of the aid is crucial. Especially when a natural disaster hits an area with weak institutions – containing a higher intensity of corruption, lower civic engagement and, plausibly, less familiarity and experience in the management of public funds – aid supervisors must set proper rules to avoid the irregular use of resources. Indeed, an improper use of financial aid may not only be less productive but also may have detrimental effects in the long run.

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Tables

Table 1. Descriptive statistics

Variables:	All sample				Friuli-Venezia Giulia		Campania and Basilicata	
	mean	s.d.	min	max	mean	s.d.	mean	s.d.
GDP per capita	6,274	3,138	1,242	13,41	6,767	3,297	4,184	1,625
Investments/GDP	0.277	0.081	0.144	0.689	0.268	0.041	0.250	0.159
Share agriculture	0.067	0.040	0.013	0.229	0.044	0.012	0.073	0.024
Share industry	0.330	0.083	0.174	0.628	0.351	0.028	0.296	0.037
Share market services	0.409	0.065	0.178	0.570	0.426	0.042	0.397	0.054
Share non market services	0.194	0.049	0.091	0.303	0.179	0.017	0.234	0.017
Population density	1.701	0.991	0.288	4.307	1.546	0.020	2.512	0.203
Share university degree	0.030	0.020	0.010	0.075	0.032	0.021	0.028	0.019
Corruption and fraud rate	4.455	3.803	0.972	28.55	3.089	2.037	7.160	8.107
Electoral turnout (Italy = 100)	98.3	10.2	74.0	128.3	104.8	3.2	64.1	37.6
Diffusion of newspaper readership	8,089	4,831	927.9	32,29	13,65	4,765	2,502	1,713

All variables are drawn from Crenos with the exception of share of university degree (Census), corruption and fraud rate (AIS), electoral turnout (Ministry of Interior) and diffusion of newspapers readership (ADS).

Table 2. Donors

Earthquake	Region in the synthetic control (weight)	MSPE
Friuli (Friuli-Venezia Giulia)	Piedmont (0.002)	208.9
	Tuscany (0.397)	
	Umbria (0.438)	
	Latium (0.065)	
Irpinia (Campania and Basilicata)	Campania (0.097)	54.6
	Liguria (0.101)	
	Molise (0.332)	
	Calabria (0.566)	

The weights of the synthetic controls are chosen to minimize the distance with Friuli-Venezia Giulia (top panel) and Campania and Basilicata (bottom panel) in terms of GDP per capita and predictors of its subsequent growth. See Section 3 for a methodological discussion.

Table 3. Balancing properties

	Panel A: Friuli		
	Treated area	Synthetic control	All donors
GDP per capita	5431.8	5426.0	5458.8
Investment/GDP	0.310	0.311	0.292
Share of graduates	0.016	0.017	0.015
Population density	1.561	1.566	2.238
Share VA agriculture	0.038	0.053	0.068
Share VA industry	0.393	0.392	0.373
Share VA market services	0.383	0.374	0.383
Share VA non market services	0.186	0.180	0.177

	Panel B: Irpinia		
	Treated area	Synthetic control	All donors
GDP per capita	4127.3	4169.4	6130.3
Investment/GDP	0.337	0.373	0.262
Share of graduates	0.019	0.019	0.019
Population density	2.527	1.354	2.249
Share VA agriculture	0.081	0.090	0.059
Share VA industry	0.311	0.275	0.368
Share VA market services	0.382	0.403	0.395
Share VA non market services	0.226	0.230	0.178

The table reports the characteristics of the treated regions (Friuli-Venezia Giulia in panel A and Campania and Basilicata in panel B), their synthetic controls and all the regions in the set of donors during the 5 years before each quake. The weights used to build the synthetic controls are presented in Table 2.

Table 4. Estimated factor shares in the Cobb-Douglas regression

Dependent variable:	$\ln GDP_t - \ln GDP_{t-1}$
$\ln K_t - \ln K_{t-1}$	0.268*** (0.078)
$\ln L_t - \ln L_{t-1}$	0.719*** (0.059)
Constant	0.013*** (0.003)
Obs.	480
R ²	0.319
Test: $\alpha + \beta = 1$	0.02 (0.879)

The table reports the results of production function estimates across Italian regions during the period 1970-1994. Robust standard errors are in parenthesis; *, **, and *** denote coefficients significantly different from zero at the 90%, 95% and 99% confidence level, respectively. The last row of the table reports the Wald tests for the factor shares to sum up to unity (p-value in parenthesis).

Table 5. Growth accounting

	Panel A: Friuli	
	Treated area	Synthetic control
GDP per capita growth	69.6	47.8
GDP growth	63.5	48.3
Contribution:		
Labour units	2.0	6.1
Capital stock	20.5	21.7
TFP	41.0	20.6

	Panel B: Irpinia	
	Treated area	Synthetic control
GDP per capita growth	29.7	37.2
GDP growth	36.9	40.0
Contribution:		
Labour units	-2.8	-1.3
Capital stock	19.4	15.4
TFP	20.3	25.9

Figures refer to the growth rates in the 20 years after the quake. Contributions of labour and capital has been computed using coefficients estimated in Table 4; contribution of the TFP is determined residually.

Figures

Figure 1. Steady state equilibrium with the earthquake

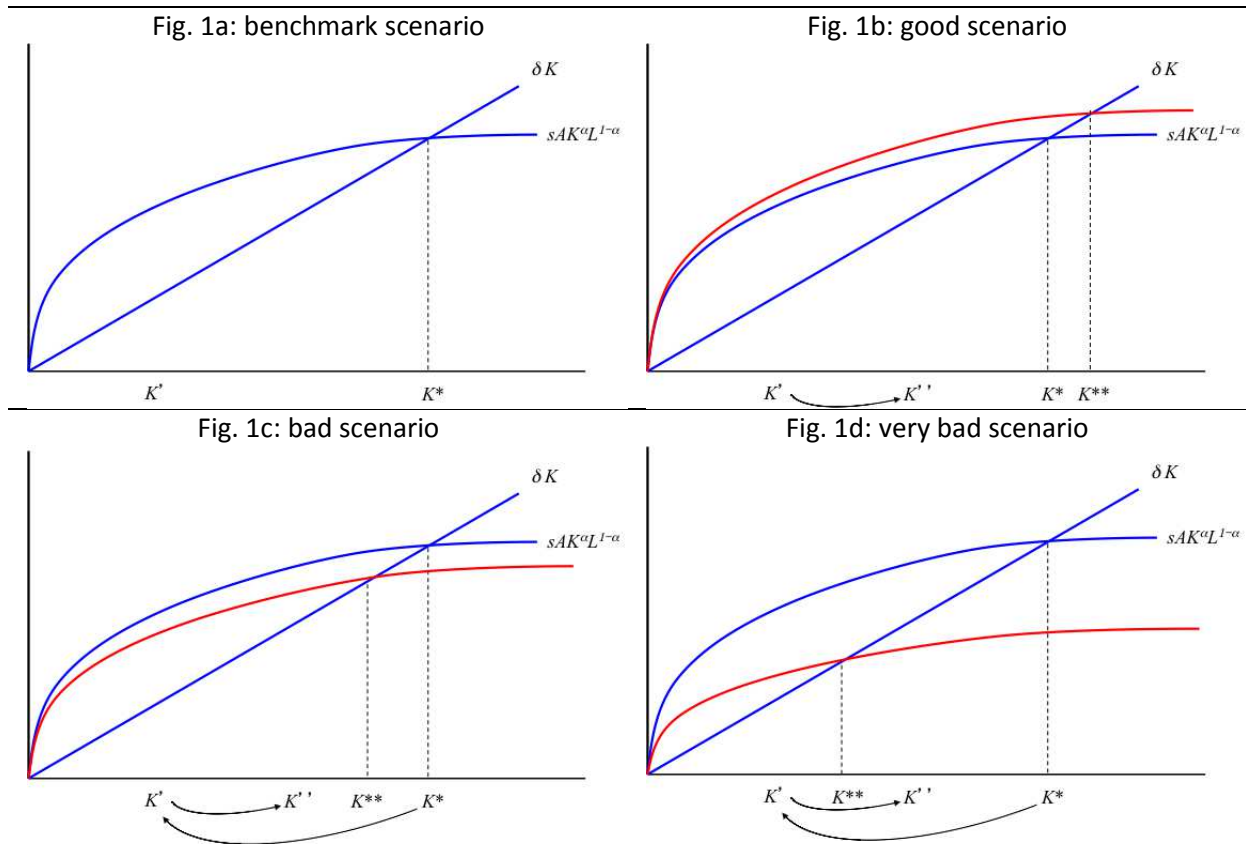


Figure 2. GDP dynamics in different scenarios

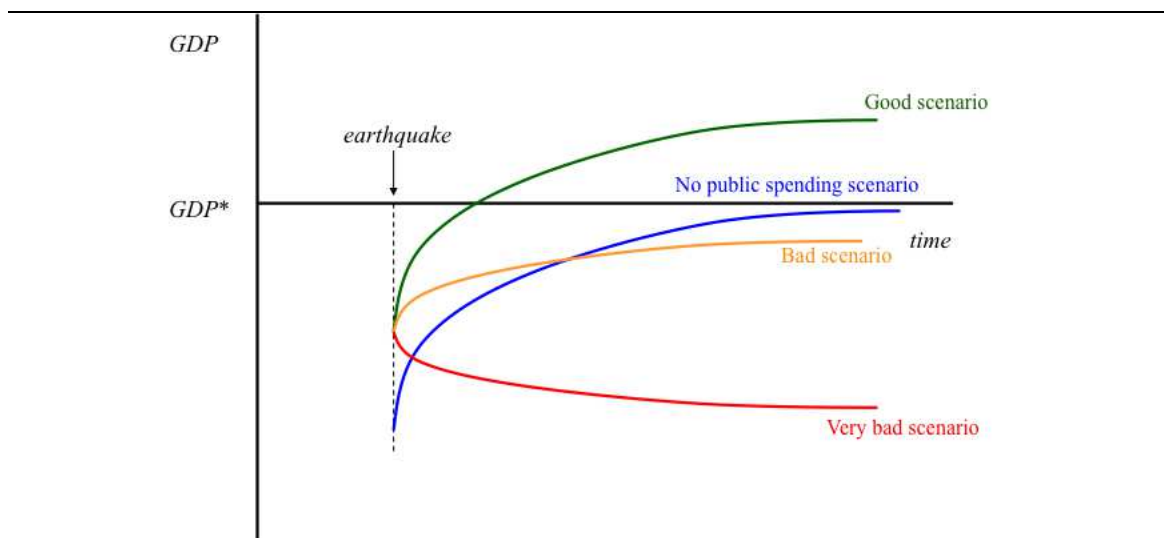


Figure 3. World major plate boundaries

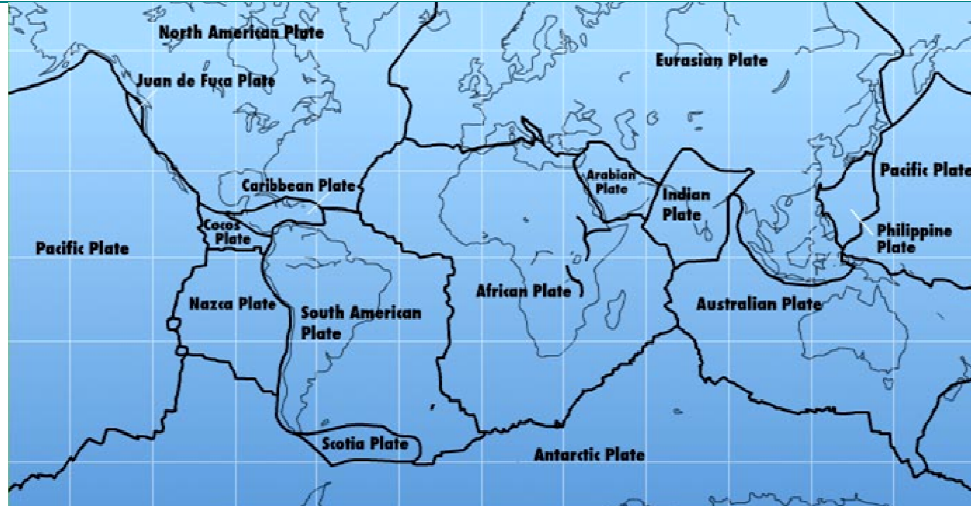
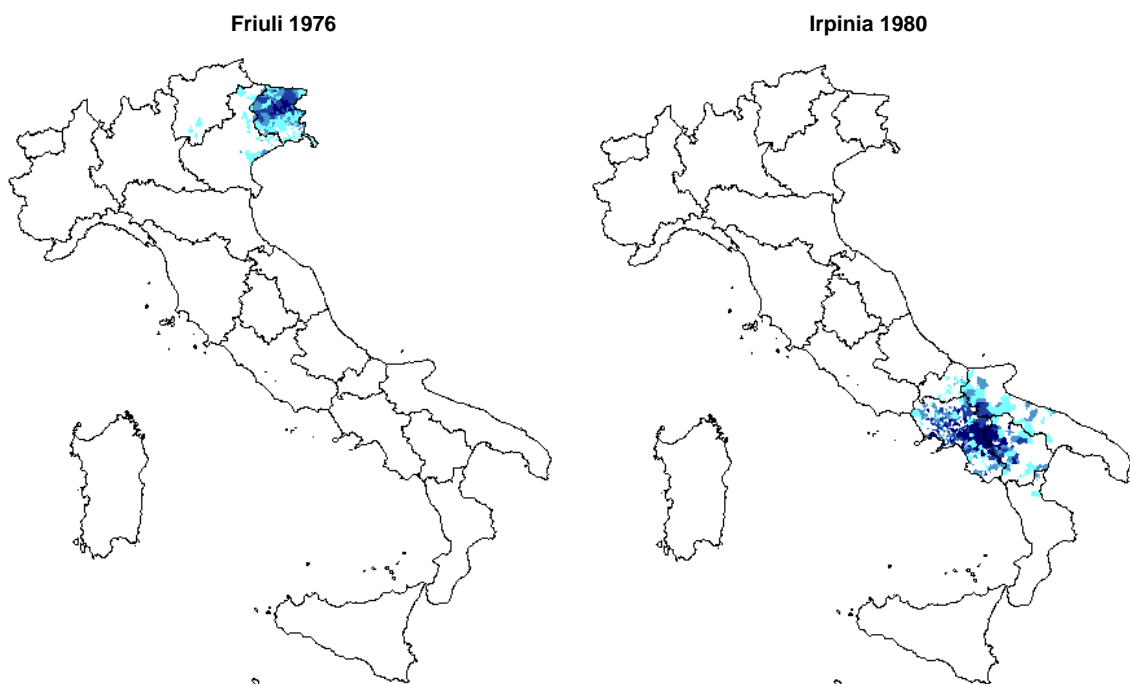


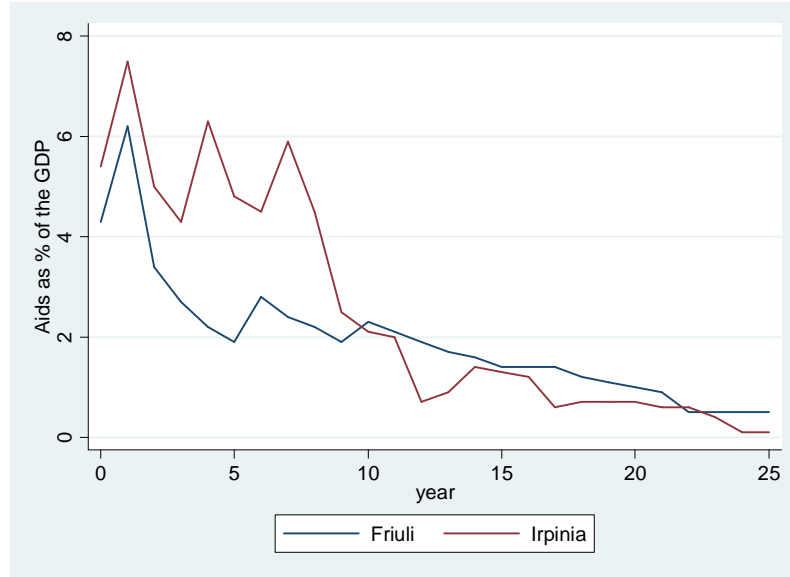
Plate boundaries are found at the edge of the lithosphere and are of three types, convergent, divergent and conservative; the Eurasian Plate and the African Plate in the Mediterranean Sea are converging.

Figure 4. The areas hit by the two earthquakes



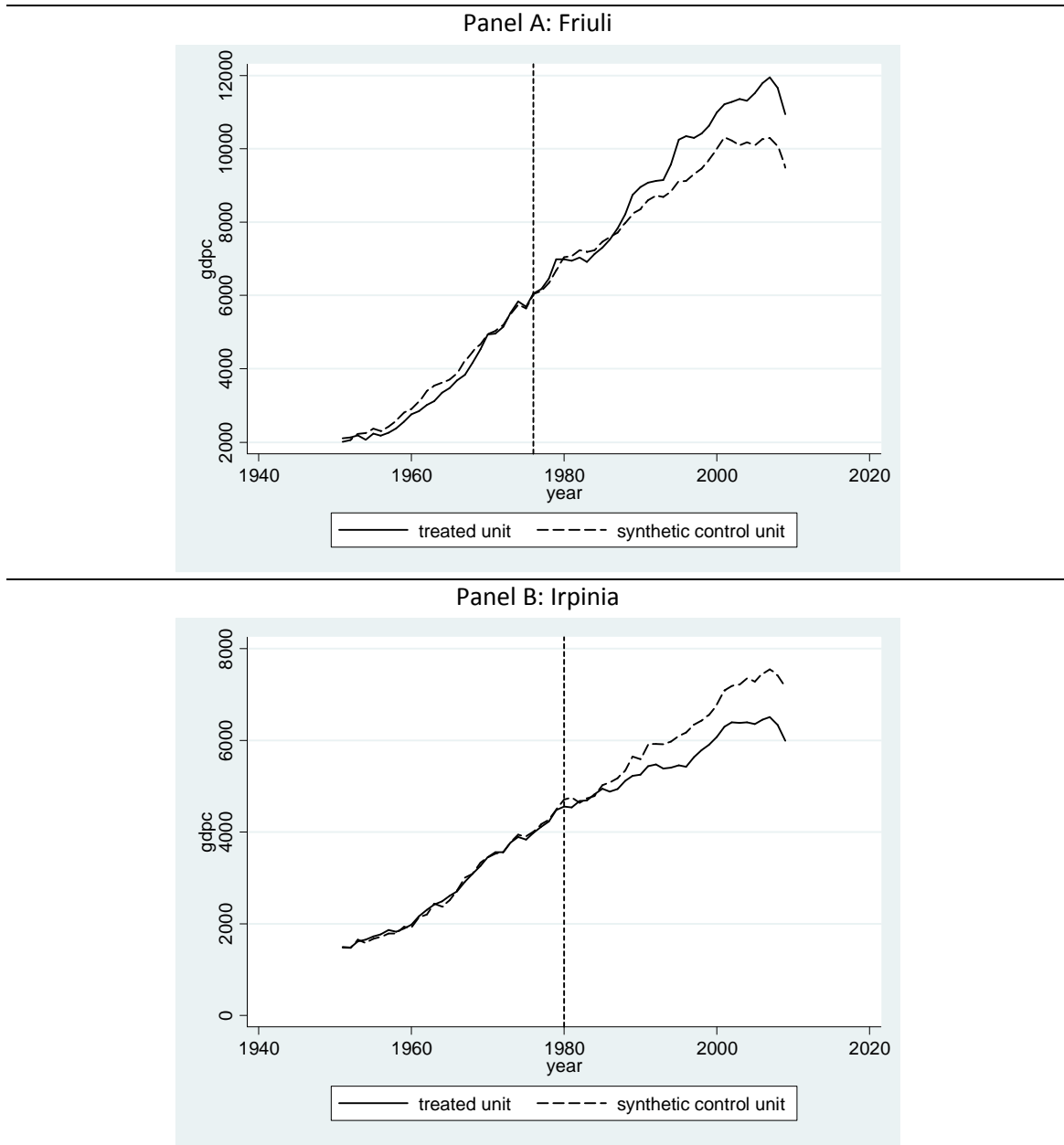
Source: INGV and Istat. Each map shows the quartiles of the earthquake intensity on the Mercalli scale for all municipalities where the intensity was at least 6. Darker colors indicate more severe intensity.

Figure 5. Public transfer over GDP



The figure represents the amount of transfer as % of the local GDP; the x-axis represents the number of year after the quake. Source: Italian parliament (see <http://documenti.camera.it/leg16/dossier/testi/Am0065.htm>) and Crenos.

Figure 6. Baseline results: GDP per capita 1951-2009



The graphs report the GDP per capita of the treated regions (Friuli-Venezia Giulia in panel A and Campania and Basilicata in panel B) and of respective synthetic control. The weights used to build the synthetic controls are presented in Table 2.

Figure 7. Placebo test

Panel A: Friuli

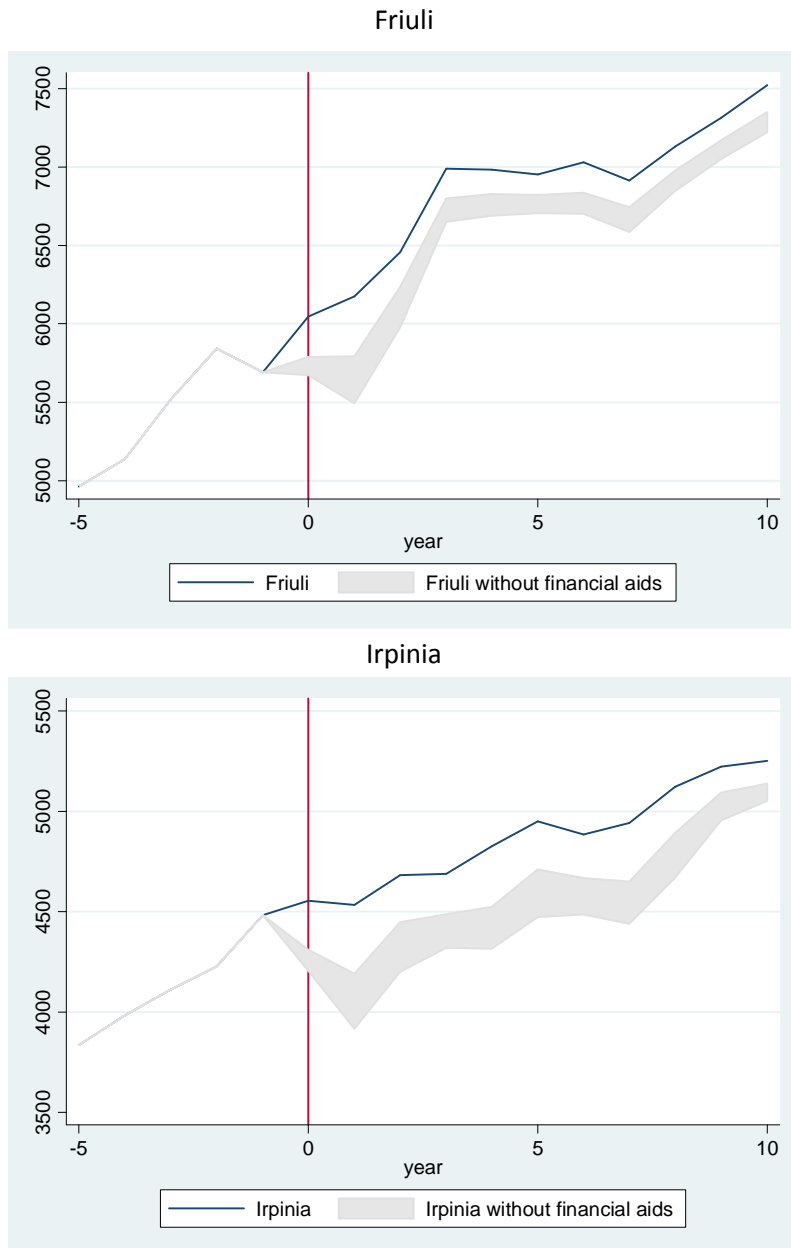


Panel B: Irpinia



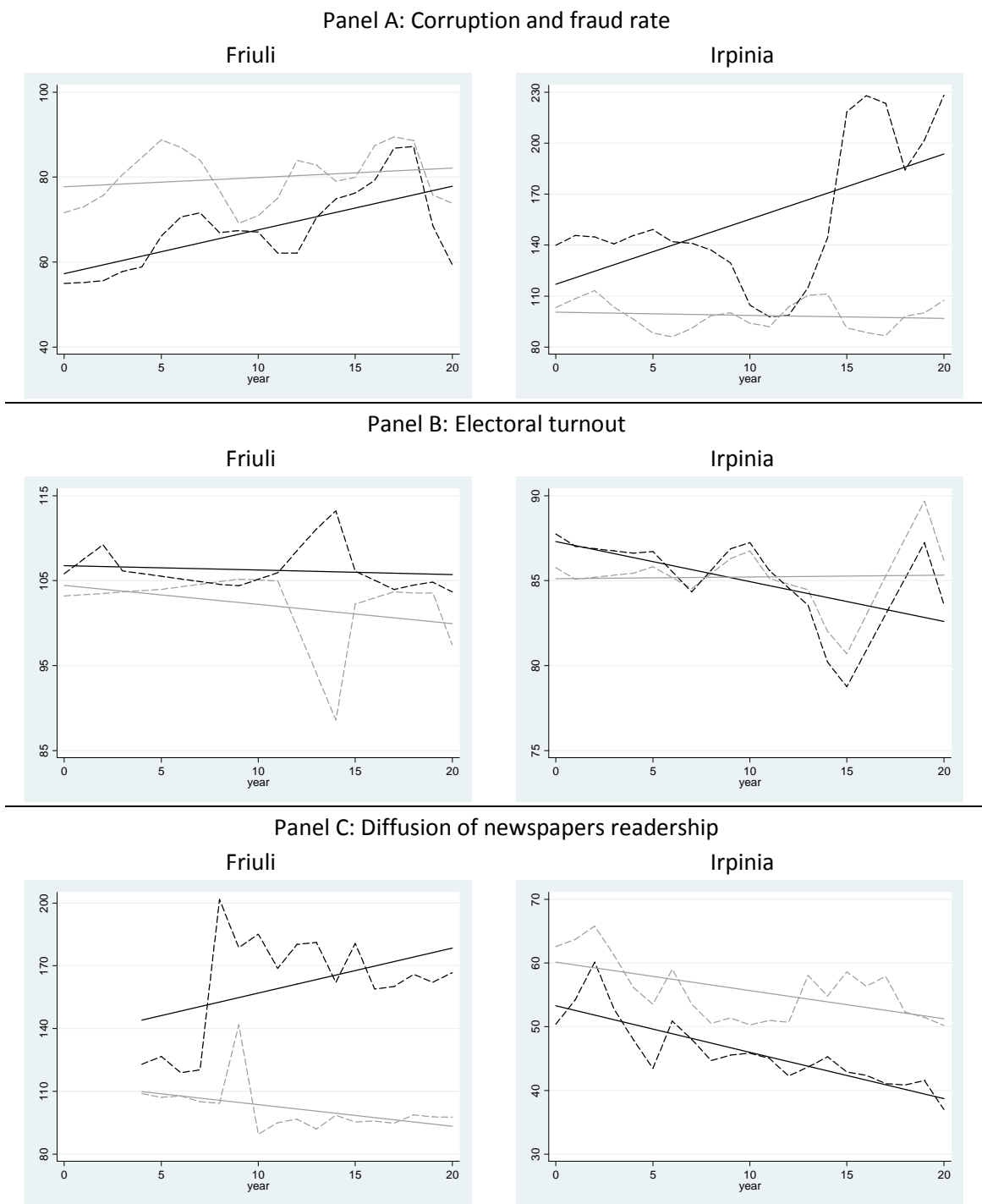
The graphs report the difference, in terms of GDP per capita, between the treated regions (Friuli-Venezia Giulia in panel A and Campania and Basilicata in panel B) and their synthetic control (black lines) as well the same differences for all other Italian regions (placebo in grey lines).

Figure 9. The role of financial aids in the short-term



The shaded area indicate the GDP of the treated region without financial aids: the fiscal multiplier is assumed to be equal to 1 as lower bound and to 1.8 (including the effects of lagged spending) as upper bound.

Figure 10. Trends of the institutional variables in the post-quake period



In each plot, the regional figures are normalized (Italy=100). The black lines refer to the treated regions and the grey lines to the synthetic control. Solid lines refer to the long-term trend whereas dashed lines to the yearly observations.