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ORIGINAL RESEARCH

The Determinants of the Implementation Speed of Cohesion Projects in Europe: A Regional and Project-level Analysis

Debora Gambina[1] · **Fabio Mazzola**[1]

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Abstract
Time overruns of public works hinder the impact of investment policies and spill over negatively on aggregate prosperity. Particularly for sustainability-related projects, postponing operations may hamper the environmental objectives. This paper highlights the regional dimension of the problem and evaluates the hypothesis that the regional conditions in which the projects are implemented affect time efficiency of EU cohesion policy. We deal with interventions of the 2014–2020 programming period targeted to sustainable infrastructures and energy saving of SMEs and big companies by extracting the relevant information from Kohesio database. We apply linear regression models and logistic regressions as well as survival techniques to support our results. The evaluation is carried out at two scales. In the NUTS-2 framework, the duration is explained by proxies of territorial context such as development level, urbanization and institutional quality calculated at the regional level. At a micro-level, we scrutinize the effects of regional conditions, in comparison with those of project-specific features, also across categories of interventions. According to our findings, urbanization and institutional capacity turn out to drive timely completion while per capita GDP, capturing project dimensionality and complexity, does not. Moreover, we find that time efficiency increases monotonically as we approach the end of the programming period and that national cofinancing lengthens the duration, especially of the incentives to large firms. Our assessment enriches the debate on regional policy effectiveness by addressing a topic that has not been thoroughly empirically tested at the supranational level and offering policy suggestions relevant to the 2021–2027 programming.

Keywords European cohesion policy · Implementation speed of public interventions · Time-efficient performance · Low-carbon economy · EU NUTS-2 analysis · Project-level assessment

JEL Codes H41 · H54 · O22 · R58

Extended author information available on the last page of the article

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1 Introduction

Low time performance in completing public works can undermine the outcome of fiscal policy shocks as well as determine relevant social costs and popular discontent particularly for infrastructures and sustainability-related projects.

Public investment is a relevant driver of economic growth (Arrow and Kurz 1970; Aschauer 1989; Barro 1990) and, when effective, it gives rise to productive public capital in the long-run. To thoroughly quantify its impact, we should consider that the authorized expenditure is not immediately implemented but, on the contrary, is subject to the time-to-build (Kydland and Prescott 1982).

The occurrence of delays can generate negative externalities on society, by postponing the utilization of public goods (Lewis and Bajari 2011; Hussain et al. 2023) and dampen the positive effects of investment policies both in the short- and in the long-run, as empirically demonstrated by Leeper et al. (2010) for the U.S. case. Unexpected delays spill over into the private sector since uncertainty about the completion date of infrastructures influences resource allocation decisions of the economic agents and, ultimately, economic growth (Chatterjee et al. 2017). Another relevant sequel of delays can be cost overruns (Guccio et al. 2012), namely the discrepancy between the ex-ante planned cost and the actual ex-post one.

The existing literature on time performance of public works presents several shortcomings, such as the adoption of a country-specific perspective (see, among others, Assaf and Al-Hejji 2006; Olawale and Sun 2015; Alzara et al. 2016; Senouci et al. 2016; Carlucci et al. 2019) and the limitation of the investigation to selected projects, like large transport infrastructure, mainly relying on survey-based techniques for the empirical assessment (see, among others, Chevroulet et al. 2011; Kelly et al. 2015; Zidane and Andersen 2018; Fashina et al. 2021). These types of analyses are motivated by the relevance of such projects for national competitiveness, as in the case of transportation, environmental, and telecommunications infrastructures. However, the conclusions from studies using a specific country and a small sample of selected interventions are difficult to extend to broader contexts. Consequently, the policy implications might have a limited external validity.

Disclosing the drivers of timely completion and the determinants of delays is crucial for policymakers in order to direct resources towards territories whose characteristics allow them to be more efficient in implementation. In addition, they might condition the funds allocation to the structural improvement of those factors associated with inefficiency through, for instance, incentive mechanism design. Indeed, to avoid misallocation, public funds should be managed by territories committed to mitigate the sources of bottlenecks.

The issue is even more important for European cohesion policy due to the need of maximizing the impact of supranational financing and justify its allocation.

A typical supranational concern of our time is climate change. In this respect, the selection process of environmental projects should be of high quality and their implementation should be as efficient as possible.

This paper analyses the projects implemented during the recently concluded programming period (2014–2020) of the European Regional Development Fund (ERDF) under the thematic area ‘Low-carbon economy’. Indeed, at the end of the 2014-20

Table 1 Absorption rates of ERDF by EU countries – low-carbon economy

Member State	2017	2020	2023
Bulgaria	7.08	79.23	107.73
Estonia	40.68	74.18	98.00
Netherlands	15.55	43.79	97.97
Sweden	13.18	55.24	96.59
Ireland	23.23	77.34	95.69
Malta	30.92	92.90	94.37
UK	11.74	45.11	91.83
France	22.06	40.11	91.24
Slovakia	24.20	58.50	91.21
Lithuania	31.03	52.49	90.40
Poland	12.11	57.80	89.70
Germany	18.72	39.29	87.30
Denmark	19.86	22.53	87.04
Finland	45.00	63.42	87.00
Hungary	1.76	42.22	86.94
Portugal	16.60	27.85	85.30
Croatia	3.72	55.80	83.17
Latvia	4.84	39.22	82.11
EU average	**16.44**	**47.56**	**81.99**
Luxembourg	9.42	27.85	78.71
Austria	26.07	41.85	74.43
Czechia	0.00	31.85	67.92
Belgium	5.41	28.54	67.73
Slovenia	0.00	48.56	66.26
Greece	22.94	43.84	59.95
Italy	17.82	38.50	56.32
Romania	11.66	19.97	52.62
Spain	8.36	36.26	46.13

Source. Authors' calculation on Cohesion open data platform. Absorption rate is defined as the percentage of total eligible expenditure over the total amount of allocated cost. The reference day for each observed year is December 31. Cyprus is not considered in the table because it did not invest in Low-carbon economy with ERDF resources in 2014-20

cycle[1], this thematic objective recorded one of the lowest absorption rates (around 82%) of EU funds, compared to all other objectives in the whole European Union (Bachtrögler-Unger 2024).

By computing the absorption capacity of each EU Member States for ERDF at three points in time for this thematic area, we can note considerable variability across countries and serious low absorption rates for some of these (Table 1).

On the one hand, according to the principle of efficient allocation of resources, the major recipients of EU funds should be the territories with successful past completions of public projects. On the other, lagging territories may experience obstacles associated with a weak economic, social and institutional context. Therefore, to avoid an exacerbation of income inequalities across regions, the factors contributing to projects' timely implementation should be carefully analysed at the regional level. To our knowledge, there has been no supranational investigation of such factors. Our paper aims to fill this gap with the following novelties.

[1] The data refers to 2023 year due to the $n+3$ rule.

We detect the drivers of timely implementation of EU cohesion policy projects by adopting a sub-national perspective. In particular, our assessment quantifies the impact of some regional context factors, such as urbanization, economic development and institutional quality, on the time performance of European regions exploiting the variability both between regions and between the implemented interventions, as well as over the years, through regional and project-level assessments. The latter framework also questions whether the time efficiency changes across the programming period and the effect of the financial involvement of member states on projects' duration through national co-financing.

Moreover, we carry out the evaluation on different typologies of interventions, namely infrastructures, incentives for SMEs and incentives for large firms.

We apply linear regression models and use logistic regressions as well as survival techniques for robustness checks.

The remaining parts of the paper are structured as follows. The second section reviews the literature on the implementation speed of public works (sub-Sect. 2.1) and narrows the focus to EU cohesion policy (sub-Sect. 2.2). The third section describes our empirical analysis. The fourth section presents and discusses the empirical findings. The final section concludes by offering policy suggestions that are particularly relevant to the current debate on European regional policy, especially in the context of the novel (and temporary) expansionary fiscal policy framework introduced through instruments such as *Next Generation EU*.

2 Literature Review

2.1 Time Efficiency of Public Works

Our paper contributes to two strands of literature. The first analyses the execution speed of public works and the second focuses more specifically on time efficiency, one of the dimensions of EU cohesion policy effectiveness.

The arguments for investment policies are often weakened by the presence of some factors that make public capital unproductive, including a selection of projects which does not reflect the real priorities of the economies, cost escalation (Flyvbjerg et al. 2003; Bajari et al. 2006; Love et al. 2016) as well as unfinished works and delays (Rajaram et al. 2010).

A strand of macroeconomic literature has studied the potential *solutions* to the implementation delays, one of these is the role of monetary policy. Elekdag et al. (2022) demonstrated, for the German case, that expansionary monetary policy can neutralize the negative effects of time-to-build constraint. Bouakez et al. (2014) showed that the size of the fiscal spending multiplier is mediated by the length of time-to-build. When it is relatively long, the multiplier is a decreasing function of the fraction of public investment in normal times. The key to the underlying macroeconomic reasoning is that, in presence of implementation delays, the positive (long-run) supply-side effect of spending (such as raising productivity of the economy and reducing the inflation), is postponed and the demand-side effect prevails by generating inflation and reducing consumption. The opposite happens in a liquidity

trap when the spending multiplier is an increasing function of the fraction of public investment (always considering a relative long time-to-build[2]).

A potential structural reform intended to shorten the completion duration of public capital can stimulate social demand for public investments leading the economy to a higher steady-state public capital-to-output ratio and aggregate output, as demonstrated by Ozbilgin (2020) for the Turkish case. Another stream of literature focused on the role of monitoring, but with mixed results dependent on country-specific characteristics. On this point, Calvo et al. (2019), by analysing, through a regression discontinuity design method and for the U.S., the effects of the supervision of public works implemented between 2005 and 2015, concluded that monitoring caused an increase in delays and cost overruns. On the opposite, Gori et al. (2024), considering the Italian publicly funded constructions from 2011 to 2019 and applying the same causal identification strategy, showed that monitoring improved the projects' execution especially through diminishing slowdowns in the initial phase.

A further channel to cope with implementation delays can be the incentive mechanism design. Lewis and Bajari (2011), by analysing Californian highways between 2003 and 2008, concluded that the presence of incentives based on time had a positive effect on social welfare.

Among the studies on the *determinants* of slow implementation, Guccio et al. (2014) analysed the execution time of about 9.000 Italian public works, awarded between 2000 and 2004 and completed by 2005. They found that local governments were less efficient in time performance with respect to the central one. Other causes discovered in the literature were more specific to the company signing the contract, as in the contribution of Alsuliman (2019) for the Saudi Arabia case. Instead, the role of the experience of the contracting authority was stressed by Gori et al. (2017) and Baltrunaite et al. (2021), by examining, respectively, public works implemented in a specific Italian region (Tuscany) from 2012 to 2015 and Italian public works from 2012 to 2020. In synthesis, the existing literature on the determinants of delays has been mostly country-specific and based on limited samples.

2.2 Time Efficiency of EU Cohesion Policy

A related strand of literature on the performance of EU cohesion policy looks at the absorption capacity of EU funds, i.e. the ability of the regions to spend the allocated resources successfully. Slower absorption can have important negative impacts on the economic outcome of EU funds and may also damage the reputation of cohesion policy (Marques Santos et al. 2025).

Consequently, many studies have empirically identified factors associated with high absorption capacity. To cite some relevant contributions, at the EU country level, Tosun (2014) found that absorption capacity was negatively related with income levels during 2000-06 programming period and, on the opposite, positively

[2] In a liquidity trap this situation is optimal because the nominal interest rate is close to zero, so the real interest rate becomes the negative value of the generated inflation. Thus, the reduction of real interest rates stimulates the consumption. In this case, it is convenient that the implementation time is as long as possible so that the demand-side effect prevails over the supply-side one for a longer period.

linked with government quality. Similarly, Incaltarau et al. (2020) demonstrated that funds absorption was higher in countries with higher government effectiveness and control of corruption during the 2007-14 period.

At NUTS2 level, Kersan-Škabić and Tijanić (2017), for the 2000-13 programming period and Marques Santos et al. (2025), for the 2014-20 one, demonstrated empirically that EU funds absorption may be explained by some regional context characteristics, such as government quality, human and infrastructural endowment, and negatively correlated with unemployment rate.

Although these works have provided interesting insights for the evaluation of the administrative performance of European funds, by stressing the speed of spending, none of them has instead addressed the issue of project execution speed.

Timely completion of the projects is strictly linked to cohesion policy effectiveness and the European Commission has raised this concern especially for complex projects such as rail networks, ICT, broadband and low-carbon interventions (European Commission 2014). However, the issue should be tackled at the territorial level.

Recently, Crescenzi et al. (2021) and Marques Santos et al. (2023) introduced empirical considerations on time performance. However, the former still concentrated on a single country (Italy) and on drivers related to individual projects, neglecting regional variables. The latter stressed the importance of the speed of absorption capacity of European funds only indirectly linking absorption rate with duration.

Our study fills the gap in the empirical assessment of project execution time performance.

The analysis is carried out at two levels. At a macro (regional) level, we operate by considering the European regions as unit of observation and identifying the territorial factors that most contribute, on average, to the regional implementation efficiency.

Our key regional explanatory factors of the time efficiency of EU cohesion policy are the development level (proxied by per capita GDP), urbanization (proxied by population density) and the institutional context (proxied by the European Quality of Government Index, or EQI).

Indeed, it is very likely that the more developed regions would manage projects efficiently. For instance, Carlucci et al. (2019) analysed the implementation performance of public works in Italy financed by cohesion funds between 2000 and 2013 and found that the municipalities in central and northern Italy (characterized by higher levels of per capita GDP) were more efficient than those in southern Italy. However, more developed regions can invest in more complex projects which may be time consuming. For regional policy objectives, if projects' implementation is strictly dependent on regional performance, territorial inequalities could worsen in the long-run.

Moving to the second factor, urbanized areas are better equipped with basic infrastructure such as transport, energy and access resources (materials, skilled labour and so on). The potential obstacles of less-populated areas to complete works on time could be due to the lack of these crucial factors. From a policy point of view, investigating the impact of agglomeration on time performance of public projects is instrumental for effective regional and urban planning.

Lastly, EQI captures average citizens' perceptions and experiences with corruption and the extent to which public services are of good quality and delivered impartially.

Government quality implies transparency, accountability, effective public funds management and less corruption. In all these areas, strategic delays should occur. High level of corruption is associated with poor infrastructure quality and insufficient maintenance allocations (Tanzi and Davoodi 1997). In corrupt regional contexts, the risk of adaptation costs is higher and this, in turn, is associated with longer execution duration (Guccio et al. 2012). Chakraborty and Dabla-Norris (2009) and Dabla-Norris et al. (2012) emphasized the importance of the institutional environment for the management of public investments and their effectiveness. Low government quality can affect the level of public investment and its volatility (Grigoli and Mills 2014).

In the specific context of European cohesion policy, there is a widespread scientific literature which discussed the leading role of the institutional context and administrative capacity on absorption rate and cohesion funds' outcomes (see, among others, Milio 2007; Bachtler et al. 2014; Rodríguez-Pose and Garcilazo 2015; Terracciano and Graziano 2016; Crescenzi et al. 2016; Arbolino and Boffardi 2017; Incaltarau et al. 2020; Arbolino et al. 2020; Bachtrögler-Unger 2024).

Mendez and Bachtler (2022) found, at the European NUTS-2 level, a positive impact of institutional quality on administrative capacity for the 2007-13 programming period. However, the influence of government quality on time performance of cohesion projects across EU regions has not been explicitly explored.

At a micro (project) level, we compare the role of the regional context (proxied by our three regional variables) in completion time with that of the specific interventions' characteristics. The project-level features are expenditure, national cofinancing rate, typology and starting year due to the following hypotheses.

The eligible expenditure of the project is a proxy for the degree of project dimensionality and complexity as suggested in the literature (see, among others, Bajari et al. 2009; Chong et al. 2014; Gori et al. 2017; Baltrunaite et al. 2021).

Higher support from member states through national cofinancing could reflect a perceived relevance of the interventions and, therefore, the need for a relatively short time-to-build. However, cofinancing also implies more bureaucracy and monitoring, which could slow down the processes.

The specific effect of the share of national cofinancing in European projects' implementation has never been empirically tested in the literature. We only noticed an indirect reference in the paper by Guccio et al. (2014) which considered the influence of different financing sources for public works in Italy from 2000 to 2005 through a dummy variable equal to one if the project was financed mainly by the contracting authority and not by external sources.

Moreover, we assess whether the regional context has a diversified impact across three different typologies of intervention. The first covers infrastructural projects, the second includes incentives oriented towards the sustainability of small and medium-sized enterprises and the third typology comprises financing for large enterprises.

Lastly, we evaluate if the duration changes over the years of the programming cycle[3]. Indeed, the final years of the European programming period are characterised by faster execution (Guccio et al. 2014).

[3] In our analysis the 2014-20 programming period does not overlap with the 2021-27 one because we only consider projects financed by the ERDF in the 2014-20 period.

We are confident that our results are quite generalizable across several contexts because our assessment encompasses many countries, a large set of projects (37,212), and eight years. Indeed, we can assume that our identified drivers of efficiency are particularly relevant also for the current cycle (2021-27).

3 Empirical Analysis

3.1 Data

Our investigation focuses on Policy Objective P02 of the 2014–2020 EU cohesion policy, labelled as '*Greener*, *carbon-free Europe*'. In particular, we concentrate on the Thematic Objective 04, named '*Low-carbon economy*'. The interventions were all financed by the European Regional Development Fund.

The analysis of delays in projects targeted to reduce carbon emissions is a topic of growing importance due to the social and economic relevance of climate change mitigation and environmental policies. Low time performance can defer the achievement of sustainability goals, thereby undermining the overall effectiveness of strategies against climate change.

The data on concluded projects were extracted from 'Kohesio', a database managed by the European Commission which tracks each cohesion investment in European member states during the 2014–2020 programming period[4]. There are several interventions under the TO04 *Low-carbon economy* such as improvement of energy distribution networks, energy saving in large enterprises and in SMEs, sustainable public transport infrastructures, cycling and walking infrastructures, energy efficiency of public infrastructure.

We computed the project implementation time by calculating the difference in the number of days between the starting and the completion dates. Figure A1 in the Appendix displays the regional variability of project implementation time with a breakdown by typology of intervention (infrastructures, incentives for large firms, incentives for SMEs).

Previous studies have used as time performance measure the difference between actual and expected completion, i.e. the deviation from the foreseen date in the contract (see, for instance, Guccio et al. 2012; Guccio et al. 2014). However, contrasting the predicted completion date with the actual one can introduce biases if the predicted duration is under or overestimated. One of the related shortcomings is the high level of initial uncertainty and a generalized optimistic bias which leads to provide initially an underestimated expected duration (Chadee et al. 2021). Our duration measure is, instead, based on actual time.

We standardized the duration by the amount of eligible expenditure to control for project dimension as a proxy for project complexity. We aggregated the data at the

[4] The countries considered are Austria, Belgium, Bulgaria, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden. We excluded Cyprus because it did not invest in Low-carbon economy with ERDF resources, Ireland and Malta due to the limitation of projects, Greece due to the lack of regionalization of projects on Kohesio and United Kingdom since it is not included in Kohesio.

Table 2 Variables' summary statistics

	Mean	Std. Dev	Min	Max
Project implementation time (days)				
Infrastructures	1,017.75	332.41	122	2,247.84
Incentives for SMEs	746.39	361.81	156	2,587
Incentives for large firms	728.02	361.48	284	1,800.50
Expenditure (euro)				
Infrastructures	1,389,718	11,400,000	672	622,000,000
Incentives for SMEs	276,402.2	796,031	164.92	37,400,000
Incentives for large firms	647,279.5	1,658,149	571.45	39,800,000
Cofinancing rate (%)				
Infrastructures	73.42	18.10	0.28	100
Incentives for large firms	55.84	23.50	5.55	100
Incentives for SMEs	63.24	16.94	9.65	100
Per capita GDP (per capita euro)	24,267.96	7,933.34	8,500	68,000
Population density (inhabitants per km^2)	204.27	451.93	3.4	7,526.70
Institutional quality EQI (index)	-0.18	0.72	-2.63	1.73

Source: Authors' calculations

NUTS-2 level by calculating the regional average. The sample embraces projects started between 2014 and 2021[5]. The main explanatory variables include per capita GDP (Eurostat Regional Database) as a proxy for regional development level; population density as a proxy for urbanization (Eurostat Regional Database); and institutional context proxied by the European Quality of Government Index, or EQI, based on data coming from two surveys conducted in 2013 and 2017[6]. Table 2 presents summary statistics. The variable 'project implementation time' and some others are provided with the typology breakdown.

3.2 Models Specification

For the regional level analysis, we consider a panel specification covering two different sub-periods in which implementation time is explained by our hypothesized drivers. The first sub-period includes projects started and completed between 2014 and 2017, while the second one comprises those started and completed between 2018 and 2021[7].

The model is estimated through random effects GLS methodology[8] with standard errors clustered at the regional level. The model specification is:

[5] Despite the $n+3$ rule for the 2014–2020 programming, we decided to exclude projects started after 2021, since mostly still ongoing; by doing so, we avoided biases arising from truncated data.

[6] See Charron et al. (2015) and Charron et al. (2019), respectively.

[7] One of the limitations of the panel approach is the exclusion of the projects started in the first period and completed in the second one. However, the project-level analysis overcomes this problem by considering all the projects.

[8] Although the fixed effect estimator is often preferred when using regional observations, we had to discard it due to the small sample size since, in a fixed effect framework, the estimation of region-specific intercepts reduces the degrees of freedom, leading, in our specific case, to severe inefficiency issues.

$$Reg_impl_time_{it} = b_0 + b_1 Development_{it} + b_2 Urbanization_{it} + b_3 Institutions_{it} + \lambda_t + \varepsilon_{it} \quad i = 1, \ldots, n;\ t = 1, 2 \tag{1}$$

where *Reg_impl_time* is the regional average time standardized by eligible expenditure; *Development* is proxied by regional per capita GDP; *Urbanization* is measured by regional population density; *Institutions* refers to regional institutional quality; λ_t is time fixed effect; ε_{it} is the idiosyncratic error term. To account for potential endogeneity issues, the explanatory variables for the first period are calculated in 2013 year and, for the second period, in 2017 year.

The model specification of the project-level analysis, one of the key novelties of our work, follows.

$$Proj_impl_time_j = b_0 + b_1 Exp_j + b_2 Cofin_j + b_3 Development_j + b_4 Urbanization_j + b_5 Institutions_j + \mathbf{Typology} + \mathbf{Starting\ year} + \varepsilon_j \quad j = 1, \ldots, J \tag{2}$$

where, *Proj_impl_time* is the duration in years of each project *j*; *Exp* refers to project expenditure; *Cofin* represents the project co-financing rate; *Development*, *Urbanization*, *Institutions* have the same meaning as in (1); *Typology* are dummies related to the three different categories of the projects (infrastructures ('INFRA'), incentives to SMEs ('SMEs') and incentives to large firms ('LARGE')[9]; *Starting year* refers to dummies for each starting year; ε_j is the idiosyncratic error term. The explanatory variables are calculated at the project starting year to account for potential endogeneity. Since the EQI is not available as a continuous historical series, we use the 2013 value for projects started between 2014 and 2017, and the 2017 value for those started between 2018 and 2021. We applied OLS and survival techniques for robustness. Projects implemented in the same region may not be independent. To adjust for intra-regional correlation, we clustered standard errors at the NUTS-2 level. For robustness, the models have also been estimated by clustering the standard errors at the category level.

Lastly, to assess whether regional context variables influence the implementation speed of the three typologies in a different manner, we estimated the model separately for each category.

Furthermore, the results of the Breusch-Pagan Lagrange Multiplier and Hausman tests supported the use of the RE-GLS estimator.

[9] In detail, the first group concerns the following categories: *'Clean urban transport infrastructure and promotion (including equipment and rolling stock)'*; *'Cycle tracks and footpaths'* and *'Energy efficiency renovation of public infrastructure*, *demonstration projects and supporting measures'*. The second group encompasses the categories: *'Energy efficiency and demonstration projects in SMEs and supporting measures'* and *'Support to environmentally friendly production processes and resource efficiency in SMEs'*. The third group includes the following categories: *'Promotion of energy efficiency in large enterprises'* and *'Productive investment in large enterprises linked to the low-carbon economy'*.

4 Empirical Results and Discussion

4.1 Regional-level Evaluation

The results of the random effect GLS estimation of the regional panel Eq. (1) with standard errors clustered at the regional level are presented in Table 3. In the specification (b), we included a dummy for the second period to account for (global) time-specific effects. Indeed, the final period of the cohesion programming can generate higher efficiency due to the acceleration of the execution and the need to avoid the return of the allocated grant to the European Union (Guccio et al. 2014).

All the coefficients turn out to be statistically significant in specification (b). As expected, in this model, the inclusion of the period dummy, through with a non significant coefficient, drives an improvement of the explanatory power of the other variables.

Urbanization and institutional quality appear to be positive drivers for implementation speed (negative coefficients). On the contrary, the coefficient of the regional development level is positive, indicating the potential negative role of this variable on time performance.

On the basis of this evidence, regions with a higher level of per capita GDP seem to invest in more complex projects which might be time-consuming.

Urban areas seem more efficient in implementation and this may reflect the presence of high-quality infrastructure and a more dynamic labour market, but perhaps also a greater awareness of the social relevance of infrastructures and incentives aimed at energy saving and with environmental concern. Indeed, in less populated contexts, with low levels of human capital, it may turn out to be more costly to identify and prevent climate change-related disruptions.

The institutional context turns out to be a crucial factor for efficiency, due to a close link between government quality and administrative capacity in terms of simplification, effective bureaucracy and transparency. Furthermore, in contexts characterized by low institutional standing, project selection by policymakers is likely to be mediated by political cycles, self-interest, rent seeking and it might not be in line with social welfare considerations.

Table 3 Drivers of implementation speed of low-carbon economy projects - Regional level panel evaluation – RE-GLS regression

Variables	(a)	(b)
Development	0.0027	0.0038*
	(1.39)	(1.87)
Urbanization	-0.0022**	-0.0023**
	(-2.27)	(-2.35)
Institutions	-0.0013**	-0.0015**
	(-1.83)	(-2.14)
2nd period dummy		-0.0011
		(-1.23)
N. Obs	324	324
Breusch-Pagan LM test	62.46***	62.46***
Hausman test	0.16	
R^2	0.0396	0.0493

Notes: Robust t-test in parentheses. Standard errors clustered at the regional level

***: p-value < 0.01, **: p-value < 0.05, *: p-value < 0.10

Table 4 Drivers of implementation speed of low-carbon economy projects - Project-level evaluation – Full sample - OLS methodology

Variables	(a)	(b)	(c)	(d)
Expenditure	0.4173***	0.4200***	0.3524***	0.3610***
	(21.10)	(23.84)	(14.58)	(16.66)
Cofinancing rate	0.0086***	0.0096***	0.0030	0.0045**
	(3.00)	(3.94)	(1.30)	(2.18)
Development	-0.0019	0.3940	0.1869	0.5438**
	(-0.01)	(1.54)	(0.76)	(2.27)
Urbanization	0.0343	-0.0669	-0.0207	-0.1113*
	(0.44)	(-0.96)	(-0.28)	(-1.72)
Institutions	-0.1990*	-0.2086*	-0.1978**	-0.2075**
	(-1.72)	(-1.81)	(-2.04)	(-2.11)
Dummy 2015		-2.1207***		-2.0519***
		(-9.57)		(9.32)
Dummy 2016		-2.5936***		-2.4816***
		(-12.01)		(-12.16)
Dummy 2017		-2.7376***		-2.6296***
		(-13.84)		(-13.57)
Dummy 2018		-2.7630***		-2.6079***
		(-14.30)		(-13.63)
Dummy 2019		-3.0370***		-2.8922***
		(-15.82)		(-15.20)
Dummy 2020		-3.1818***		-3.0374***
		(-16.15)		(-15.56)
Dummy 2021		-3.7358***		-3.5888***
		(-18.74)		(-17.66)
Dummy LARGE			-1.0265***	-0.9085***
			(-10.48)	(-9.38)
Dummy SME			-0.6619***	-0.6028***
			(-7.36)	(-6.42)
N. Obs	37,212	37,212	37,212	37,212
R^2	0.2749	0.3590	0.3161	0.3923
VIF	1.35			

Notes: Robust t-test in parentheses. Standard errors clustered at the regional level

Baseline year: 2014. Baseline category: Infrastructure. ***: p-value < 0.01, **: p-value < 0.05, *: p-value < 0.10

4.2 Project-level Evaluation

Our regional analysis is complemented by a project-level assessment which investigates the influence of project-specific attributes on time performance. In particular, we estimated model (2) for the full sample of projects using OLS (Table 4) and, for robustness, a survival model with a log-normal distribution (see Table 8 in sub-section 4.3).

To discover whether the inclusion of time and typology[10] dummies contributes to explain the variability of the dependent variable, we estimated different model specifications both with and without these dummies. Indeed, the explanatory power of the model increases considerably when moving from the specification (a), which does not consider any dummy, to specification (d), which includes both of them. The same

[10] In several parts of this paper the terms 'typology' and 'category' are used interchangeably. However, to be precise, for typology we mean 'Infrastructure'; 'SMEs incentives'; 'Large firms incentives'. For category we mean the specific interventions described in note 9 (Sect. 3.2).

effect persists by changing the estimation method and using survival techniques, as shown in Table 8. Therefore, in commenting the results, we focus on specification (d).

Overall, the effect of the regional drivers remains confirmed. Namely, population density and institutional quality are associated with faster implementation time while per capita GDP is associated with slower execution.

As for the project-level variables, the coefficient associated with project expenditure (a proxy for complexity) is positive and statistically significant. This result, together with the positive sign of the per capita GDP coefficient, supports the conclusion that the wealthier regions tend to invest in more complex projects with higher expenditure value.

The effect of national co-financing seems to slow down the implementation speed which could be related to the existence of more bureaucratic processes.

With respect to the 'Infrastructure' baseline, incentives to SMEs and projects involving large firms are less time consuming.

Lastly, according to our findings, it is clear that efficiency increases monotonically as we approach the end of the programming period. Hence the pressure to lose the financing is a strong determinant of implementation efficiency. This result induces important policy considerations. Towards the final years of the programming period (with the extension due to the application of the $n+3$ rule), policymakers might launch projects that guarantee fast completion. Therefore, the pressure to avoid fund losses may damage the quality of the project selection process.

In order to evaluate the hypothesis that regional factors could differently impact the implementation of the various categories of investments, Eq. (2) was estimated separately using both OLS and survival analysis on three subsamples, referring to 'Infrastructure', 'Incentives to SME' and 'Incentive to large firms' interventions[11]. The OLS and survival analysis results are shown in Table 5 hereafter and in Table 9 (see Sect. 4.3), respectively.

The signs of the coefficients of all the variables remain confirmed across the different sub-samples, but the regional context indicators appear to be more relevant for infrastructural interventions rather than for the two typologies of incentives. On the contrary, national co-financing is a factor that increases the duration of incentives but only for large companies. This could be due to a more stringent bureaucratic control applied by member states in the case of incentives to large firms. Interestingly enough, the monotonic improvement in efficiency for projects starting closer to the end of the programming period is clearly supported by the results only for infrastructural projects while it does not hold for incentives in the first part of the period.

4.3 Additional Results and Robustness Checks

As additional exercises, at the regional level, we performed our model (1) in a cross-sectional specification that covers the whole period. We employed OLS with heteroskedasticity-robust standard errors by using two specifications, one with the EQI at

[11] When we estimate the three subsamples separately, the model remains as in Eq. (2) but with the elimination of the vector of typology dummies.

Table 5 Drivers of implementation speed of low-carbon economy projects - Project-level evaluation by typology of interventions - OLS methodology

Variables	INFR	SME	LARGE
Expenditure	0.4173***	0.2816***	0.2100***
	(21.99)	(8.59)	(5.94)
Cofinancing rate	0.0027	0.0005	0.0090**
	(1.18)	(0.14)	(2.31)
Development	0.6530**	0.2903	0.4828
	(2.34)	(1.15)	(0.88)
Urbanization	-0.1264	-0.1000*	-0.1219
	(-1.40)	(-1.68)	(-0.72)
Institutions	-0.3220***	-0.0521	-0.3055**
	(-2.84)	(-0.60)	(-2.38)
Dummy 2015	-1.8888***	-0.4297	-1.1583
	(-8.91)	(-1.16)	(-1.41)
Dummy 2016	-2.3653***	-0.8154***	-2.2952***
	(-12.09)	(-2.77)	(-2.83)
Dummy 2017	-2.5647***	-0.8185***	-2.1235**
	(-13.11)	(-2.76)	(-2.60)
Dummy 2018	-2.6500***	-0.6869**	-2.0065**
	(-13.29)	(-2.26)	(-2.49)
Dummy 2019	-2.9288***	-0.9624***	-2.1841***
	(-14.74)	(-3.16)	(-2.74)
Dummy 2020	-3.0747***	-1.1674***	-2.1998***
	(-14.41)	(-4.00)	(-2.73)
Dummy 2021	-3.8565***	-1.5118***	-2.4233***
	(-18.35)	(-5.26)	(-2.96)
N. Obs	21,424	14,456	1,332
R^2	0.3044	0.2871	0.1977
VIF	1.35	1.52	2.06

Notes: Robust t-test in parentheses. Standard errors clustered at the regional level

Baseline year: 2014. ***: *p*-value < 0.01, **: *p*-value < 0.05, *: *p*-value < 0.10

Table 6 Drivers of implementation speed in low-carbon economy projects - Regional-level cross-sectional evaluation - OLS regression

Variables	(a)	(b)
Development	0.0023	0.0040
	(1.06)	(1.63)
Urbanization	-0.0019**	-0.0021**
	(-2.26)	(-2.45)
Institutions (EQI 2013)	-0.0016**	
	(-2.24)	
Institutions (EQI 2017)		-0.0025***
		(-2.85)
N. Obs	198	198
R^2	0.053	0.075
VIF	1.90	1.87

Notes: Heteroskedasticity-robust t-test in parentheses. ***: *p*-value < 0.01, **: *p*-value < 0.05, *: *p*-value < 0.10. (a): 2013 EQI value; (b): 2017 EQI value

2013 and the other at 2017. Development level and urbanization were expressed in terms of regional average values in the period. These variables can be considered as exogenous since it is very unlikely that implementation speed can affect development level and urbanization (as well as institutional quality) in such a short period of time. The estimation results (Table 6), confirm the previous conclusions.

As further robustness check, we applied a logistic regression (Table 7) by dichotomizing the dependent variable. In this specification, the binary dependent variable assumes value 1 if the projects average completion time in region *i* is longer than the national average; 0 otherwise[12]. In this case, the coefficient of the regional development level turns out to be statistically significant with a positive sign. This means that the increase in per capita GDP is associated with an increase in the probability that, on average, regions have an implementation time above their national average. Instead, the growth of institutional quality and urbanization decreases the probability of inefficiency compared to their national average.

However, expressing the regional development proxy (per capita GDP) in terms of regional average values in the period, as we did in the cross-sectional evaluation (Tables 6 and 7), could raise reverse causality concerns. Thus, for robustness, we provide in Tables A1 and A2 of the Appendix the estimates obtained by calculating the per capita GDP variable at 2013 year. The results remain robust to this variation.

Moving to the robustness checks for the project-level framework, since our outcome variable concerns time-to-event data (specifically, project duration until completion), we used the survival analysis as a methodology specifically designed to model such type of phenomena and to evaluate the determinants of the length of time elapsed before the occurrence of the events (in this case, the completion of the projects).

Survival analysis is also robust to potential issues arising from skewed distributions. For instance, the presence of projects with significantly longer implementation times than the average does not compromise the reliability of the estimates as survival analysis explicitly accounts for extreme values and right-skewed distributions.

Technically, in our context, the survival time is the time until the project is completed while the event (or failure) is the completion[13]. In a parametric survival framework, we assume that the survival time follows a known distribution such as exponential, Weibull, log-normal, generalized gamma (Kleinbaum and Klein 2012).

Table 7 Drivers of implementation speed of low-carbon economy projects - Regional-level cross-sectional evaluation – Logistic regression

Variables	(a)	(b)
Development	4.1239**	3.3737*
	(2.34)	(1.95)
Urbanization	0.7171*	0.7468*
	(-1.95)	(-1.72)
Institutions (EQI 2013)	0.6290**	
	(-2.38)	
Institutions (EQI 2017)		0.6827*
		(-1.86)
N. Obs	198	198
Hosmer-Lemeshow	197.69	197.93
	(p=0.41)	(p=0.40)

Notes: Heteroskedasticity-robust t-test in parentheses. ***: p-value < 0.01, **: p-value < 0.05, *: p-value < 0.10. ODDS ratios are reported. (a): 2013 EQI value; (b): 2017 EQI value

[12] In this case, the specification follows: $logit(P(Y_i = 1)) = log\left(\frac{P(Y_i=1)}{1-P(Y_i=1)}\right) = \beta_0 + \beta_1 Development_i + \beta_2 Urbanization_i + \beta_3 Institutions_i + \varepsilon_i$. Where $P(Y_i = 1)$ is the probability that the projects average time completion in region *i* is longer than the national average and $\frac{P(Y_i=1)}{1-P(Y_i=1)}$ = ODDS ratio (OR). Thus OR = $\exp(\beta)$.

[13] We are in a context of uncensored data since all interventions have been completed.

We employed a log-normal distribution, which allows for a potential non-linear relationship between project duration and the explanatory variables. Among these distributions, the log-normal is one of the most used in economics due to its flexibility. Indeed, unlike other distributions, it imposes no constraints on the shape of the hazard function[14]. The form of our empirical model in Eq. (2) is therefore modified as shown in Eq. (3) (Cleves et al. 2010):

$$\begin{aligned} &ln\left(Proj_Impl_Time_j\right) = b_0 + b_1 Exp_j + b_2 Cofin_j + b_3 Development_j + b_4 Urbanization_j \\ &+b_5 Institutions_j + \mathbf{Typology} + \mathbf{Starting\,year} + \varepsilon_j \\ &j = 1, \ldots, J \end{aligned} \tag{3}$$

where *ln(Proj_Impl_Time$_j$)* is the natural logarithm of the survival time and the other variables have the same meaning and definition as before.

The results of the survival analysis, reported in Table 8 for the full sample of projects and in Table 9 for the breakdown by typology, confirm the findings of the main analysis.

The only notable difference is a weaker effect of the national co-financing rate (see Table 8 compared to Table 4). However, this discrepancy arises only in specifications (c) and (d) which control for project typology and may indeed be due to the inclusion of typology dummies. When estimating the model separately for each typology (Table 9), the national co-financing rate delays the implementation time only for incentives to large firms, consistently with the main findings reported in Table 5.

Finally, due to the poor data availability, in this paper unfortunately we cannot take into account the differences in time efficiency between government levels (i.e. national, regional, local managing authorities). In a supranational context, indeed, the homogenization of management authority levels across countries is not straightforward and prone to errors.

5 Conclusions

The speed of implementation of public works has always been a relevant policy issue in different countries and researchers have extensively questioned the potential causes and solutions to the problems caused by slow project execution.

In particular, the issue is of paramount importance in the context of European cohesion policy, perhaps the most evaluated of all EU policies (Darvas et al. 2019; Asatryan et al. 2025).

Traditionally, the debate has focused on the effectiveness of this policy and its outcome for economic convergence. However, a growing body of scientific literature has recently started to conduct policy evaluations beyond the (final) impact on economic growth, particularly by considering the administrative processes and institutional aspects. In fact, in our analysis, institutional quality is a factor that has consistently been associated with shorter implementation time of EU cohesion projects.

[14] The hazard function *h(t)* represents the probability that the event completion will occur in a very small time interval, given that the project has not yet been completed up to that point.

Table 8 Drivers of implementation speed of low-carbon economy projects - Project-level evaluation – Full sample - Survival analysis

Variables	(a)	(b)	(c)	(d)
Expenditure	0.2366*** (15.38)	0.2430*** (15.92)	0.1924*** (15.72)	0.2009*** (17.39)
Cofinancing rate	0.0034* (1.93)	0.0038** (2.45)	-0.0002 (-0.17)	0.0003 (0.28)
Development	-0.0439 (-0.36)	0.1554 (1.26)	0.0832 (0.73)	0.2622** (2.30)
Urbanization	-0.0192 (-0.44)	-0.0708* (-1.79)	-0.0565 (-1.41)	-0.1026*** (-2.84)
Institutions	-0.0899* (-1.66)	-0.0942* (-1.77)	-0.0895** (-2.23)	-0.0939** (-2.37)
Dummy 2015		-0.4299*** (-5.14)		-0.3830*** (-4.91)
Dummy 2016		-0.6752*** (-9.02)		-0.5990*** (-10.11)
Dummy 2017		-0.7215*** (-13.44)		-0.6478*** (-13.80)
Dummy 2018		-0.7040*** (-12.65)		-0.5972*** (-11.61)
Dummy 2019		-0.8670*** (-12.64)		-0.7675*** (-12.65)
Dummy 2020		-0.9604*** (-11.89)		-0.8619*** (-12.03)
Dummy 2021		-1.3252*** (-11.05)		-1.2264*** (-11.22)
Dummy LARGE			-0.5951*** (-13.31)	-0.5461*** (-12.30)
Dummy SME			-0.4479*** (-7.43)	-0.4291*** (-7.00)
N. Obs	37,212	37,212	37,212	37,212
Wald chi^2	247.83***	999.61***	705.70***	2030.48***

Notes: Log-normal distribution. Robust t-test in parentheses. Standard errors clustered at the regional level. Baseline year: 2014. Baseline category: Infrastructure. ***: p-value < 0.01, **: p-value < 0.05, *: p-value < 0.10

Needless to say, some public projects are more *urgent* than others, such as climate-related ones.

This paper contributes to the existing debate by providing, as novel addition, *supranational* empirical scrutiny at the European level considering, in particular, the regional dimension of this problem.

According to our main findings, regional context determinants, such as the level of development, the urbanization pattern and the institutional conditions have a significant influence on implementation speed, particularly for infrastructures. Implementation is clearly more efficient in urban contexts and where institutional quality is higher.

Table 9 Drivers of implementation speed of low-carbon economy projects - Project-level evaluation by typology of interventions - Survival analysis

Variables	INFR	SME	LARGE
Expenditure	0.1895***	0.2274***	0.1852***
	(17.60)	(8.05)	(7.15)
Cofinancing rate	-0.0008	0.0018	0.0078***
	(-0.78)	(0.60)	(3.99)
Development	0.2846**	0.2078	0.1120
	(2.36)	(1.06)	(0.42)
Urbanization	-0.0948**	-0.1128**	-0.0255
	(-2.29)	(-2.16)	(-0.30)
Institutions	-0.1351***	-0.0409	-0.1682***
	(-2.95)	(-0.78)	(-3.06)
Dummy 2015	-0.3891***	-0.2554	-0.3787
	(-7.37)	(-0.98)	(-1.28)
Dummy 2016	-0.5494***	-0.5256***	-1.1902***
	(-11.37)	(-2.84)	(-4.01)
Dummy 2017	-0.6622***	-0.4697***	-1.0072***
	(-13.65)	(-2.79)	(-3.42)
Dummy 2018	-0.6664***	-0.3679**	-0.9555***
	(-12.54)	(-2.02)	(-3.30)
Dummy 2019	-0.7448***	-0.6308***	-1.1120***
	(-13.02)	(-3.42)	(-3.81)
Dummy 2020	-0.7935***	-0.7894***	-1.1148***
	(-11.46)	(-4.52)	(-3.81)
Dummy 2021	-1.2640***	-1.0704***	-1.1912***
	(-9.92)	(-5.66)	(-3.84)
N. Obs	21,424	14,456	1,332
Wald chi^2	1158.83***	578.33***	587.96***

Notes: Robust t-test in parentheses. Standard errors clustered at the regional level

Year baseline: 2014. ***: p-value < 0.01, **: p-value < 0.05, *: p-value < 0.10

This result pushes for monitoring the speed of investment flows in less populated areas where popular discontent with slow and unfinished works may be high and awareness of climate change issues potentially left unaddressed.

The timely and tangible implementation of cohesion policy investments is crucial not only for their direct economic impact, but also for fostering citizens' satisfaction with the EU (Capello and Perucca 2019), strengthening European identity (Borz et al. 2022) and reducing political disaffection (Rodríguez-Pose and Dijkstra 2020), especially in structurally lagging areas. Delays undermine these broader objectives by weakening the perceived legitimacy of EU actions in the eyes of citizens, particularly where trust in public institutions is already fragile.

Indeed, European policymakers should also be concerned on regional institutional contexts during the EU funds allocation processes in order to reduce phenomena of strategic delays in project selection which responds to interests not always in line with social welfare considerations.

The negative influence of per capita GDP on time efficiency is more puzzling and may be due to the complexity of the implemented projects in richer territories as also confirmed by the micro-level analysis. In particular, projects targeted at reducing carbon emissions often use advanced and more complex technologies.

Projects starting towards the end of the programming period are necessarily implemented more quickly than those launched earlier and this may be due to the strong pressure on policymakers to avoid the loss in financing.

Our analysis provides novel theoretical and empirical insights by stressing the relevance of evaluating not only the effectiveness of EU funds on regional growth but also the efficiency of their implementation, particularly in terms of project duration. This aspect is crucial for the current debate on the future of cohesion policy, as it can inform European policymakers about the context-specific factors that contribute to regional time performance variability.

The implementation of cohesion policy in the current cycle (2021-27) began with a delay, starting only in 2023 (European Commission 2025). This was largely due to the simultaneous launch of the Next Generation EU (particularly the Recovery and Resilience Facility (RRF)) which, being subject to more stringent time constraints, temporarily absorbed administrative and financial attention.

Recent academic literature has raised concerns about a potential shift in political and financial attention away from cohesion policy in favour of the RRF (see, for instance, Polverari 2025).

Additionally, the current programming period (2021-27) is governed by the stricter $n+2$ rule, as opposed to the $n+3$ rule applied previously (2014-20), pushing the final deadline for the use of structural funds to 2029. In this framework, enhancing the efficiency of fund absorption and ensuring timely project execution are critical not only to maximize the impact on development but also to maintain the credibility of cohesion policy as a cornerstone of EU territorial development.

This also strengthens the case for independent academic evaluations. Linked to this point, Asatryan et al. (2025) compared the results of the 'official' and mandatory assessments of the outcomes of the European cohesion policy performed by EU Member States with those from the economic literature (such as Di Caro and Fratesi 2022; Fidrmuc et al. 2019; Canova and Pappa 2021; Crucitti et al. 2022), finding substantial differences which the authors have attributed to potential limited impartiality and an optimistic bias in the assessments by Member States.

Timely implementation of low-carbon interventions encourages the fulfilment of long-run environmental objectives, particularly the reduction of carbon emissions. A wise mechanism of public monitoring of implementation is therefore necessary. The implementation slowness of public projects in non-urban and less populated areas generates important long-term challenges.

It is not politically feasible the reduction of resources to those regions with weak economic, social and institutional contexts to avoid exacerbating the unbalanced income distribution. The ultimate risk is that these areas remain underdeveloped also due to inefficient public projects implementation.

Definitely, these regions should become more efficient to ensure the improvement of their structural conditions. For this reason, investment in the accumulation of human capital is strategic to better face projects complexity and to increase awareness for environmental issues and popular discontent towards slow or not completed public works.

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Author Contributions Gambina: Conceptualization; Data curation; Formal analysis; Methodology; Software; Validation; Visualization; Writing – original draft; Writing – review & editing. Mazzola: Conceptualization; Formal analysis; Methodology; Project administration; Supervision; Validation; Visualization; Writing – original draft; Writing – review & editing.

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Data Availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Competing Interests There are no other competing interests to state. There are no additional relationships to disclose. There are no patents to disclose.

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Authors and Affiliations

Debora Gambina[1] · **Fabio Mazzola**[1]

✉ Debora Gambina
debora.gambina@unipa.it

Fabio Mazzola
fabio.mazzola@unipa.it

[1] Department of Economics, Business and Statistics, University of Palermo, Viale delle Scienze, Building 13, Palermo 90128, Italy