Economics of Governance (2026) 27:45
https://doi.org/10.1007/s10101-026-00388-w

ORIGINAL PAPER

Regulatory certification, informal governance, and productivity under weak state capacity

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Received: 4 October 2025 / Accepted: 16 July 2026

Abstract

This paper examines firm-level productivity differences among Sicilian firms characterized by varying degrees of compliance with anti-Mafia regulatory frameworks. Utilizing data from 2013 to 2021, we find that firms operating in public procurement without formal anti-Mafia certification consistently exhibit higher total factor productivity (TFP). These productivity differentials are more pronounced in provinces characterized by higher Mafia intensity and are negligible in areas with stronger institutional enforcement. The observed productivity patterns suggest potential competitive asymmetries stemming from institutional dualism: the coexistence of formal compliance frameworks and informal governance mechanisms. The analysis highlights the complex interaction between organized crime, regulatory compliance, and firm productivity, underscoring the challenges faced by regulatory frameworks in contexts characterized by weak or uneven institutional enforcement.

Keywords Total factor productivity · Anti-Mafia certification · Informal institutions · Organized crime

JEL Classification D24 · P48 · K42 · O17 · C23

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Published online: 02 August 2026

1 Introduction

Total factor productivity (TFP) measures economic efficiency, capturing how effectively firms transform inputs (such as labor, capital, and materials) into outputs. Understanding variations in TFP is crucial, especially in contexts where resource allocation and competition deviate from standard economic models, such as regions influenced by organized crime.

This paper investigates systematic differences in firm-level TFP associated with differing exposure to Mafia influence by comparing firms certified in Italy's voluntary anti-Mafia White List (hereafter WL) with firms not in the White List (hereafter NWL). Using a 2013–2021 firm panel, we estimate TFP with established methods in the productivity literature (Guérin 2023) and relate it to WL/NWL status across heterogeneous Mafia intensity, documenting systematic associations between alignment and productivity.

Starting from the assumption that firm-level total factor productivity is shaped by the context in which firms operate, we distinguish between two dimensions: (i) province-level Mafia intensity, as a measure of the territorial environment, and (ii) firms' alignment, proxied by enrollment in the WL, as an indicator of legal compliance at the micro-level. We then analyze heterogeneity in outcomes by interacting WL/NWL alignment with provincial Mafia intensity.

Introduced in 2012, the Italian WL certification, while not mandatory, serves as a benchmark of institutional alignment, indicating firms' compliance with anti-Mafia requirements. We classify firms into three categories: (1) WL-certified firms; (2) non-certified firms with no recorded procurement activity in administrative procurement data (NWL-PVT); and (3) non-certified firms engaged in public procurement below the €150,000 regulatory threshold (NWL-PUB).[1] Beyond its classificatory function, the WL can also be interpreted as a policy instrument, a formal attempt to reassert regulatory authority in sectors particularly exposed to organized crime. We restrict our analysis to firms receiving EU cohesion funds to ensure comparability across economic and institutional contexts.

In contexts of weak state capacity, organized crime may act as a form of informal governance (e.g., enforcement, protection, and access to networks/markets). In such environments, formal alignment (WL) entails compliance costs and greater transparency, while non-certification (NWL) may preserve opacity and operational flexibility and, in some cases, facilitate access to informal mechanisms. A testable implication is that the WL/NWL–TFP relationship is context-dependent and can reverse as local Mafia intensity changes. We do not identify causal effects in a strict sense; rather, our approach consists in estimating firm-level TFP across heterogeneous institutional contexts and documenting systematic correlations between WL/NWL status and productivity outcomes, in line with the framework developed in Sect. 2.2.

Our results indicate that non-certified firms, potentially more exposed to organized crime, tend to exhibit higher TFP than certified firms, particularly in areas with strong Mafia presence. From a conventional perspective, this finding appears

[1] See Sect. 4.2 for details on the procurement data source.

paradoxical, as anti-Mafia certification aims explicitly to enhance productivity by increasing transparency and reducing criminal infiltration. However, contexts characterized by weak institutional enforcement might allow non-certified firms to strategically exploit regulatory flexibility and informal governance mechanisms, thereby achieving productivity advantages.[2] This outcome reflects an underlying institutional dualism (Runst and Wagner 2011), whereby formal compliance does not necessarily translate into superior economic performance. Consistent with evidence from other institutional settings, such as the Brazilian Amazon, strengthening enforcement capacity through targeted interventions can mitigate the relative advantages derived from informal governance structures (de Oliveira and Miranda 2024).

Within the broader institutional economics and governance literature, a substantial body of work examines how organized crime interacts with formal institutions and economic performance: for instance, Yahagi and Cato (2023) model strategic crackdowns by local governments against organized crime; Berrittella (2018) studies how the composition of public expenditure relates to organized crime across EU countries; Cerruti (2024) documents how political connections shape Italian municipal growth; and Battisti et al. (2025) explore the historical roots of the Sicilian Mafia, while classic contributions interpret organized crime as a substitute for state enforcement in weak-governance contexts (Skaperdas 2001). Complementing this strand, the economics of organized crime has documented wide-ranging effects on political and economic outcomes (Buonanno et al. 2016; De Luca and De Feo 2017; Acemoglu et al. 2020), and recent work has focused on the consequences of judicial interventions that remove Mafia-controlled firms (Calamunci and Drago 2020). However, to our knowledge, no study tests explicitly whether a formal alignment device, as the WL/NWL certification, mediates the impact of Mafia presence on firm-level productivity. We address this gap by bringing micro-level TFP evidence to bear on how heterogeneous compliance regimes (WL vs. NWL-PUB vs. NWL-PVT) are associated with productivity along the territorial gradient of Mafia influence.

From a theoretical standpoint, we interpret Mafia presence as an informal governance structure substituting for formal institutional mechanisms (Kingston and Caballero 2009). In regions with weak state capacity and limited formal enforcement, organized crime groups provide alternative governance functions, such as contract enforcement, protection services, and facilitated market access. As argued by Candela (2020), insecure property rights and a weak rule of law raise transaction costs, incentivizing rent-seeking behaviors and fostering alternative governance structures such as the Sicilian Mafia. Institutional dualism arises not only from weak state capacity but also from deeply rooted social norms that conflict with formal rules. For instance, Lipari and Andrighetto (2021) document how the Sicilian anti-racket movement, (*Addiopizzo*), challenged prevailing norms around extortion payments (*pizzo*), showing that informal norms can either undermine or reinforce formal interventions. Consistent with this framework, our empirical analysis documents systematic associations between certification status and productivity.

[2] See Sect. 2.2.

The remainder of the paper is organized as follows. Section 2 introduces the WL certification system, designed to prevent Mafia infiltration in public procurement, and develops the theoretical framework on the interaction between formal and informal institutions under weak enforcement. Section 3 provides the historical and institutional background on Mafia infiltration in Sicily. Section 4 presents the empirical setting and strategy, including the EU cohesion policy context, data sources, and the methodology for estimating firm-level productivity. Section 5 reports the main results: average productivity differences, heterogeneity by Mafia intensity, robustness checks, and alternative explanations. Section 6 concludes with policy implications and the broader relevance of institutional asymmetries in Mafia-affected environments.

2 Institutional context: anti-Mafia certification and theoretical framework

2.1 Anti-Mafia certification as institutional signal

The WL system, introduced by Law 190/2012 and managed by Italian prefectures, serves as an institutional tool to prevent Mafia infiltration in economic sectors considered at high risk (i.e., construction, transportation, waste management, and security services). Firms operating in these sectors may voluntarily apply for WL certification, which replaces traditional anti-Mafia documentation for both public and private contracts.[3] The certification is granted following a rigorous vetting process that verifies compliance with legal, fiscal, environmental, and labor regulations, as well as the absence of criminal affiliations.

To enroll, a firm submits a formal request to the Prefecture of its legal headquarters and provides accompanying documents, such as the Chamber of Commerce certificate and self-declarations for corporate officers and cohabiting family members under Article 85 of the Anti-Mafia Code. The Prefecture then verifies both the absence of disqualifying conditions (under Article 67 of Legislative Decree 159/2011) and possible Mafia influence (under Article 84(3)). Registration remains valid for 12 months from the official date and can be renewed by notifying the Prefecture within 30 days prior to expiry. Any corporate changes during the registration period, such as changes in directors or ownership, must also be reported within 30 days.

Importantly, WL enrollment does not imply direct monetary fees. In this institutional setting, the relevant costs are primarily administrative and procedural: preparing and updating documentation, complying with traceability requirements, undergoing periodic renewals and checks, and maintaining an organizational setup that facilitates verification. While such requirements may be relatively easier to meet for firms already operating within formal standards, they still impose time,

[3] A complete list of high-risk sectors identified by Article 1, paragraph 53 of Law 190/2012 and subsequent amendments is reported in Appendix 9.

coordination, and organizational burdens. For this reason, WL status can be interpreted as an observable signal of formal institutional alignment.

At the same time, firms may still have strong incentives to obtain WL certification despite these administrative burdens. Certification provides a more predictable compliance status when interacting with public administrations, reduces the risk of exclusion from procurement procedures, and allows firms to compete for a broader set of regulated opportunities, including contracts above the anti-Mafia documentation threshold. Hence, WL enrollment may reflect a trade-off between broader market access and reputational legitimacy, on the one hand, and administrative and organizational compliance costs, on the other.

While not legally required, enrollment in the WL provides a streamlined pathway for firms to meet anti-Mafia compliance requirements and bypass repeated clearance procedures. It also functions as a strong reputational signal in environments where institutional trust is limited. WL certification stands out as the most rigorous and transparent form of institutional alignment. In our framework, it thus serves as a meaningful indicator to distinguish firms that adhere to formal governance channels from those that operate under informal or relational arrangements.

Under Italian law, WL certification substitutes anti-Mafia certification, which is mandatory for public procurement contracts exceeding €150,000. Therefore, we are able to distinguish WL-certified firms from non-certified firms that either participate in public procurement below the €150,000 threshold without certification (NWL-PUB) or operate mainly in private markets (NWL-PVT). This classification enables us to investigate the productivity effects of different levels of institutional compliance and exposure to Mafia-related informal institutions. Specifically, we define

(i) WL firms as firms enrolled in the WL, within the set of sectors covered by the regulation;
(ii) NWL-PUB firms are non-enrolled firms that are observed in ANAC administrative procurement records and participate exclusively in public contracts with a total awarded value below the €150,000 statutory threshold. In the ANAC database, each procurement procedure is identified by a unique code, referred to as the CIG.[4] For each firm, we observe the total contract value associated with each CIG and classify firms as NWL-PUB if all their observed public procurement contracts fall below the threshold requiring anti-Mafia certification;
(iii) NWL-PVT firms as the remaining non-enrolled firms that are never observed in the ANAC procurement data. While we cannot exclude the possibility that these firms receive direct awards from public administrations that are not captured by the ANAC database, the absence of any recorded procurement activity allows us to reasonably characterize them as firms operating predominantly in private markets.

This classification relies exclusively on administrative information and does not require assumptions on unobserved contract values or procurement activity. To

[4] *Codice Identificativo di Gara.*

make the classification fully transparent and operational, Table 1 reports the step-by-step assignment algorithm.

The NWL-PUB/NWL-PVT distinction is based on observed administrative procurement records and should not be interpreted as a perfect separation between public-market and private-market firms. NWL-PUB firms are non-certified firms observed in ANAC procurement records with below-threshold procurement activity. Some of these firms may still conduct businesses also in private markets. Conversely, NWL-PVT firms are non-certified firms not observed in ANAC procurement records; this is consistent with predominant private-market activity, but we cannot exclude unobserved public sector interactions outside the available procurement data.

This institutional configuration provides the empirical anchor for the theoretical framework developed in the next subsection.

2.2 Theoretical framework: formal and informal institutions

This paper builds on the comparative institutional literature, which emphasizes the interaction between formal and informal institutions in shaping economic outcomes (North 1990; Helmke and Levitsky 2012; Greif 2006). In particular, we focus on contexts where state capacity is limited, and informal governance structures, sometimes sustained by criminal organizations, can emerge as substitutes for formal regulatory mechanisms (Kingston and Caballero 2009; Runst and Wagner 2011). In such environments, firms may face a choice between aligning with formal institutions (e.g., by adhering to legal and regulatory standards) or operating outside these frameworks, potentially accessing informal networks that reduce transaction costs or offer protection, credit, or market access. This alignment may shape not only firms' behavior but also their productivity outcomes. In our context, WL certification represents explicit formal institutional alignment. By contrast, non-certification (NWL status) does not necessarily imply illegality but may allow for greater operational opacity or flexibility. As discussed in Sect. 2.1, non-certified firms can be divided into two broad groups with distinct institutional incentives. NWL-PUB firms participate in public tenders below the regulatory threshold that would otherwise require anti-Mafia certification. In principle, these firms could benefit from certification by enhancing their legitimacy and access to public contracts. Their decision to remain uncertified, despite these potential advantages, raises questions about their institutional alignment and strategic positioning. These firms are therefore of particular interest in our analysis. NWL-PVT firms operate mainly in private markets and face no direct incentive to obtain WL certification. Their choice not to certify may simply reflect the absence of need rather than a strategic response to institutional constraints. For this group, we refrain from formulating strong prior assumptions: they may range from fully law-abiding private actors to firms embedded in informal or criminal networks.

We frame our analysis in terms of the potential advantages that non-certified firms may enjoy by operating outside the formal institutional framework. These include reduced regulatory oversight, strategic opacity, and, where relevant, access

Table 1 Operational assignment of firms to WL, NWL-PUB, and NWL-PVT

Step	Data source	Operational rule (what we observe)	Assigned group
1	WL registry (Prefectures)	Firm is enrolled in the WL (within the sectors covered by the regulation)	WL
2	ANAC procurement records	Among non-enrolled firms: firm is observed in ANAC procurement data with all public contracts below €150,000	NWL-PUB
3	Residual category	Among non-enrolled firms: firm is never observed in ANAC procurement data	NWL-PVT

to informal governance arrangements. Our empirical analysis tests whether these differential alignments correlate with systematic differences in firm-level productivity.

Although conventional wisdom would suggest that WL firms should benefit from formal compliance through increased transparency and reduced uncertainty, in contexts of weak enforcement, it is also theoretically plausible that non-certified firms, especially those strategically avoiding certification, may exploit regulatory flexibility or informal governance mechanisms, potentially leading to higher productivity. The direction of this effect, however, remains ultimately an empirical question.

We posit two channels through which alignment affects productivity:

(C1) Protection/coordination (informal governance). In high-Mafia areas, NWL firms may access extra-legal enforcement/protection and coordination devices that reduce frictions and stabilize transactions.
(C2) Strategic opacity/flexibility. Avoiding WL can preserve operational opacity and flexibility (e.g., employment practices, financing patterns), yielding short-run efficiency gains under weak enforcement.

Importantly, because productivity is estimated from accounting-based revenue and observed inputs, the "opacity/flexibility" channel may reflect both genuine operational efficiency and mechanisms that affect measured outcomes (e.g., margins, contracting frictions, and reporting practices, potentially including opportunistic responses to enforcement). With the available data, these components cannot be separately identified; therefore, our results should be interpreted as differences in measured productivity rather than unequivocal evidence of superior underlying efficiency.

We capture institutional context using (i) a province-level index of Mafia intensity and (ii) firm-level certification status (WL vs. NWL, with NWL-PUB and NWL-PVT distinguished as in Sect. 2.1). After estimating firm-level TFP (Sect. 4), we compare productivity systematically across these alignment groups and examine whether the observed gaps vary with local Mafia intensity. Mechanism (C1) is assessed by stratifying or interacting alignment categories with an index of Mafia presence at provincial level, while (C2) is explored through firm-level financial diagnostics (e.g., liquidity, leverage, personnel expenses per employee). We report associations consistent with this framework rather than causal effects.

Figure 1 summarizes the conceptual framework underpinning our analysis. The upper part illustrates the institutional environment in Southern Italy, where limited state capacity and the presence of informal governance structures, sometimes linked to criminal networks, coexist with formal regulatory mechanisms such as the WL certification.

In this setting, firms adopt different institutional strategies. WL-certified firms are formally aligned with anti-Mafia compliance mechanisms and fulfill all regulatory obligations, including those required for public procurement. Non-certified firms (NWL) do not hold such certification. Among them, NWL-PUB firms, those participating in public procurement below the regulatory threshold, stand out because they could, in principle, benefit from certification but choose not to. This decision may reflect perceived costs, the advantages of regulatory flexibility, or, in some cases, alignment with informal arrangements. NWL-PVT firms are not observed in administrative procurement records and can be reasonably characterized as operating predominantly in private markets, with potentially weaker incentives to certify.

These differences in institutional positioning may influence firm performance. WL firms operate within the formal legal framework and demonstrate compliance with institutional requirements. NWL-PUB firms, by contrast, might benefit from operating outside this framework, enjoying greater flexibility, reduced oversight, or alternative coordination mechanisms, especially in contexts of weak state enforcement. The role of NWL-PVT firms remains primarily descriptive in our framework, as their productivity may reflect heterogeneous structural conditions rather than institutional alignment.

These theoretical considerations lead us to formulate context-dependent expectations about productivity patterns, which we examine empirically.

In particular, we analyze how firm-level productivity varies across WL and NWL firms, and whether these differences are systematically associated with the institutional environment. We expect that in regions with stronger state capacity and lower criminal presence, WL firms may exhibit higher productivity, as certification potentially reflects greater legitimacy, improved access to public procurement, and more stable relations with regulatory authorities. Conversely, in areas characterized by high-Mafia infiltration, certified WL firms, presumably non-collusive, may be more exposed to negative externalities stemming from criminal activity, such as extortion or protection rackets, which may erode operational efficiency and lower observed productivity.

The same reasoning applies in reverse to NWL-PUB firms. In institutional environments with effective legal enforcement, the absence of certification may be associated with reputational or contractual disadvantages, potentially leading to lower productivity. In contrast, in Mafia-dominated contexts, NWL-PUB firms may benefit from strategic opacity or informal protections, allowing them to avoid compliance costs and access illicit or collusive advantages. As a result, their productivity could appear comparatively higher. In this framework, the direction of productivity differences across certification status is expected to depend on the broader institutional context in which firms are embedded.

These context-dependent expectations are tested empirically in the next sections.

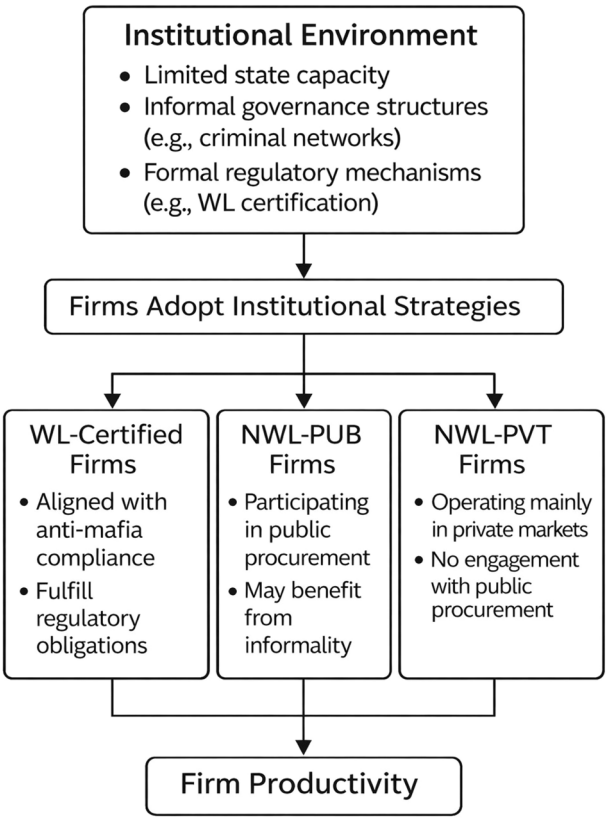

Fig. 1 Conceptual framework: how institutional context shapes firm behavior and productivity

3 Historical roots of territorial Mafia presence in Sicily

The Sicilian Mafia emerged in the second half of the nineteenth century in a context characterized by weak state capacity, insecure property rights, limited trust in formal institutions, and a growing demand for private protection. In this environment, Mafia-type organizations progressively acquired a governance role, providing enforcement, protection, and access to local networks where formal legal institutions were weak or not fully credible. This interpretation is consistent with the classic view of the Mafia as an industry supplying private protection (Gambetta 1992), as well as with economic accounts emphasizing the role of local shocks, weak formal institutions, and heterogeneous demand for protection across Sicilian territories (Bandiera 2003; Buonanno et al. 2015; Dimico et al. 2017; Acemoglu et al. 2020).

A central feature of this process is that Mafia presence did not develop uniformly across Sicily. Historical evidence indicates that the phenomenon took root with different intensity across provinces. Drawing on historical evidence from Cutrera (1900) and comparing it with a contemporary synthetic index of Mafia presence,

Mocetti and Rizzica (2021) emphasize three facts that are directly relevant for our setting: Mafia presence was largely absent before the nineteenth century; it emerged unevenly across Sicilian provinces; and it displays substantial persistence over time, with the provinces most exposed today broadly corresponding to those already more exposed a century ago.[5] This persistence suggests that local Mafia intensity can be interpreted as a structural component of the institutional environment in which firms operate.

Over time, Mafia organizations adapted to changes in the economic and political environment. While their origins were closely connected to rural protection markets and local coercion, their activities progressively expanded into legal markets and sectors exposed to public regulation, public spending, and public procurement. This evolution is central to our empirical setting. The White List system was introduced precisely to reduce the risk of Mafia infiltration in sectors considered vulnerable to criminal influence. The relevant historical background is therefore not simply that the Mafia has long been present in Sicily, but that Mafia presence has been territorially heterogeneous, persistent, and to legal economic activities and public procurement.

This territorial persistence provides the link between the historical background and the institutional setting analyzed in the paper. Since Mafia presence has not been spatially uniform within Sicily, province-level variation in Mafia intensity provides a useful way to characterize the local environments in which firms operate. In the empirical analysis, we capture this territorial dimension using the Index of Mafia Presence (IMP), which distinguishes areas with relatively lower Mafia intensity from areas where Mafia-type organizations have historically been more deeply rooted. In this sense, Mafia intensity should be understood not merely as a contemporaneous measure of criminal activity, but as a historically sedimented feature of Sicily's local institutional landscape.

4 Empirical setting and strategy

This section presents the empirical framework used to investigate whether firms' alignment with formal institutions, proxied by WL certification, is associated with differences in productivity. We begin by describing the regional context and the role of EU cohesion funding in Sicily, which provides a unique setting for this analysis. We then outline our data sources and the construction of the firm-level panel dataset, followed by the empirical strategy used to estimate TFP.

4.1 Regional context and EU cohesion funding in Sicily

Sicily constitutes a particularly relevant setting for our analysis. As a region historically targeted by EU Cohesion Policy, it has received substantial funding to foster

[5] The historical discussion is not used as an exogenous source of identification. Rather, it motivates the use of province-level variation in Mafia intensity as a relevant dimension of the institutional environment faced by firms.

economic development and reduce territorial disparities. However, the coexistence of structural weaknesses (such as high unemployment, an underdeveloped industrial base) and persistent Mafia infiltration has hindered the effectiveness of these investments. This institutional environment provides fertile ground to study how formal policy instruments interact with informal governance structures in shaping firm behavior and productivity outcomes.

The European regional policy is a major international initiative to reduce disparities among less developed areas. To meet the EU Cohesion Funds' goals, Italy has received significant financial resources and implemented complementary national measures. These include funding through the Rotation Fund (Law 183/1987) and additional resources from the Development and Cohesion Fund, aimed at addressing economic and social imbalances.

Sicily has long faced significant challenges, worsened by Italy's economic globalization.

Recognized as a "less favored" region since 1975, it has been a major recipient of EU Structural Funds (Cirelli et al. 2007). Post-war policies aimed at boosting investment, along with the development of sectors like tourism and the presence of large industrial plants, have failed to create self-sustaining growth. Despite some small business dynamism, overall progress remains disappointing. The entrepreneurial fabric remains underdeveloped, further exacerbated by the presence of organized crime. The unemployment rate is among the highest in Italy (16.88% according to Istat data for 2023), and the underground economy remains a significant issue. The Sicilian industrial sector is weak and fragmented, with a lower percentage of employees compared to the national average; Sicily's per capita GDP stands at 17,068 euros, significantly below the 30,600 euros recorded in Lombardy. These challenges were seen not only as a significant threat to Italy's economic stability but also as a concern for the trajectory of European integration.

Structural policies, financed with European resources, have had a marginal impact on the production structure, preferring instead a "diffusive" strategy of income and expenditure effects, aimed at gaining and managing consensus rather than radically transforming the socio-economic regional context. Table 2 shows a significant increase in total funding and cohesion funds from the European Union during the period 2014–2020 compared to the previous period (2007–2013), indicating a greater commitment to addressing economic and social disparities among European regions.

Criminal organizations are attracted to regions with significant public funding, such as those from the European Union. They exploit these opportunities to infiltrate decision-making, secure contracts, launder money, and control resources. By leveraging corruption and clientelism, they access funds and influence politics. Therefore, Sicily serves as a crucial case for studying the interaction between Mafia presence and economic factors, and for developing strategies to reduce the negative impact on growth and social development.

4.2 Data sources

To carry out our empirical analysis, we construct a firm-level panel dataset covering Sicilian companies that received EU cohesion funding. In particular, we collect yearly data on all Sicilian firms that have received funding from cohesion policies during the 2007–2013 and 2014–2020 programming periods. The main source of data was OpenCoesione, the open government initiative on EU regional and cohesion policy in Italy managed by the Department for Cohesion Policy at the Italian Prime Minister's Office.[6] The portal provides access to detailed information on projects co-funded by EU structural and cohesion funds, including individual data on the sources of financing, thematic areas, implementing authorities, beneficiaries, start, end and payment dates. Firms enter our data through channels governed by explicit eligibility rules, selection procedures, and ex-post conditionality, rather than automatic transfers. This includes business-support measures and State-aid schemes (access based on call-specific admissibility and selection), public procurement financed by Cohesion funds (where firms enter as contractors selected through procurement procedures and payments are conditional on verified performance), and financial instruments (where firm-level support follows the operational rules of the instrument). In all cases, access is project-specific and time-limited, and does not provide firms with a stable or recurring entitlement to public resources. At the point of data extraction, OpenCoesione covered 102,935 projects funded by national and EU resources to a total of €63 billion, including EU and national resources.[7]

After selecting the companies recorded in OpenCoesione, we proceeded to evaluate TFP by integrating financial statement data sourced from Bureau Van Dijk's AIDA database.

This entailed gathering financial statement information from Sicilian companies spanning the years 2013 to 2021. We selected firms belonging to business sectors at the highest risk of Mafia infiltration (i.e., firms potentially eligible for the provincial WL), recorded in the AIDA database, and active between 2013 and 2021. To operationalize firms' institutional alignment and procurement exposure, we merge two additional administrative sources. First, we use Prefectures' WL registries to identify firms enrolled in the WL certification system within WL-eligible sectors.[8] Second, we use ANAC administrative procurement records, where each procurement procedure is identified by a unique code (CIG) and includes the awarded contract value.[9] These sources allow us to distinguish non-enrolled firms observed

[6] OpenCoesione is a monitoring and transparency system that records the implementation of Cohesion-funded operations and links each project to the relevant actors and financial flows; it does not identify firms with guaranteed or automatic access to subsidies.

[7] Data were extracted in December 2022.

[8] Prefectures' WL registers record only successful enrolments; information on applications, rejections, or processing outcomes is not available. Hence, non-WL firms may include both firms that did not apply and firms whose applications were not successful.

[9] It is important to clarify that OpenCoesione project values and ANAC procurement values refer to different units of observation. In OpenCoesione, the project value refers to the overall financial envelope of a monitored intervention, which may involve multiple beneficiaries, implementing bodies, contractors,

Table 2 Comparison of projects and funding monitored

	2007–2013	2014–2020
Projects	48,701	51,245
Funding	18.7	43.7
of which Cohesion funds	14.4	31.8
Payments	12.2	16.4
of which Cohesion funds	11.1	15.4

Monetary values are in billions of euros

Source: Authors' elaboration on OpenCoesione data

in below-threshold public procurement (NWL-PUB) from non-enrolled firms not observed in ANAC procurement records (NWL-PVT), consistently with the assignment algorithm summarized in Table 1 (Sect. 2.1). The final dataset comprises 17,778 firms.

Table 3 reports descriptive statistics on below-threshold procurement activity based on ANAC data, focusing on NWL-PUB firms and on the subset of WL firms observed in ANAC procurement records. The table reports the distribution of firms' average awarded values for contracts below the €150,000 threshold and the number of distinct CIG procedures per firm. This evidence documents the mechanical link between the NWL-PUB classification and below-threshold procurement activity, while also providing transparency on the scale of observed contracts.

WL firms observed in ANAC and NWL-PUB firms appear broadly comparable in terms of the scale of below-threshold procurement activity. In particular, both groups display similar average and median contract values and a comparable number of procedures per firm. This suggests that the distinction between the two groups is not mechanically driven by large differences in the observed size of below-threshold contracts.

Additional descriptive evidence on the procurement exposure of NWL-PUB firms is reported in Appendix 1.1. The evidence indicates that near-threshold procurement behavior exists but appears quantitatively limited: only 3.42% of NWL-PUB firm-year observations have an average CIG value in the €140,000–149,999 range, and only 8.74% of NWL-PUB firms have at least one firm-year above the €140,000 threshold. This suggests that the NWL-PUB category is not mainly driven by firms systematically clustering just below the statutory threshold.

To further characterize the groups used in the production function estimation, Table 9 in Appendix 1 reports descriptive statistics for key firm observables by firm type. The table makes differences in size, inputs, and balance-sheet indicators transparent and helps interpret the subsequent productivity comparisons. Overall, Table 9

Footnote 9 (Continued)

or procurement procedures. By contrast, in ANAC, the CIG value refers to the amount awarded within a specific procurement procedure. Therefore, the average value of OpenCoesione projects should not be mechanically compared with the €150,000 anti-Mafia threshold, which applies to firm-level procurement procedures. In the empirical analysis, procurement exposure is measured using ANAC CIG-level information, while OpenCoesione is used to identify firms associated with cohesion-policy interventions.

indicates that WL and NWL-PUB firms are broadly comparable along core observables used in the empirical analysis, such as turnover and input proxies, while both groups appear systematically larger and older than NWL-PVT firms. This profiling exercise suggests that the NWL-PUB–WL contrast is not mechanically driven by large differences in basic firm size or input levels, whereas NWL-PVT firms exhibit a distinct profile consistent with structural disadvantages. At the same time, these descriptive statistics do not eliminate selection concerns. WL status may still reflect unobserved factors such as managerial capacity, risk preferences, relational networks, expected access to above-threshold contracts, or different exposure to formal and informal governance. For this reason, we further address observable procurement comparability in Sect. 5.5, where we match WL firms observed in ANAC with NWL-PUB firms on procurement scale and other observable characteristics.

4.3 Empirical strategy

A key challenge in this empirical analysis is to obtain reliable estimates of TFP at the firm level. We estimate a Cobb–Douglas production function with three inputs (labor, materials, and capital) using the semi-parametric approach of Levinsohn and Petrin (2003), which addresses simultaneity and selection biases. This method uses intermediate inputs as proxies for unobserved productivity shocks and corrects for the endogeneity of input choices.

We estimate the following Cobb–Douglas production function in log form:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + \varepsilon_{it} \tag{1}$$

Output y_{it} is produced by a combination of three inputs: labor l_{it}, materials m_{it}, and capital k_{it}. β_0 is the mean efficiency level across firms and over time, and ε_{it} is the time and producer specific deviation from that mean. The last component can then be further decomposed into observable (v_{it}) and unobservable (u_{it}) components. We can rewrite Eq. (1) as follows:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + v_{it} + u_{it}, \tag{2}$$

where $\omega_{it} = \beta_0 + v_{it}$ represents firm-level productivity. Then, estimated productivity can be calculated as

$$\hat{\omega}_{it} = \hat{\beta}_0 + \hat{v}_{it} = y_{it} - \hat{\beta}_k k_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_m m_{it} \tag{3}$$

The productivity measure resulting from Eq. (3) can be used to evaluate the influence and impact of various variables directly at the firm level; the TFP in levels is the exponential of $\hat{\omega}_{it}$.[10]

The dependent variable in the analysis is *Output*, defined as the firm's turnover. The production function includes inputs for *Labor* (measured as the monetary cost per employee), *Capital* (total fixed tangible assets), and *Materials* (including raw materials, consumables, services, and other goods). All monetary variables

[10] Estimation is conducted in Stata 18 using the prodest package (Rovigatti and Mollisi 2018).

Table 3 Public procurement activity below the €150,000 threshold

Firm group	Firms	Mean (€)	Median (€)	Min (€)	Max (€)	Mean no. of contracts	Median no. of contracts
WL	981	86,068	84,834	9720	149,742	5.97	3
NWL-PUB	1315	78,272	76,489	4288	149,939	5.12	2

The table reports firm-level descriptive statistics based on ANAC public procurement data. Contract values refer to the firm-level average awarded value across procurement procedures below the statutory threshold. The number of contracts corresponds to the total number of below-threshold procedures (CIG) observed for each firm

are deflated using three-digit producer price indices from Istat, making them real values.[11]

Because output is proxied by turnover, the productivity measure used in the empirical analysis is revenue-based rather than quantity-based. This distinction is important for the interpretation of the results. The estimated TFP residual may capture not only differences in technological or organizational efficiency, but also price–cost margins, demand-side conditions, market power, and reporting-related differences in revenues or inputs. This issue is particularly relevant in settings where competition and reporting behavior may be affected by informal governance or uneven enforcement. Therefore, throughout the paper, we interpret TFP differences as differences in measured revenue-based productivity, rather than as direct evidence of superior physical or technological efficiency.

A further limitation concerns the proxy assumption underlying the Levinsohn–Petrin estimator. The method relies on intermediate inputs as a proxy for unobserved productivity shocks, which requires intermediate inputs to be measured reliably and to respond monotonically to productivity. In our setting, this assumption may be problematic if firms operating through informal arrangements misreport, inflate, or otherwise manipulate intermediate input costs. Such measurement error could affect the estimated TFP residual and may be systematically correlated with certification status, especially for NWL-PUB firms. For this reason, our estimates should be interpreted as accounting-based measures of revenue productivity rather than as direct measures of physical efficiency. We partially assess the sensitivity of the results to the choice of estimator by using the alternative Wooldridge control-function approach in the robustness section, while acknowledging that no estimator based on the same accounting data can fully eliminate this concern.

The right-hand side of the productivity equation includes several control variables: firm age (calculated as the difference between 2021 and the year of establishment), provincial fixed effects (to capture structural differences across

[11] We had the ATECO codes of Sicilian companies at the four-digit level and reclassified them to three digits to match the sectoral price indices provided by ISTAT. When a match was not possible, a general price index was used.

Sicilian areas), year dummies (to control for trends and seasonality), and sector fixed effects.[12]

In addition, we control for the logarithm of total assets as a proxy for firm size, given that larger firms may display different productivity patterns due to scale economies or greater resource access. Following the literature (Anderson and Raissi 2018; Ganau and Rodríguez-Pose 2018), we also include financial indicators such as the cash-to-assets ratio (liquidity), tangible-to-assets ratio (capital intensity), debt-to-assets ratio (leverage), return on assets (ROA, profitability), and EBITDA (operational performance). The inclusion of these financial variables aligns with established empirical practices in productivity and firm performance research.[13]

5 Results

5.1 General results

The findings in Table 4 indicate comparable materials productivity across groups, with a notably high capital coefficient for NWL-PUB firms and significant labor productivity for certified firms.

We calculated firm-level TFP as the residual of the production function estimates. We then computed the average TFP for each group and plotted its year-by-year trends in Fig. 2.

A notable pattern emerges: on average, NWL-PUB firms exhibit the highest measured revenue-based TFP, exceeding WL firms by approximately 20% and reaching nearly 30% higher than the productivity level observed in NWL-PVT firms. TFP remains relatively stable over time across all groups.

A further issue concerns the imbalance in group size. As shown in Table 4, the NWL-PVT group accounts for a much larger number of firm-year observations than the WL and NWL-PUB groups. This reflects the construction of the categories: NWL-PVT is a broad residual group of non-certified firms not observed in ANAC procurement records, whereas WL and NWL-PUB firms are more directly connected to the institutional setting analyzed in this paper. Table 9 in Appendix 1 also shows that NWL-PVT firms are structurally different from the other two groups, being on average smaller and younger. For this reason, we do not interpret NWL-PVT as a close counterfactual for WL firms. Rather, it is retained as a descriptive benchmark for non-certified firms outside observed public procurement. The central comparison for our interpretation is the contrast between WL and NWL-PUB firms.

To verify that the large size of the NWL-PVT group does not mechanically drive the estimated differences or the precision of the estimates, we also estimate a size-balanced specification in which the NWL-PVT group is randomly restricted to a

[12] Sector fixed effects are defined using a policy-relevant classification of WL-eligible activity groups (as per Law 190/2012 and subsequent amendments), which aggregates firms into ten mutually exclusive categories based on their institutional exposure to infiltration risk.

[13] Definitions and data sources for all variables used in the empirical analysis are reported in Table 8 in Appendix 1.

subsample equal in size to the WL group, while retaining all WL and NWL-PUB firms. The results, reported in Table 26 in Appendix 7, confirm that the NWL-PUB premium remains positive and statistically significant. In the restricted comparison sample, the NWL-PUB–WL difference is 0.042 log points (s.e. = 0.011; $p < 0.001$), while the NWL-PVT–WL difference becomes economically negligible and statistically insignificant. Standard errors are clustered at the firm level throughout, so inference accounts for within-firm serial correlation rather than treating firm-year observations as independent.

Consistent with the measurement discussion in Sect. 4.3, this premium should not be interpreted as unequivocal evidence of superior technological efficiency. It may reflect a combination of lower compliance or administrative burdens, higher margins arising from reduced competition or informal market power, and reporting-related differences associated with opacity. With the available data, which do not include firm-level prices, physical quantities, or direct markup measures, these components cannot be separately identified.

One potential concern is that our results may suffer from self-selection bias if firms that choose to register in the WL differ systematically from others in terms of pre-existing productivity. To address this, we compute TFP for a subsample of firms with data available from 2004.[14] This allows us to compare productivity levels across groups before the introduction of the WL system in 2012.

Table 5 (in the main text) and Fig. 3 (in Appendix 2) present production function estimates for the 2004–2021 period across the three firm groups: NWL-PVT, NWL-PUB, and WL. The estimated coefficients are stable across groups and over time, indicating comparable input–output relationships regardless of compliance status. These results suggest that WL enrollment is unlikely to be systematically related to differences in production technology or efficiency. The absence of diverging pre-trends reinforces the plausibility of our identification strategy.

To further address concerns about potential pre-existing differences across firms, we extend the pre-trend analysis to both key production inputs and the main outcome variable. Specifically, we estimate event-study specifications for log employment, log capital, and TFP, normalizing the year immediately preceding WL entry as the reference period and focusing on the pre-entry window. Firm and year fixed effects are included, and standard errors are clustered at the firm level. Figures 4, 5, and 6 in Appendix 2 plot the estimated pre-entry coefficients, while Table 13 reports the corresponding lags and formal joint tests of statistical significance. The estimated coefficients are statistically indistinguishable from zero and do not display systematic pre-entry divergence. This evidence indicates that firms entering the WL do not exhibit differential pre-entry trends in employment, capital, or productivity, but it does not rule out persistent level differences or selection on unobservable firm characteristics.

Although our analysis is intentionally framed in terms of associations rather than causal effects, we further examine the temporal relationship between WL certification and firm productivity using a set of difference-in-differences and event-study specifications. These additional analyses, reported in Appendix 3, account for

[14] We have data for 7395 firms, that is about 42% of our sample.

Table 4 Production function estimates

	NWL-PVT	NWL-PUB	WL
Labor	0.195***	0.220***	0.246***
	(0.0044)	(0.0079)	(0.0028)
Capital	0.293***	0.303***	0.243***
	(0.0010)	(0.0016)	(0.0015)
Materials	0.738***	0.711***	0.758***
	(0.0010)	(0.0009)	(0.0012)
Observations	64,853	8515	8753

All regressions include firm age, firm size, liquidity, capital intensity, leverage, return on assets, as well as calendar year dummies, province fixed effects, and sector fixed effects

Statistical significance is denoted as follows: $*p<0.1$, $**p<0.05$, $***p<0.01$

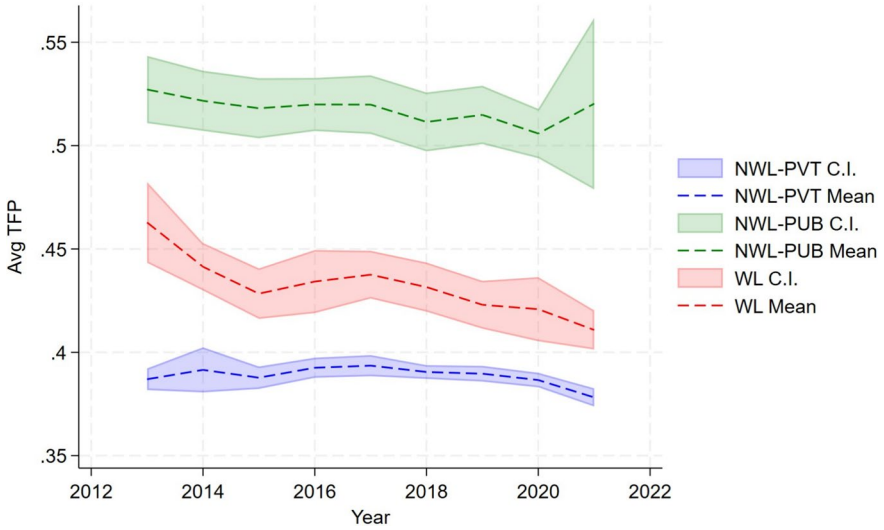

Fig. 2 TFP of WL, NWL-PUB, and NWL-PVT firms, overall

time-invariant firm heterogeneity and allow productivity dynamics to vary around both the institutional introduction of the WL and the timing of firm enrollment. Across specifications, we find no evidence of discrete productivity changes associated with WL certification, supporting its interpretation as a signal of institutional alignment rather than as a productivity-enhancing intervention.

5.2 Financial indicators and institutional asymmetries

The decision of NWL-PUB firms to limit themselves to public contracts below the €150,000 threshold, thereby avoiding certification scrutiny, combined with their

Table 5 Production function estimates 2004–2021

	NWL-PVT	NWL-PUB	WL
Labor	0.171***	0.122***	0.138***
	(0.0060)	(0.0124)	(0.0059)
Capital	0.223***	0.004***	0.026***
	(0.0018)	(0.0006)	(0.0013)
Materials	0.802***	0.888***	0.940***
	(0.0017)	(0.0044)	(0.0023)
Observations	49,557	9239	9064

All regressions include firm age, firm size, liquidity, capital intensity, leverage, return on assets, as well as calendar year dummies, province fixed effects, and sector fixed effects

Statistical significance is denoted as follows: $*p<0.1$, $**p<0.05$, $***p<0.01$

unexpectedly high productivity, raises concerns about their potential exposure to Mafia infiltration. These firms may benefit from Mafia-related externalities, such as reduced costs, lower compliance burdens, or minimal oversight, ultimately gaining a competitive edge through informal arrangements. To explore whether NWL-PUB firms exhibit traits indicative of Mafia influence, we draw on insights from the financial literature, which identifies red flags based on liquidity, financing structure, and labor cost behavior (Ravenda et al. 2015). Specifically, we consider six diagnostic indicators that capture firm-level characteristics commonly associated with Mafia-infiltrated enterprises.[15]

To connect the descriptive evidence in this section to the conceptual framework, we explicitly relate the accounting-based indicators to the two channels in Fig. 1. Indicators capturing short-term liquidity and working-capital conditions (e.g., CRatio and CaTa), together with proxies for credit and reliance on formal bank finance (e.g., RecTa and LevBank), are most naturally consistent with Channel 1 (protection/coordination), insofar as informal governance may mitigate payment risk and contractual frictions and, in turn, affect firms' short-term financing and liquidity profiles. By contrast, indicators more directly related to operational opacity and flexibility in input use and reporting (e.g., InvTa and PersEmpl) are more naturally aligned with Channel 2 (opacity/flexibility), as they may reflect greater discretion in inventory management and labor arrangements in settings with weaker enforcement. We stress that these links are interpretative: the indicators are presented as descriptive patterns consistent with the channels in Fig. 1, not as causal tests of mechanisms.

First, we focus on liquidity (Channel 1; Fig. 1). The current ratio (CRatio), defined as current assets over current liabilities, reflects a firm's ability to meet short-term obligations. An unusually high value may signal financial flexibility that facilitates informal or illicit transactions. Similarly, the assets to total assets ratio (CaTa) measures the proportion of liquid resources within a firm's asset base. A

[15] Table 17 in Appendix 4 provides a summary of the indices used.

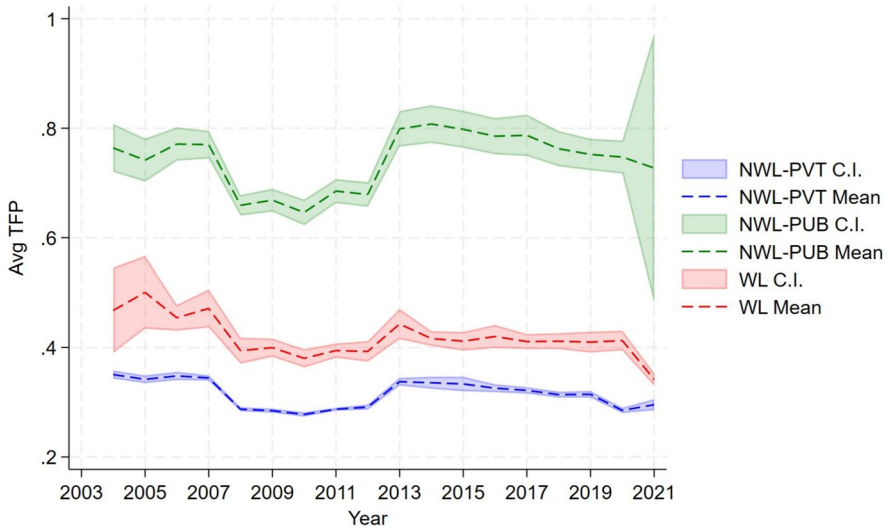

Fig. 3 Average TFP of firms from 2004

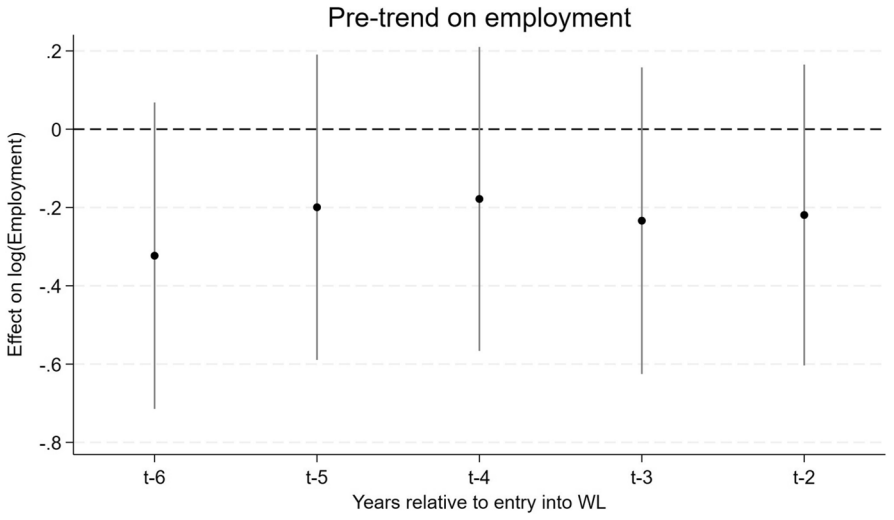

Fig. 4 Pre-entry trends in employment

high value here may indicate a strategic preference for holding easily movable or concealable assets.

Second, we examine credit and debt behavior (Channel 1; Fig. 1). The receivables to total assets ratio (RecTa) captures the extent to which firms rely on credit-based transactions, which may be harder to monitor and trace. The bank debt to total assets ratio (LevBank) captures a distinct dimension of financing behavior, namely firms' reliance on formal bank credit. Lower values of LevBank may indicate limited

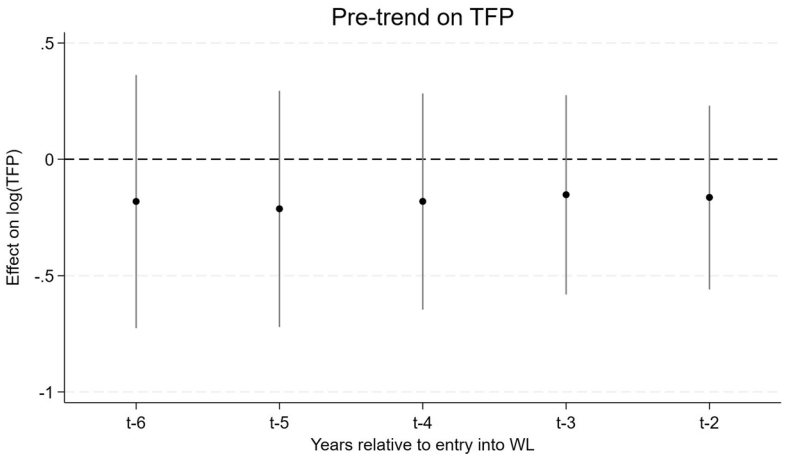

Fig. 5 Pre-entry trends in capital

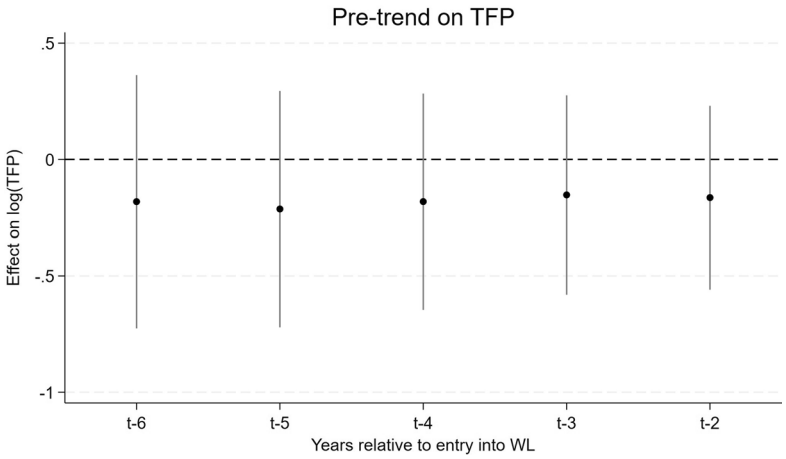

Fig. 6 Pre-entry trends in TFP. Note. Firm and year fixed effects included. Standard errors clustered at the firm level. The omitted category is the year immediately preceding WL entry ($t-1$). Vertical bars denote 95% confidence intervals

dependence on formal credit markets and, potentially, access to alternative or informal sources of financing.

Third, we consider operational indicators (Channel 2; Fig. 1). The inventory to total assets ratio (InvTa) reflects investment in physical stock. Lower values may suggest efforts to minimize exposure to scrutiny or seizure. Lastly, we include the personnel expenses per employee (PersEmpl), which can signal the use of informal labor or underreporting of wages when abnormally low.

Taken together, these indicators provide a descriptive picture of accounting and financial differences across institutional groups. The results, summarized in Table 6,

Table 6 Indices

	CRatio	CaTa	RecTa	LevBank	InvTa	PersEmpl
NWL-PVT	1.808	0.722	0.002	– 0.496	– 2.392	5.468
WL	1.705	0.745	0.002	– 0.463	– 2.172	4.850
NWL-PUB	1.854	0.764	0.003	– 0.525	– 2.559	4.681

show that NWL-PUB firms display higher liquidity, lower leverage, and lower personnel expenses per employee relative to WL firms. These patterns are consistent with financial traits highlighted in the literature on Mafia-influenced firms, but they may also reflect leaner organizational structures, lower administrative overhead, and weaker exposure to formal compliance burdens among firms that remain outside the WL system. We therefore interpret these indicators as descriptive evidence of broader institutional asymmetries, rather than as direct evidence of Mafia influence.

5.3 Territorial heterogeneity and institutional interpretation

In the baseline heterogeneity analysis, firms are matched to provincial Mafia intensity using the province of their legal headquarters, as reported in AIDA. The IMP variable should therefore be interpreted as capturing the institutional environment associated with the firm's registered location. This choice is institutionally meaningful because WL enrollment is administered by the Prefecture of the province where the firm is legally headquartered. The headquarters province is therefore the relevant jurisdiction for the certification process and for the firm's formal institutional alignment. Accordingly, the territorial heterogeneity analysis should be read as an analysis of headquarters-based institutional exposure, not as a reconstruction of the complete geography of each firm's sales or contracts.

Building on our findings, we further investigate whether TFP patterns hold across different Sicilian provinces. Mafia influence is not uniform across the region, with some areas exhibiting significantly lower levels of infiltration. Using the Transcrime Index of Mafia Presence (IMP),[16] we classify Messina, Ragusa, and Siracusa as low-infiltration provinces, while grouping the rest of Sicily as high-infiltration areas.[17]

To assess how this variation affects productivity, we estimate firm-level TFP across the two regional clusters. The results show that in provinces with lower IMP scores, WL-certified firms exhibit higher TFP than their non-certified counterparts,[17] consistent with the intuition that Mafia infiltration is associated with lower efficiency among WL firms.

Conversely, NWL-PUB firms exhibit lower TFP in low-infiltration provinces, suggesting that their competitive advantage depends on context. In the absence of

[16] See the 2015 Transcrime report on Mafia, available online at https://www.transcrime.it/wp-content/uploads/2014/02/PON-Gli_investimenti_delle_mafie_ridotto.pdf [17]See Fig. 8 in Appendix 5.

[17] See Table 18 and Figs. 9 and 10 in Appendix 6.

Mafia-related distortions, they may face stronger competition and greater regulatory scrutiny, which could limit their productivity.

Finally, NWL-PVT firms display relatively stable productivity across both regional clusters, suggesting that their performance is less affected by Mafia presence.

Among the three firm categories, WL-certified firms appear to be the most vulnerable to Mafia-related distortions. In high-Mafia provinces, these firms likely face extortion, coercion, and bureaucratic hurdles that divert resources from productive activities. In low-Mafia areas, by contrast, they tend to be more productive, suggesting that their disadvantages are not intrinsic but stem from the distorted institutional environment. We also verified that our qualitative conclusions are not driven by the specific choice of the IMP cutoff.[18]

Given that our baseline findings are framed in terms of discrete institutional environments, we also estimate an auxiliary specification using the continuous-IMP index to assess whether productivity gaps vary smoothly with Mafia presence or instead emerge primarily across distinct institutional regimes. To maintain comparability with the baseline analysis, we rely on a pooled-technology measure of TFP and interact the continuous-IMP index with firm-type indicators (NWL-PVT and NWL-PUB, with WL as the omitted category), controlling for the same set of firm-level covariates, year fixed effects, and sector fixed effects. The results, reported in Table 19 in Appendix 6, show that both NWL-PVT and NWL-PUB firms exhibit higher pooled TFP relative to WL firms, while the interaction terms between firm type and continuous IMP are negative but not precisely estimated. The continuous-IMP specification provides an important qualification to the cutoff-based heterogeneity analysis. Although NWL-PVT and NWL-PUB firms display higher pooled TFP than WL firms on average, the interaction terms between firm type and the continuous-IMP index are negative but statistically indistinguishable from zero. Therefore, the data do not support the interpretation that the NWL-PUB productivity advantage increases smoothly or monotonically with Mafia intensity. The binary high-/low-IMP comparison should instead be interpreted as descriptive evidence of differences across broad institutional environments. A further concern is that the Transcrime IMP index is time-invariant and therefore cannot capture year-to-year variation in Mafia-related enforcement or judicial activity during the 2013–2021 period. We therefore interpret IMP as a structural measure of territorial exposure to Mafia presence, rather than as a time-varying measure of contemporaneous enforcement intensity. To complement this province-level measure, we construct a more granular local proxy of Mafia-related institutional exposure based on municipalities dissolved for Mafia infiltration. Specifically, we compute the distance between each firm's legal headquarters and the nearest dissolved municipality and define an indicator equal to one for firms located within 10 km of such a municipality. This measure does not replace the IMP index. Municipal dissolutions capture both Mafia infiltration and the institutional capacity to detect and sanction it; hence, they are not

[18] Robustness checks using alternative cutoffs of the IMP distribution (varying the number of provinces classified as low- versus high-infiltration around the baseline split) yield the same qualitative ranking across firm types; results are available upon request.

a pure measure of Mafia intensity. However, they provide a useful local proxy for Mafia-related institutional disruption. The results, reported in Table 20 in Appendix 6, show that the NWL-PUB productivity premium relative to WL firms is positive and statistically significant both outside and inside the 10 km radius, but it is substantially larger for firms located within 10 km of a dissolved municipality. The estimated NWL-PUB–WL gap increases from 0.048 log points outside the radius to 0.089 log points within the radius. The difference between the two gaps is 0.041 log points and is statistically significant at the 5% level. This evidence is consistent with the interpretation that the productivity gap between NWL-PUB and WL firms is more pronounced in areas more directly exposed to Mafia-related institutional disruption.

These patterns underscore how organized crime may function as an informal governance structure that substitutes for the state in contexts of weak enforcement. As Helmke and Levitsky (2012) and North (1990) emphasize, informal institutions emerge and persist when formal rules are ineffective or lack credibility. In such settings, Mafia organizations offer alternative enforcement, protection, and credit arrangements, often backed by coercion and reputation, thereby reshaping the incentives faced by firms.

From this perspective, the lower productivity of certified firms reflects not inefficiency but the costs of operating within formal constraints in an environment where informal systems dominate. Certification becomes less a mark of quality and more a source of exposure. Meanwhile, firms embedded in informal networks may thrive, not because they are more efficient, but because they are better adapted to a dual institutional order that penalizes formal compliance.

5.4 Robustness checks

To assess the robustness and consistency of our results, we implemented a series of additional empirical tests aimed at addressing potential sources of bias and heterogeneity.

First, we investigated whether the productivity differences we observe might be driven by firms' exposure to repeated funding opportunities. Specifically, we distinguished between firms that were awarded a single EU-funded project and those that obtained multiple projects. The latter may display higher TFP not because of their exposure to organized crime or compliance decisions, but rather due to structural advantages such as greater managerial capacity, experience in navigating public procurement systems, or better access to financial and human capital. By comparing these two groups, we test whether our results are robust to firm-specific characteristics related to funding intensity and diversification.[19]

Second, we exploit the temporal variation across the two EU programming periods (2007–2013 and 2014–2020) to evaluate whether institutional reforms, changes in oversight mechanisms, or shifting policy priorities affected the relationship between funding, certification, and productivity. Given that the anti-Mafia

[19] See Tables 21 and 22 and Figs. 11 and 12 in Appendix 7.

certification system was introduced in 2012 and gradually strengthened in subsequent years, this comparison allows us to test whether the observed TFP patterns are specific to a particular regulatory context or persist across institutional phases.[20]

Third, we re-estimate the production function using the alternative control-function approach developed by Wooldridge (2009). This exercise assesses whether the qualitative ranking across firm types is specific to the Levinsohn–Petrin estimator. The results remain qualitatively unchanged. However, this robustness check should not be interpreted as fully resolving the possibility of accounting-based measurement error in intermediate inputs. If input costs are misreported or strategically manipulated, all productivity estimates based on balance-sheet data may be affected. The purpose of this exercise is therefore more limited: it verifies that the main pattern is not mechanically driven by one specific production function estimator.[21]

Fourth, we address the concern that the baseline sample of EU cohesion-fund recipients is not a random sample of Sicilian firms. Firms enter OpenCoesione through eligibility rules, selection procedures, procurement mechanisms, and ex-post conditionality. Hence, program administrators may screen firms differently across projects and institutional categories, and this selection process could in principle affect the observed comparison between WL, NWL-PUB, and NWL-PVT firms. To assess whether our results are driven by this sample restriction, we replicate the production function estimation on Sicilian firms that never received EU cohesion funds during the period under study.

The results are reported in Table 7. The qualitative pattern is consistent with the baseline evidence: non-certified firms observed in public procurement continue to display higher measured TFP than WL firms also outside the cohesion-fund recipient sample. This exercise does not eliminate all concerns about selection into WL certification or procurement participation, but it shows that the main ranking across firm types is not mechanically generated by the selection rules governing EU cohesion-fund participation.

Fifth, as an additional robustness check, we replicate our baseline specification using accounting-based performance measures as dependent variables. In particular, we consider EBITDA, as a measure of operating performance, and ROA, as a measure of profitability. The qualitative pattern mirrors the productivity results: differences across institutional groups are small in low-IMP provinces and become more pronounced in high-IMP provinces, where non-certified firms, especially NWL-PUB, tend to outperform WL firms.[22]

Sixth, since our main TFP measure is revenue-based, it may also capture price–cost margins rather than purely technological efficiency. To address this concern, we conduct an additional check using EBITDA over sales as an accounting proxy for operating margins. The results, reported in Appendix 7, do not support a simple markup-based explanation. Conditional on firm size, liquidity, capital intensity, leverage, ROA, firm age, year effects, province effects, and sector effects,

[20] See Tables 23 and 24, and Figs. 13 and 14 in Appendix 7.

[21] See Table 25 and Fig. 15 in Appendix 7.

[22] See Tables 27 and 28 in Appendix 7.

Table 7 Production function estimates for firms never funded by EU cohesion funds

	NWL-PVT	NWL-PUB	WL
Labor	0.156***	0.178***	0.193***
	(0.0010)	(0.0108)	(0.0040)
Capital	0.300***	0.259***	0.265***
	(0.0014)	(0.0021)	(0.0011)
Materials	0.744***	0.745***	0.761***
	(0.0006)	(0.0014)	(0.0006)
Observations	116,998	8498	7516

The table reports production function estimates for Sicilian firms that never received EU cohesion funds during the period under study. All regressions include firm age, firm size, liquidity, capital intensity, leverage, return on assets, calendar year dummies, province fixed effects, and sector fixed effects

Statistical significance: *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$

NWL-PUB firms display a lower EBITDA-to-sales ratio than WL firms. NWL-PVT firms also display lower operating margins than WL firms.

This result should not be interpreted as a structural estimate of markups, since EBITDA over sales cannot fully separate prices, costs, and reporting behavior. However, it weakens a simple price- or markup-only interpretation of the measured TFP premium, although it does not rule out revenue-side components more generally.

Taken together, these robustness checks show that the main qualitative ranking across institutional groups is not driven by repeated funding exposure, programming-period differences, the specific production function estimator, the restriction to cohesion-fund recipients, or the use of TFP rather than alternative accounting-based performance measures. At the same time, these exercises do not eliminate concerns about selection into WL certification, procurement participation, or accounting-based measurement. They therefore strengthen the credibility of the documented patterns while supporting a cautious interpretation: the NWL-PUB productivity premium should be read as a robust difference in measured revenue-based productivity, consistent with institutional asymmetries under weak enforcement, rather than as definitive evidence of superior technological efficiency or of a single Mafia-related mechanism.

5.5 Alternative explanations

The empirical evidence presented above shows that NWL-PUB firms display significantly higher levels of TFP compared to both WL-certified firms and non-certified firms operating mainly in private markets (NWL-PVT). While this pattern aligns with theoretical expectations about the economic distortions associated with organized crime, alternative, non-institutional explanations could also account for these findings. In this section, we explore some of the most plausible.

A first hypothesis is that the observed productivity premium may arise from the nature of engagement with the public sector itself, rather than from informal

advantages tied to regulatory evasion. Working with public administrations might provide firms with more stable demand, lower-risk exposure, and more predictable payment flows, especially in economically disadvantaged regions. These features could in turn promote capital reinvestment, smoother production cycles, and better long-term planning, thereby enhancing productivity. If this mechanism were driving the observed TFP differentials, then we would expect to find that all firms working with public entities, regardless of their certification status, tend to outperform their private-sector counterparts.

To test this hypothesis, we subdivide WL-certified firms into two groups: those that secured at least one public contract (WL-PUB) and those operating entirely in private markets (WL-PVT). We then estimate and compare the average TFP for these subgroups.[23] The results are instructive: while NWL-PUB firms still display the highest productivity, within the WL-certified group we find that WL-PVT firms are more productive than WL-PUB firms. This suggests that public sector engagement per se is not associated with higher efficiency; on the contrary, it may be negatively correlated with productivity when not accompanied by informal mechanisms that reduce regulatory or competitive pressure. These findings weaken the hypothesis that access to public procurement alone explains the productivity advantage of NWL-PUB firms.

A second possible explanation relates to firm size. It is well known that larger firms often benefit from economies of scale and scope, improved managerial capabilities, and better access to finance and technology. If NWL-PUB firms were disproportionately medium-sized relative to other groups, this structural feature could explain their higher productivity, independently of their exposure to Mafia-related dynamics.

To rule out this possibility, we rely on two complementary checks. First, in all previous estimates, we control for firm size. Second, we stratify the sample by size class to assess within-group differences, distinguishing between small firms (annual turnover below €7 million) and medium firms (€7–€40 million), in accordance with EU definitions.[24] We then re-estimate TFP separately within each category.[25]

The results show that within both size classes, NWL-PUB firms consistently exhibit the highest average productivity. Among small firms, TFP values generally range between 0.4 and 0.6, whereas medium firms display greater dispersion, with values spanning from 0.5 to over 3.5. Nonetheless, the group-level ranking remains stable: NWL-PUB firms outperform all others in both strata. This finding reinforces the interpretation that firm size alone cannot account for the observed productivity gap.

A third possible explanation is that WL and NWL-PUB firms may differ in their observable public procurement exposure. If certified firms systematically obtained larger or more frequent public contracts, while NWL-PUB firms operated only at the margin of public procurement, the estimated productivity gap could partly reflect differences in procurement scale rather than institutional alignment. To address

[23] See Table 30 and Fig. 17 in Appendix 8.

[24] Our dataset does not include firms above the €40 million threshold, which are classified as Large.

[25] See Table 31 and Figs. 18 and 19 in Appendix 8.

this concern, we restrict the comparison to firms observed in ANAC procurement records and match WL-certified firms appearing in ANAC with NWL-PUB firms. The propensity score is estimated using firm size, total awarded below-threshold contract value, the number of below-threshold CIG procedures, province, and sector. This exercise allows us to compare certified and non-certified firms with similar observable procurement scale and similar territorial-sectoral environments. Since NWL-PVT firms are not observed in ANAC procurement records, they are excluded from this matching exercise.

The matching diagnostics reported in Appendix 8 indicate a substantial improvement in comparability between WL-ANAC and NWL-PUB firms. The appendix also reports the propensity-score overlap before and after matching, together with the average measured TFP of the matched groups. As shown in Fig. 21, NWL-PUB firms continue to display higher measured TFP than comparable WL-ANAC firms even after matching on observable procurement exposure. This suggests that the baseline productivity gap is not mechanically driven by differences in observable procurement scale, although the exercise cannot rule out selection on unobserved determinants of WL certification.

We also examine whether WL status is systematically associated with lower productivity, especially in high-IMP provinces. Appendix 8 reports logit and probit models for the probability of being WL rather than NWL-PUB among procurement-active firms, together with average marginal effects of TFP by IMP area. The estimated marginal effects are negative but statistically insignificant in both low- and high-IMP provinces, and they are not larger in high-IMP areas. This evidence does not support the alternative interpretation that lower-productivity firms in high-Mafia-intensity areas are systematically more likely to seek WL certification.

A related concern is that firms may be associated with OpenCoesione projects of different overall scale. Larger projects may involve more complex administrative procedures, broader contractor networks, or different competitive environments than smaller projects. However, as clarified in Sect. 4.2, OpenCoesione project values do not correspond to the amount received by an individual firm and are not directly comparable with ANAC CIG values. We therefore use project size only as an indicator of project-scale exposure, not as a direct measure of firm-level funding or procurement-level competition. To explore this issue, we compute, for each firm, the average value of the OpenCoesione projects with which it is associated and split the sample according to whether this value is below or above the sample median. We then compare average measured TFP across firm groups within the low- and high-project-scale subsamples. The results, reported in Figs. 22 and 23 in Appendix 8, show that the qualitative ranking across firm types is preserved in both subsamples. In particular, NWL-PUB firms continue to display higher measured TFP than WL firms among firms associated with both lower-scale and higher-scale OpenCoesione projects. This suggests that the baseline productivity ranking is not mechanically driven by association with larger OpenCoesione projects.

A further alternative explanation is that the productivity gap may reflect differences in local market competitiveness. WL firms may operate in thinner markets, possibly because they participate in larger or more specialized procurement segments, whereas firms in denser local markets may face stronger competitive pressure

and therefore display higher measured productivity. To explore this possibility, we construct a proxy for local market thickness based on the number of active firms operating in the same province–sector–year cell. Appendix 8 reports the full descriptive comparison by firm type and market thickness regime. The evidence does not indicate that the productivity ranking is driven by WL firms being concentrated in thinner local markets. NWL-PUB firms display higher average measured TFP than WL firms in both low- and high-thickness markets. Hence, differences in local market density do not mechanically explain the productivity gap documented in the baseline analysis.

A further alternative explanation is that the observed TFP gap may reflect the direct productivity cost of WL compliance. WL certification does not involve direct monetary fees, but it requires firms to comply with administrative and procedural obligations, including documentation, periodic renewal, traceability requirements, communication with prefectures, and the reporting of corporate changes. These obligations may generate organizational and coordination costs that mechanically reduce measured TFP, independently of any Mafia-related mechanism. To assess the quantitative plausibility of this channel, we perform a back-of-the-envelope calibration, reported in Appendix 8. The observed NWL-PUB–WL productivity gap is approximately 20%, corresponding to $\Delta = \ln(1.20) = 0.182$. Since TFP is computed as the residual from the estimated production function, higher input use by WL firms, holding output constant, would mechanically reduce measured TFP. Using the WL-specific input elasticities from the baseline production function estimates, explaining the full TFP gap through higher materials and services would require WL firms to use approximately 27.2% more materials/services, holding output constant. If the same gap were attributed entirely to labor or capital, the required input increases would exceed 100%.

This calibration suggests that compliance costs may plausibly explain part of the measured productivity gap, especially if they are recorded through services and administrative expenses. However, they are unlikely to provide a complete explanation unless they are quantitatively large. We therefore treat the compliance-cost channel as a relevant component of the broader institutional-asymmetry interpretation, rather than as a mechanism that can be fully separated from informal governance with the available data.

Taken together, these tests suggest that neither public sector engagement, firm size, observable procurement exposure, OpenCoesione project-scale exposure, nor local market thickness sufficiently explains the higher measured TFP of NWL-PUB firms. The compliance-cost calibration also indicates that administrative and procedural burdens may account for part of the gap, especially through services and other intermediate inputs, but are unlikely to fully explain it unless they are quantitatively large. While we cannot exclude selection on unobserved characteristics, the consistency of the results across institutional regimes, project frequency, firm characteristics, matched procurement exposure, and local market-density environments is consistent with a broader interpretation based on institutional asymmetries. In Mafia-influenced areas, measured productivity may be shaped by the coexistence of formal compliance requirements and informal governance arrangements. Non-certified firms may retain lower administrative burdens, greater operational flexibility, or

stronger strategic opacity. At the same time, because our TFP measure is revenue-based, the estimated gap should be interpreted as a difference in measured revenue productivity rather than as definitive evidence of superior technological efficiency.

These results offer important insights into how organized crime may be associated with differences in measured productivity through institutional asymmetries, which we further discuss in the concluding section.

6 Conclusion

Our findings suggest that firm-level productivity systematically varies across contexts with different levels of exposure to organized crime. Non-certified firms participating in public procurement below the anti-Mafia regulatory threshold (NWL-PUB) tend to exhibit higher measured TFP than certified firms (WL) and, on average, than non-certified firms not observed in ANAC procurement records (NWL-PVT). This pattern is especially pronounced in provinces with stronger Mafia presence. By contrast, in lower-risk provinces, WL-certified firms generally outperform NWL-PUB firms, indicating that the productivity gap is not uniform across contexts and is closely related to the institutional environment and the asymmetries it may generate.[26]

We interpret the relative underperformance of WL-certified firms in high-Mafia areas as consistent with a setting in which formal alignment can entail non-negligible administrative and procedural burdens, even in the absence of direct monetary fees. These burdens may divert organizational resources away from productive activities and reduce measured revenue-based productivity. At the same time, where informal governance mechanisms are more pervasive, non-certified firms may retain operational flexibility, strategic opacity, or access to alternative coordination mechanisms. Because our TFP measure is revenue-based, the observed gap may also incorporate margin, demand-side, or reporting-related components. With the available data, we cannot fully decompose the relative contribution of compliance costs, informal governance, market power, and reporting differences. We therefore interpret the evidence as consistent with broader institutional asymmetries rather than as direct evidence of a single mechanism.

Our results support the view that, in weak institutional settings, voluntary compliance tools like the WL may generate uneven private costs when enforcement is incomplete. This does not imply that certification is economically or socially undesirable. Rather, it suggests that certification can become privately disadvantageous if compliant firms bear formal administrative burdens while competitors retain greater opacity or face weaker effective constraints.

These findings echo a broader literature in institutional economics, which emphasizes how informal institutions, such as Mafia governance, can neutralize or distort the effects of formal rules when enforcement is partial or legitimacy is weak (Greif 2006; Kingston and Caballero 2009; Runst and Wagner 2011). Voluntary

[26] For completeness, NWL-PVT firms, never observed in ANAC procurement records, display lower measured TFP on average than the other groups in our sample.

mechanisms, in such settings, may fail to change firm behavior as intended and instead create perverse incentives that reproduce existing power imbalances.

Building on this interpretation, we outline two implications. First, we discuss policy design options aimed at reducing compliance asymmetries and closing regulatory margins in high-risk procurement. Second, we briefly discuss why the underlying mechanism may generalize beyond the Italian context to settings with uneven enforcement and entrenched informal governance.

A direct implication of our findings is that a purely voluntary certification regime may be insufficient in high-risk sectors when enforcement is uneven. In our setting, firms can participate in public procurement below the €150,000 anti-Mafia threshold without holding WL certification, creating a regulatory margin in which non-certified operators can remain eligible for public resources while avoiding the most stringent screening. Mandating WL certification as a condition for accessing public contracts in high-risk sectors would therefore aim to reduce compliance asymmetries and close this loophole. Implementation, however, raises non-trivial challenges. For example, a mandatory regime shifts WL from a reputational signal into an administrative bottleneck, potentially generating delays along the procurement timeline.[27] More generally, effective implementation would require sufficiently strong administrative capacity and predictable procedures to avoid delays and discretion along procurement timelines.

A further concern is unintended exclusion of small firms. If certification becomes a prerequisite for any access to public procurement, fixed administrative burdens may disproportionately affect smaller operators and reduce participation in public tenders. Any move toward mandatory certification would therefore need to be designed with proportionality in mind, so that integrity requirements do not translate into de facto entry barriers for smaller contractors.

Finally, the policy trade-off is straightforward. Widening certification in high-risk procurement can reduce the scope for operating in regulatory margins and weaken the relative advantage of opacity. Yet, scaling up screening may increase administrative frictions and discourage participation, especially among smaller contractors. The goal is to expand integrity screening while keeping procedures predictable and proportionate.

While our empirical setting is Sicily, the underlying mechanism (i.e., the interaction between formal alignment devices and informal governance under weak or uneven enforcement) is not Italy-specific. A useful parallel comes from contexts in which the State attempts to reassert control by combining (i) targeted enforcement capacity and (ii) the closing of institutional loopholes that allow illegal or informal appropriation to persist. For instance, de Oliveira and Miranda (2024) study the Brazilian Amazon and evaluate the introduction of the list of priority municipalities (*Municípios Prioritários*), a policy that allocates additional monitoring resources

[27] Illustrative frictions include (i) backlogs in processing first-time applications and periodic renewals; (ii) heterogeneous turnaround times across Prefectures due to capacity constraints; (iii) delays from fragmented IT systems and inter-agency information exchange (e.g., verification steps involving contracting authorities, business registries, and law-enforcement/administrative databases); and (iv) timing mismatches between tender deadlines and certification/renewal completion.

to high-deforestation areas and tightens requirements in order to curb illegal activity. Using a difference-in-differences design, they find that strengthening monitoring and enforcement is associated with lower deforestation and lower violence in resource-conflict environments characterized by poorly defined property rights. The lesson for our setting is not that environmental policy maps one-to-one into anti-Mafia certification, but that integrity-enhancing instruments are more likely to affect outcomes when they are backed by enforcement capacity and when they reduce the rents generated by regulatory margins.

Mechanistically similar tensions may arise in other environments where public spending and market access are mediated by clientelistic procurement networks or protection rackets: if compliance is administratively burdensome and enforcement is selective, formal alignment may become privately disadvantageous, and opacity can be rewarded. In such settings, the policy challenge is comparable to ours: expand screening where public resources are allocated while preventing the screening device itself from becoming a barrier that disproportionately penalizes compliant firms.

In conclusion, our results highlight a fundamental paradox: in weak institutional environments, firms that comply with formal rules may be penalized, not rewarded, for their adherence, especially when compliance is costly and enforcement is uneven.

6.1 Limitations and future research

While the paper provides a coherent and robust descriptive characterization of productivity differences across groups, and the main patterns prove stable across a wide set of specifications and checks, some limitations should be kept in mind. Addressing them is a natural direction for future research.

First, this paper documents systematic differences in productivity and, in Sect. 5.2, reports accounting-based patterns ("financial traits") that are consistent with the channels highlighted in the conceptual framework. We do not attempt a formal causal mediation analysis to quantify how much of the observed TFP gap operates through those traits. A mediation exercise would require either strong identifying assumptions (e.g., sequential ignorability) or additional exogenous variation capable of shifting the proposed mediators independently of productivity. Given the nature of accounting outcomes and the risk that they are jointly determined with productivity or driven by common unobservables, a mediation decomposition could be misleading and easily over-interpreted.

Second, although we discuss this issue in Sects. 4.3 and 5.1, it remains important to stress that our productivity measure is revenue-based. As a result, part of the documented TFP premium may reflect markups, demand-side components, market power, or reporting-related factors rather than purely technological efficiency. Without firm-level prices, physical quantities, or markup estimates, we cannot decompose the measured productivity premium into efficiency gains, margin effects, and reporting differences.

Third, we observe realized WL enrollment but not the underlying application and screening process (applications, rejections, processing times). As a result, we cannot

Table 8 Variables' description

Variable	Description	Source
TFP	Total factor productivity, computed as the residual from a Cobb–Douglas production function using firm-level input data (log form)	Authors' calculation based on AIDA
Turnover	Firm turnover, used as proxy for output; expressed in logarithmic form	AIDA Bureau Van Dijk
Labor	Labor cost per employee; logarithmic transformation applied	AIDA Bureau Van Dijk
Capital	Book value of tangible fixed assets; log-transformed	AIDA Bureau Van Dijk
Materials	Cost of raw materials, intermediate inputs, and services; log-transformed	AIDA Bureau Van Dijk
Age	Firm age in 2021 minus year of establishment	AIDA Bureau Van Dijk
Size	Logarithm of total assets, proxy for firm size	AIDA Bureau Van Dijk
Cash-flow	Ratio of cash holdings to total assets, expressed in logarithmic form; proxy for liquidity	AIDA Bureau Van Dijk
Tangibles	Ratio of tangible fixed assets to total assets, expressed in logarithmic form; proxy for capital intensity	AIDA Bureau Van Dijk
Debt	Financial leverage: ratio of debt to total assets, expressed in logarithmic form	AIDA Bureau Van Dijk
ROA	Return on assets, measuring profitability	AIDA Bureau Van Dijk
EBITDA	Earnings before interest, taxes, depreciation, and amortization; proxy for operational performance	AIDA Bureau Van Dijk
Mafia Index (IMP)	Index of Mafia presence by province, based on crime indicators	Transcrime (2015)
Province dummies	Fixed effects capturing province-level structural heterogeneity	Authors' elaboration
Year dummies	Fixed effects capturing common shocks and macroeconomic trends	Authors' elaboration
Sector dummies	Fixed effects capturing sector-level structural heterogeneity	Authors' elaboration

Table 9 Descriptive statistics, by group of firms

Firm group	Statistic	Turnover	Labor	Capital	Materials	Age	Size	Cash flow	Tangibles	Debt	ROA	EBITDA
NWL-PVT	Mean	10.95	4.37	8.65	10.57	10.26	5.98	− 2.66	− 2.41	− 0.46	3.95	3.55
	SD	1.78	1.57	2.38	1.89	10.08	1.59	1.66	1.57	0.53	15.10	1.62
	Min	− 2.23	− 6.91	− 2.17	− 2.14	0	− 1.23	− 14.18	− 14.96	− 5.92	− 97.98	− 6.91
	Max	20.80	11.82	19.29	20.83	101	14.91	0	0	2.95	55.76	12.53
WL	Mean	11.77	5.37	9.99	11.42	14.12	7.12	− 3.23	− 2.18	− 0.46	5.22	4.55
	SD	1.71	1.54	2.13	1.69	10.91	1.38	1.75	1.29	0.44	9.79	1.46
	Min	0.34	− 6.21	0.99	3.48	1	− 0.27	− 13.40	− 11.00	− 4.77	− 92.03	− 5.12
	Max	18.50	10.92	17.47	18.41	74	11.74	− 0.12	− 0.01	1.62	55.18	9.77
NWL-PUB	Mean	11.67	5.20	9.38	11.23	15.28	6.83	− 2.97	− 2.60	− 0.51	5.18	4.25
	SD	1.80	1.73	2.45	1.89	11.21	1.61	1.74	1.50	0.46	11.49	1.69
	Min	2.20	− 4.61	0.03	2.85	1	− 0.33	− 13.91	− 11.00	− 4.31	− 97.88	− 5.30
	Max	18.49	11.84	17.95	18.37	69	13.25	0	− 0.03	1.60	55.68	11.28

distinguish deliberate non-applicants from unsuccessful applicants within the non-WL groups.

A natural next step in this research is to enrich the data by integrating currently unavailable administrative records on WL applications and screening outcomes, together with complementary firm-level information that helps disentangle technological efficiency from margins and reporting-related components embedded in revenue-based productivity.

7 Appendix 1: Variables and descriptive statistics

The main variables used in the empirical analysis are summarized in Table 8, along with their definitions and sources. Most of them are constructed from firm-level balance sheets.

Table 9 reports the main descriptive statistics by group of firms.

7.1 Appendix 1.1: Additional evidence on NWL-PUB procurement exposure

This subsection provides additional descriptive evidence on the procurement exposure of NWL-PUB firms. As discussed in Sect. 4.2, the NWL-PUB category is defined using observed ANAC procurement records: these are non-certified firms observed in public procurement with all observed contracts below the €150,000 statutory threshold. This classification is useful to distinguish non-certified firms with some observed exposure to public procurement from non-certified firms not observed in ANAC records.

A concern is that the NWL-PUB category may combine firms with very different procurement profiles. In particular, some firms may repeatedly operate close to the €150,000 threshold, while others may have only limited or occasional below-threshold procurement activity. Ideally, one would characterize the full distribution of individual CIG values within each firm-year. Our data provide, for each firm-year, the total annual value of below-threshold CIGs and the corresponding number of CIGs. We therefore compute the average below-threshold CIG value as the ratio between total below-threshold awarded value and the number of below-threshold CIGs. This measure provides an informative proxy for proximity to the regulatory threshold.

Table 10 reports the distribution of average below-threshold CIG values among NWL-PUB firm-years with positive procurement activity. The evidence does not indicate widespread bunching immediately below the €150,000 threshold. Only 3.42% of NWL-PUB firm-year observations have an average CIG value in the €140,000–149,999 interval, while 7.83% have an average CIG value above €125,000. The largest share of observations, 59.17%, is concentrated in the €50,000–99,999 interval. This suggests that near-threshold behavior exists but does not dominate the NWL-PUB category.

We also characterize near-threshold exposure at the firm level. Table 11 reports the number and share of NWL-PUB firms with at least one firm-year in which the

average below-threshold CIG value exceeds selected thresholds. Among the 1041 NWL-PUB firms with positive below-threshold procurement activity, 18.73% have at least one firm-year with an average CIG value of at least €125,000, and only 8.74% have at least one firm-year with an average CIG value of at least €140,000. This evidence confirms that a limited subset of NWL-PUB firms displays procurement patterns compatible with near-threshold behavior, but this subset is quantitatively small relative to the overall NWL-PUB group.

A related concern is that WL enrollment may be driven by firms' dependence on public procurement, especially on contracts subject to stricter anti-Mafia screening requirements. To provide descriptive evidence on this issue, we compare WL and NWL-PUB firms in terms of their observed procurement exposure in the ANAC records. We restrict the comparison to procurement-active firms, excluding NWL-PVT firms because they are not observed in ANAC procurement data.

Table 12 reports firm-level comparisons based on procurement values and the number of CIG procedures cumulated over the sample period. The total value of observed public procurement does not differ significantly between NWL-PUB and WL firms. The mean difference in log total procurement value is 0.309 and is not statistically significant. This suggests that WL firms are not characterized by higher overall observed procurement exposure relative to NWL-PUB firms.

However, the composition of procurement exposure differs sharply across the two groups. NWL-PUB firms are concentrated in below-threshold contracts, while WL firms also participate in above-threshold procurement procedures. This pattern is consistent with the institutional definition of the groups and with the idea that WL enrollment is related less to the overall scale of public procurement activity than to access to the more regulated segment of public procurement. In this sense, WL status may partly reflect firms' need to operate in procurement markets where anti-Mafia screening requirements are more stringent.

8 Appendix 2: Historical trends in average TFP

This appendix reports the average TFP of WL, NWL-PUB, and NWL-PVT firms over the period 2004–2021. As discussed in the main text, trends appear relatively similar across groups prior to the introduction of the WL in 2012, lending credibility to our identification strategy. Post-2012 dynamics are explored in the empirical analysis.

Figures 4, 5 and 6 report pre-entry dynamics around WL enrollment. Figure 4 plots event-time coefficients for log employment, Fig. 5 for log capital, and Fig. 6 for log TFP. In all cases, the year immediately preceding WL entry ($t=-1$) is used as the omitted reference category. Table 13 reports the corresponding estimates and formal joint tests of the pre-entry coefficients. All specifications include firm and year fixed effects, and standard errors are clustered at the firm level.

Table 10 Distribution of average below-threshold CIG values among NWL-PUB firm-years

Average CIG value range	Frequency	Percent	Cumulative percent
€1–49,999	268	16.66	16.66
€50,000–99,999	952	59.17	75.82
€100,000–124,999	263	16.35	92.17
€125,000–139,999	71	4.41	96.58
€140,000–149,999	55	3.42	100.00
Total	1609	100.00	

The table reports the distribution of average below-threshold CIG values among NWL-PUB firm-years with positive procurement activity. The average CIG value is computed as the total annual value of below-threshold CIGs divided by the number of below-threshold CIGs awarded to the firm in that year. NWL-PUB firms are non-certified firms observed in ANAC procurement records with all observed public procurement contracts below the €150,000 statutory threshold

Table 11 Near-threshold procurement exposure among NWL-PUB firms

Indicator	Number of firms	Percent
NWL-PUB firms with positive below-threshold procurement activity	1041	100.00
At least one firm-year with average CIG value ≥ €125,000	195	18.73
At least one firm-year with average CIG value ≥ €140,000	91	8.74

The table reports firm-level exposure to near-threshold procurement among NWL-PUB firms. The indicators identify firms with at least one firm-year in which the average below-threshold CIG value exceeds the reported thresholds. The average CIG value is computed as the total annual value of below-threshold CIGs divided by the number of below-threshold CIGs awarded to the firm in that year

Table 12 Public procurement exposure: WL vs. NWL-PUB firms

Variable	NWL-PUB	WL	Difference	*p*-value
Log total procurement value	9.271	8.962	0.309	0.233
Log below-threshold procurement value	9.271	6.206	3.064***	0.000
Log above-threshold procurement value	0.000	7.969	− 7.969***	0.000
Log total number of CIGs	1.022	1.288	− 0.266***	0.000
Log number of below-threshold CIGs	1.022	0.783	0.238***	0.000
Log number of above-threshold CIGs	0.000	1.003	− 1.003***	0.000

The table reports two-sample comparisons between NWL-PUB and WL firms. The sample is restricted to procurement-active WL and NWL-PUB firms. NWL-PVT firms are excluded because they are not observed in ANAC public procurement records. Procurement values and number of CIG procedures are cumulated at the firm level over the sample period. Variables are expressed as $\log(1+x)$. Above-threshold procurement variables are zero for NWL-PUB firms by construction. The reported difference is computed as NWL-PUB minus WL

***$p<0.01$, **$p<0.05$, *$p<0.10$

Table 13 Pre-entry trends in key inputs and TFP

	log(Employment)	log(Capital)	log(TFP)
$t-6$	− 0.33	− 0.31	− 0.022
	(0.20)	(0.19)	(0.106)
$t-5$	− 0.20	− 0.25	− 0.023
	(0.21)	(0.20)	(0.089)
$t-4$	− 0.18	− 0.25	− 0.081
	(0.22)	(0.21)	(0.090)
$t-3$	− 0.23	− 0.22	0.009
	(0.24)	(0.22)	(0.063)
$t-2$	− 0.21	− 0.19	− 0.033
	(0.25)	(0.23)	(0.057)
Joint test p-value	0.42	0.27	0.781

Firm and year fixed effects included. Standard errors are clustered at the firm level and reported in parentheses. The omitted category is the year immediately preceding WL entry ($t=-1$). The joint test reports the p-value of the test of the null hypothesis that all reported pre-entry coefficients are jointly equal to zero

Table 14 Policy-based DiD around 2012: Future-WL firms vs Never-WL firms

	(1)	(2)
Future-WL × Post-2012	− 0.0569	− 0.0546
	(0.0375)	(0.0375)
Controls	No	Yes
Firm FE	Yes	Yes
Year FE	Yes	Yes
Observations	15,507	15,461

Dependent variable is the log TFP residual. "Future-WL" equals one for firms that enter the WL at least once during the sample; "Post-2012" equals one for years ≥ 2012. Specifications include firm and year fixed effects; standard errors are clustered at the firm level. Controls include size, cash-to-assets, intangible/material-assets ratio, leverage and ROA

Table 15 Baseline DiD: WL enrollment and productivity

	(1)	(2)
WL	− 0.008	0.000
	(0.016)	(0.016)
Controls	No	Yes
Firm FE	Yes	Yes
Year FE	Yes	Yes
Observations	73,396	73,148

Dependent variable is log TFP residual. Controls include firm size, cash flow, leverage, and liquidity. Standard errors clustered at the firm level

9 Appendix 3: Dynamic evidence on WL certification and productivity

This appendix reports a set of difference-in-differences style analyses aimed at further characterizing the dynamic relationship between WL certification and firm productivity. Given that WL enrollment is voluntary and non-random, these exercises are not intended to identify a causal treatment effect of certification. Rather, they assess whether the productivity patterns documented in the main text are robust to alternative dynamic specifications that absorb time-invariant firm heterogeneity and allow for differential post-2012 dynamics across firms.

First, we implement a policy-based DiD specification exploiting the institutional introduction of the WL framework in 2012. Using the long panel (2004–2021), we define a time-invariant indicator for firms that will enter the WL at least once during the sample period ("Future-WL") and interact it with a post-2012 indicator, including firm and year fixed effects. This specification absorbs all time-invariant firm characteristics and common macroeconomic shocks. As reported in Table 14, the post-2012 productivity differential between Future-WL and Never-WL firms is small in magnitude and statistically indistinguishable from zero, both with and without time-varying firm controls.

Next, we estimate an enrollment-based DiD-style specification treating WL enrollment as a time-varying indicator of certification status, equal to one from the first year of enrollment onward. This two-way fixed-effects specification is estimated on the full 2004–2021 panel. Although WL entry events are first observed from 2013 onward, pre-2013 observations contribute to the estimation by strengthening the identification of firm and year fixed effects and by improving precision, while all firms are mechanically in the pre-entry state during that period. As shown in Table 15, we find no statistically significant average change in productivity following WL enrollment. Given staggered enrollment and non-random selection into certification, this evidence is interpreted as descriptive of post-enrollment dynamics rather than as a causal effect.

To further examine local dynamics around certification, we complement the DiD-style specifications with an event-study analysis centered on the year of first WL enrollment. This exercise allows us to assess whether productivity exhibits anticipatory trends or discrete changes at the time of certification. The event study is necessarily implemented on the post-2013 panel, when WL entry events are observed, using firm and year fixed effects and a symmetric ± 4 year window around first certification, with $t = -1$ as the omitted baseline period. Figure 7 and Table 16 report the estimated coefficients. The estimates are essentially flat both before and after WL entry: joint tests fail to reject the null of no pre-trends and no post-entry effects, indicating that WL certification is not associated with a discrete productivity break around the time of enrollment. The results are robust to the inclusion of time-varying firm controls related to size, liquidity, balance-sheet structure, and profitability.

Overall, these DiD-style and event-study analyses provide reassurance that the baseline results are not driven by sectoral composition, time-invariant heterogeneity, or differential pre-entry trends. They reinforce the interpretation of WL certification

as a signal of institutional alignment rather than as a productivity-enhancing treatment and are fully consistent with the institutional mechanisms discussed in the paper.

10 Appendix 4: Key financial indicators for identifying red flags of Mafia influence

Table 17 presents the financial ratios used in this study to assess the potential influence of Mafia-related dynamics on firms. For each index, we detail its calculation, expected value (high or low), and the underlying rationale. These indicators offer insights into liquidity, financing practices, and operational behavior, which are particularly relevant for identifying patterns commonly associated with Mafia-influenced enterprises.

11 Appendix 5: Mafia presence index

The following figure is taken from the 2015 Transcrime report on Mafia investments in Italy and its penetration. Available online at https://www.transcrime.it/wp-content/ uploads/2014/02/PON-Gli_investimenti_delle_mafie_ridotto.pdf (See Fig. 8).

12 Appendix 6: TFP by firm type and provincial Mafia intensity

Table 18 presents a detailed comparison of production inputs across firm groups, distinguishing between low-infiltration and high-infiltration provinces; Figs. 9 and 10 illustrate the results. Specifically, Messina, Ragusa, and Siracusa are classified as low-IMP provinces, while all other Sicilian provinces fall into the high-IMP category.

As a complementary robustness check to the cutoff-based heterogeneity analysis, we estimate a specification that interacts firm-type indicators with the provincial IMP index measured continuously. To keep the framework comparable across groups, the dependent variable is pooled-technology TFP, and we include the same firm-level controls as well as year and sector fixed effects (See Table 19).

As an additional check on the territorial dimension of Mafia-related institutional exposure, we complement the province-level IMP classification with a local measure based on proximity to municipalities dissolved for Mafia infiltration. For each firm, we compute the distance between its legal headquarters and the nearest municipality dissolved for Mafia infiltration. We then define an indicator equal to one for firms located within 10 km of such a municipality. This indicator captures local exposure to documented Mafia-related administrative intervention. It should not be interpreted as a pure measure of Mafia intensity, since municipal dissolutions also reflect enforcement and detection capacity.

Table 20 reports the estimated NWL-PUB–WL productivity gap separately for firms located farther than 10 km from a dissolved municipality and for firms located

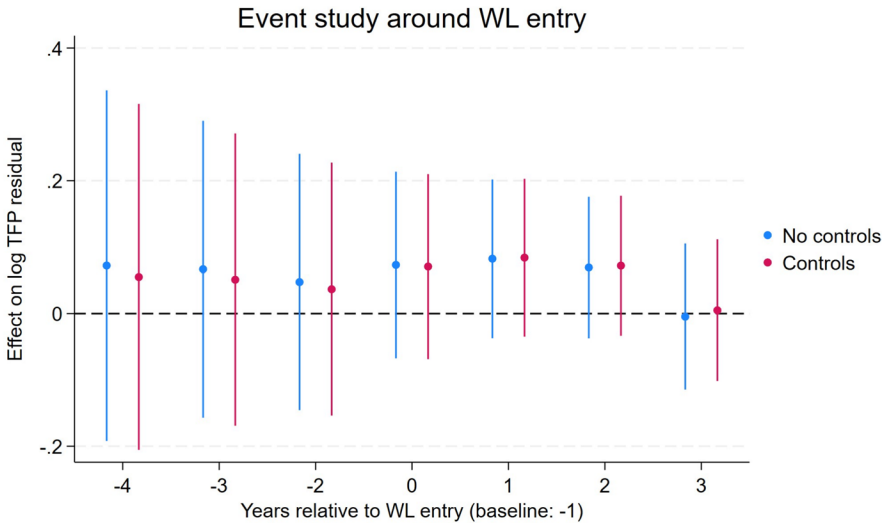

Fig. 7 Event study around WL entry (window ± 4). Markers report estimates without and with time-varying controls. Vertical bars are 95% confidence intervals (firm-clustered standard errors). Baseline period: $t = -1$

within 10 km. The productivity gap is positive and statistically significant in both areas, but it is larger within the 10 km radius.

13 Appendix 7: Robustness analysis section

This appendix reports additional robustness checks aimed at assessing whether the main productivity patterns are sensitive to project frequency, cohesion programming periods, the production function estimator, and the restriction to firms receiving EU cohesion funds.

13.1 Project frequency: single-project and multiple-project firms

Tables 21 and 22 report the production function estimates separately for firms implementing multiple funded projects and firms implementing a single funded project. The corresponding yearly TFP patterns are shown in Figs. 11 and 12, respectively.

Controlling for the number of funded projects allows us to isolate differences in firm behavior and efficiency stemming from project complexity and scale. Firms managing multiple projects may adopt distinct resource allocation strategies, leading to variations in productivity. By focusing on single-project firms, we minimize confounding factors and provide a clearer picture of how production inputs affect TFP. The graphical evidence in Figs. 11 and 12 complements the production function estimates by showing that the qualitative ranking across firm types remains broadly consistent across both subsamples.

13.2 Cohesion programming periods

Tables 23 and 24 present the results for cohesion programming during the 2007–2013 and 2014–2020 periods. The corresponding yearly average TFP trajectories are reported in Figs. 13 and 14. The findings indicate that TFP estimates remain consistent across these frameworks, reinforcing the robustness of our results across different policy cycles.

The graphical evidence in Figs. 13 and 14 complements the estimates by showing that the main productivity patterns are not confined to a single programming period. This is relevant because the two periods differ in terms of policy environment, monitoring practices, and the maturity of the anti-Mafia certification framework.

13.3 Alternative production function estimator

Table 25 presents the analysis using Wooldridge's non-parametric method to estimate the production function as an additional robustness check. Figure 15 reports the corresponding yearly average TFP trajectories obtained using this alternative estimator. The results confirm the consistency of TFP estimates, further strengthening the validity of our findings across different methodological approaches.

The evidence in Fig. 15 complements the production function estimates by showing that the qualitative ranking across firm types is not mechanically driven by the baseline estimator. At the same time, since both approaches rely on accounting data, this robustness check does not eliminate concerns related to revenue-based productivity or potential measurement error in inputs.

13.4 Firms never funded by EU cohesion funds

This subsection complements the robustness check on Sicilian firms that did not receive EU cohesion funds. This estimation serves to assess whether our main results are influenced by sample selection into EU-funded projects. The corresponding yearly average TFP trajectories are reported in Fig. 16. The findings indicate that the overall patterns observed in the main sample remain consistent, reinforcing the validity of our conclusions.

Figure 16 complements the production function estimates reported in the main text by showing that the qualitative productivity ranking is not mechanically generated by the restriction to cohesion-fund recipients.

13.5 Size-balanced comparison sample

A potential concern is that the NWL-PVT group is much larger than the WL and NWL-PUB groups. Since NWL-PVT is a broad residual category of non-certified firms not observed in ANAC procurement records, its numerical predominance could affect the precision and interpretation of group comparisons. To address this issue, we estimate an additional size-balanced specification in which the NWL-PVT

Table 16 Event study around WL entry (window ± 4)

Event time (years relative to WL entry)	(1) No controls	(2) Controls
$t=-4$	0.072	0.055
	(0.135)	(0.133)
$t=-3$	0.067	0.051
	(0.114)	(0.112)
$t=-2$	0.047	0.037
	(0.098)	(0.097)
$t=0$	0.073	0.071
	(0.072)	(0.071)
$t=1$	0.082	0.084
	(0.061)	(0.061)
$t=2$	0.069	0.072
	(0.054)	(0.054)
$t=3$	−0.005	0.005
	(0.056)	(0.054)
Pre-trends joint test ($t=-4,-3,-2$)	$F(3,1234)=0.20$ ($p=0.8935$)	$F(3,1234)=0.12$ ($p=0.9463$)
Post coefficients joint test ($t=0, 1, 2, 3$)	$F(4,1234)=0.68$ ($p=0.6039$)	$F(4,1234)=0.71$ ($p=0.5825$)
Firm FE	Yes	Yes
Year FE	Yes	Yes
Controls	No	Yes
Observations	8664	8664

group is randomly restricted to a subsample equal in size to the WL group, while retaining all WL and NWL-PUB firms. Table 26 reports the results.

13.6 Accounting-based performance outcomes

As an additional robustness check, we replicate the baseline comparison using accounting-based performance measures as dependent variables. Specifically, we consider EBITDA as a proxy for operating performance, ROA as a proxy for profitability, and EBITDA over sales as an accounting proxy for operating margins. These outcomes are not intended to replace the TFP analysis, but to assess whether the main productivity patterns are mechanically driven by revenue-based measurement or margin differences.

Tables 27 and 28 report complementary evidence on firm performance using two accounting-based outcomes: EBITDA (operating performance) and ROA (profitability). They present panel estimates by Mafia-intensity areas (IMP), using the same fixed effects, controls, and clustering strategy as in the main analysis, with WL firms

Table 17 Financial indicators used to detect Mafia influence

Index	Calculation	Expected pattern	Explanation
CRatio	$\frac{\text{Current assets}}{\text{Current liabilities}}$	High value	Indicates high liquidity; may suggest flexibility for informal or illicit transactions
CaTa	$\frac{\text{Current assets}}{\text{Total assets}}$	High value	Suggests a preference for liquid assets, which can be quickly moved or concealed
RecTa	$\frac{\text{Receivables}}{\text{Total assets}}$	High value	Reflects a reliance on credit-based transactions, which may be harder to trace
LevBank	$\frac{\text{Bank debts}}{\text{Total assets}}$	Low value	Suggests limited reliance on formal credit markets, possibly due to access to alternative financing
InvTa	$\frac{\text{Inventory}}{\text{Total assets}}$	Low value	Indicates less investment in physical inventories, possibly to avoid seizure or scrutiny
PersEmpl	$\frac{\text{Personnel expenses}}{\text{Number of employees}}$	Low value	Reflects lower reported labor costs, potentially linked to underreporting or informal labor arrangements

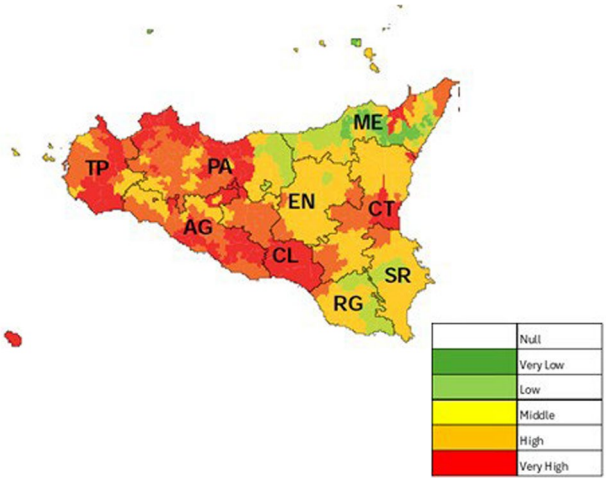

Fig. 8 Mafia presence index

Table 18 Production function estimates, firms in high-infiltration and low-infiltration provinces

	High-infiltration			Low-infiltration		
	NWL-PVT	NWL-PUB	WL	NWL-PVT	NWL-PUB	WL
Labor	0.200***	0.217***	0.255***	0.177***	0.245***	0.284***
	(0.0016)	(0.0119)	(0.0199)	(0.0056)	(0.0146)	(0.0280)
Capital	0.281***	0.299***	0.269***	0.289***	0.281***	0.247***
	(0.0012)	(0.0012)	(0.0008)	(0.0010)	(0.0020)	(0.0005)
Materials	0.754***	0.702***	0.754***	0.733***	0.687***	0.697***
	(0.0003)	(0.0008)	(0.0011)	(0.0004)	(0.0014)	(0.0006)
No. of obs.	44,803	6247	6504	20,050	2268	2259

All regressions include firm age, firm size, liquidity, capital intensity, leverage, return on assets, as well as calendar year dummies, province fixed effects, and sector fixed effects

Statistical significance is denoted as follows: $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$

as the omitted category. EBITDA is measured in levels, so coefficients capture differences in operating surplus relative to WL firms, whereas ROA coefficients should be interpreted as differences in profitability ratios.

As an additional check on the revenue-based interpretation of our productivity measure, we examine whether the NWL-PUB productivity premium could simply reflect higher operating margins. Since output is proxied by turnover, measured TFP may partly capture price–cost margins rather than purely technological efficiency. We therefore use EBITDA over sales as an accounting proxy for operating margins and estimate whether non-certified firms display higher margins relative to WL firms. This exercise should not be interpreted as a structural estimate of markups, since EBITDA over sales cannot fully separate prices, costs, and reporting behavior. Nevertheless, it provides a useful descriptive check on whether the measured

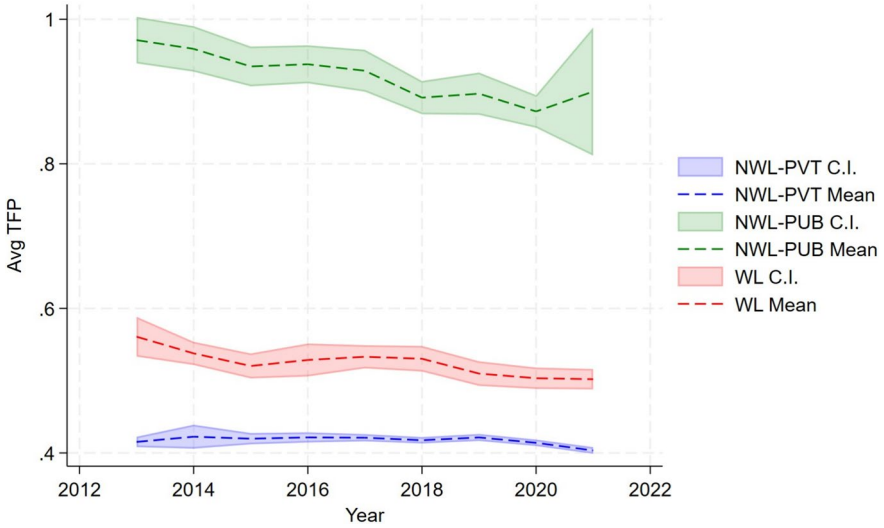

Fig. 9 TFP of WL, NWL-PUB, and NWL-PVT firms, high-infiltration provinces

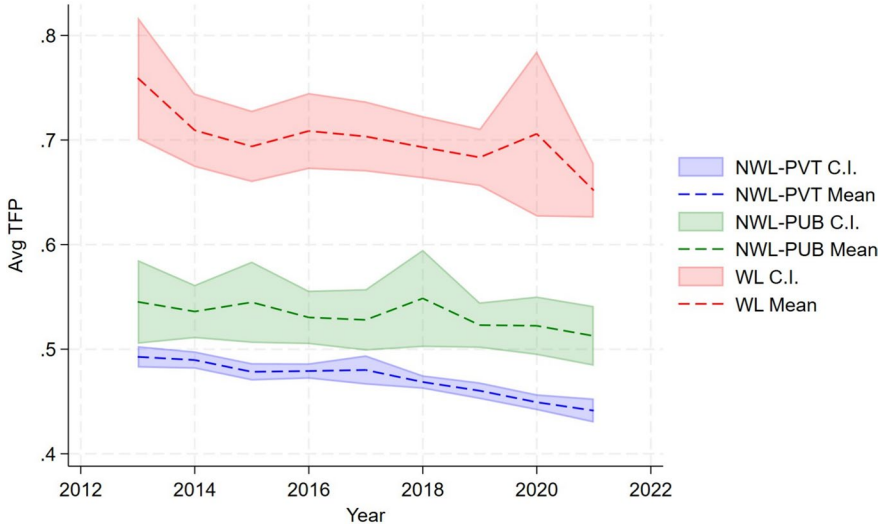

Fig. 10 TFP of WL, NWL-PUB, and NWL-PVT firms, low-infiltration provinces

TFP premium is consistent with a simple margin-based explanation. The results are reported in Table 29.

Table 19 Pooled TFP and continuous Mafia presence (IMP)

	Pooled TFP
NWL-PVT firm	0.0432*** (0.0137)
NWL-PUB firm	0.0705*** (0.0179)
IMP (continuous)	0.0000518* (0.0000274)
NWL-PVT × IMP	− 0.0000356 (0.0000293)
NWL-PUB × IMP	− 0.0000510 (0.0000433)
Controls	Yes
Year fixed effects	Yes
Sector fixed effects	Yes
Observations	60,942
Firms	13,284
*R*2	0.183

The dependent variable is pooled-technology TFP. The omitted category is WL firms. IMP denotes the continuous Transcrime Index of Mafia Presence at the provincial level. All specifications include firm-level controls: age, size, liquidity, capital intensity, leverage, and profitability. Robust standard errors clustered at the firm level are reported in parentheses

Statistical significance is denoted as follows: $^{*}p<0.10$, $^{**}p<0.05$, $^{***}p<0.01$

Table 20 NWL-PUB versus WL productivity gap by proximity to dissolved municipalities

	Farther than 10 km	Within 10 km	Difference
NWL-PUB–WL	0.048***	0.089***	0.041**
	(0.013)	(0.016)	(0.021)
Controls	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Province FE	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes

The dependent variable is log TFP. The table reports linear combinations from a regression interacting firm type with an indicator for firms located within 10 km of a municipality dissolved for Mafia infiltration. WL firms are the reference group. The "Difference" column reports the coefficient on the interaction between NWL-PUB and the within-10-km indicator. All specifications include firm-level controls, year fixed effects, province fixed effects, and sector fixed effects. Standard errors, clustered at the firm level, are reported in parentheses

Statistical significance: *$p<0.10$, **$p<0.05$, ***$p<0.01$

Table 21 Production function estimates, firms implementing multiple projects

	NWL-PVT	NWL-PUB	WL
Labor	0.212***	0.313***	0.294***
	(0.0061)	(0.014)	(0.0175)
Capital	0.279***	0.0313***	0.284***
	(0.0004)	(0.0009)	(0.0143)
Materials	0.745***	0.846***	0.725***
	(0.0012)	(0.009)	(0.0211)
Observations	25,323	4400	4322

All regressions include firm age, firm size, liquidity, capital intensity, leverage, return on assets, as well as calendar year dummies, province fixed effects, and sector fixed effects

Statistical significance is denoted as follows: $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$

Table 22 Production function estimates, firms implementing a single project

	NWL-PVT	NWL-PUB	WL
Labor	0.188***	0.248***	0.192***
	(0.0042)	(0.0119)	(0.0127)
Capital	0.286***	0.247***	0.0263***
	(0.0005)	(0.0011)	(0.0011)
Materials	0.760***	0.790***	0.860***
	(0.0004)	(0.0006)	(0.0003)
Observations	29,432	3368	3743

All regressions include firm age, firm size, liquidity, capital intensity, leverage, return on assets, as well as calendar year dummies, province fixed effects, and sector fixed effects

Statistical significance is denoted as follows: $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$

14 Appendix 8: Additional evidence on alternative explanations

14.1 Public procurement engagement and WL status

Table 30 presents the production function estimates, accounting for the potential impact of public sector engagement on productivity. The analysis focuses on firms actively working with the public sector (WL-PUB and NWL-PUB) and those eligible to collaborate with it (WL-PVT) (See Fig. 17).

14.2 Firm size

Table 31 presents the production function estimates across firm groups segmented by size (small and medium) and certification status. While the results highlight variations in how employment, capital, and materials contribute to productivity across groups, NWL-PUB firms consistently exhibit the highest TFP. This suggests that the

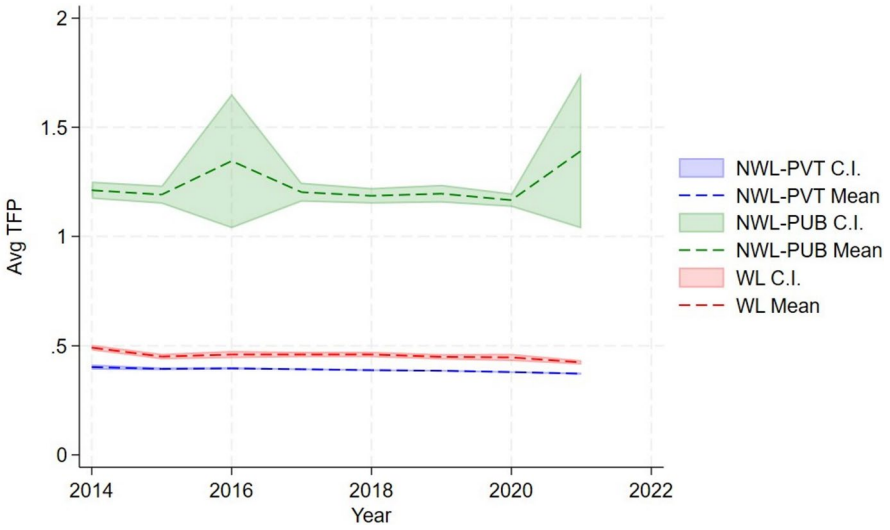

Fig. 11 Average TFP of firms implementing multiple projects

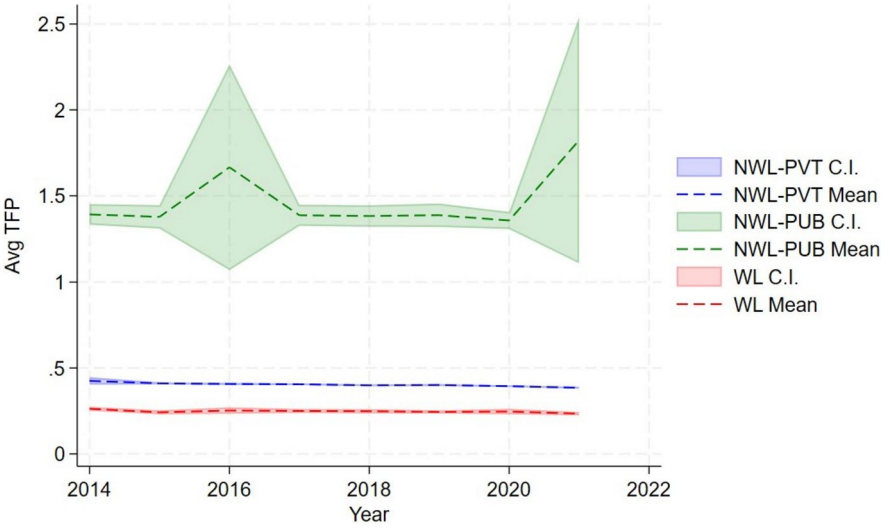

Fig. 12 Average TFP of firms implementing a single project

advantages observed in the main analysis persist regardless of firm size, reinforcing the robustness of our findings (See Figs. 18, 19).

14.3 Matched comparison of WL-ANAC and NWL-PUB firms

To address the concern that WL and NWL-PUB firms may differ in their exposure to public procurement markets, we conduct an additional propensity score matching

Table 23 Production function estimates, firms funded by 2007–2013 programming

	2007–2013		
	NWL-PVT	NWL-PUB	WL
Labor	0.208***	0.158***	0.127***
	(0.0030)	(0.0040)	(0.0158)
Capital	0.152***	0.129***	0.216***
	(0.0015)	(0.0015)	(0.0008)
Materials	0.864***	0.759***	0.793***
	(0.0086)	(0.0005)	(0.0006)
Observations	2415	750	284

All regressions include firm age, firm size, liquidity, capital intensity, leverage, return on assets, as well as calendar year dummies, province fixed effects, and sector fixed effects

Statistical significance is denoted as follows: $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$

Table 24 Production function estimates, firms funded by 2014–2020 programming

	2014–2020		
	NWL-PVT	NWL-PUB	WL
Labor	0.221***	0.247***	0.286***
	(0.0049)	(0.0090)	(0.0041)
Capital	0.263***	0.278***	0.237***
	(0.0011)	(0.0006)	(0.0002)
Materials	0.7775***	0.720***	0.784***
	(0.0006)	(0.0006)	(0.0010)
Observations	61,790	7923	8190

All regressions include firm age, firm size, liquidity, capital intensity, leverage, return on assets, as well as calendar year dummies, province fixed effects, and sector fixed effects

Statistical significance is denoted as follows: $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$

exercise based on firm-level procurement exposure below the €150,000 anti-Mafia documentation threshold. The objective is not to estimate a new causal effect, but to assess whether the WL–NWL-PUB productivity gap persists when WL-ANAC firms are compared with observationally similar NWL-PUB firms.

The matching exercise is implemented at the firm level. We aggregate procurement exposure over the observed period and compare WL firms observed in ANAC procurement records with NWL-PUB firms. The final firm-level sample includes 2410 firms: 1008 WL-ANAC firms and 1402 NWL-PUB firms. The propensity score estimation sample includes 2399 firms, corresponding to 1002 treated firms and 1397 untreated firms.

The propensity score is estimated using a logit model (reported in Table 32) in which the dependent variable equals one for WL-ANAC firms and zero for

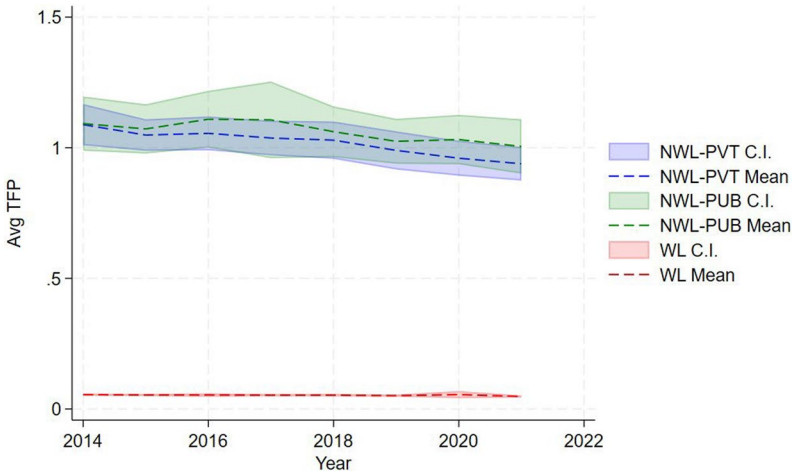

Fig. 13 Average TFP of firms funded by the 2007–2013 programming period

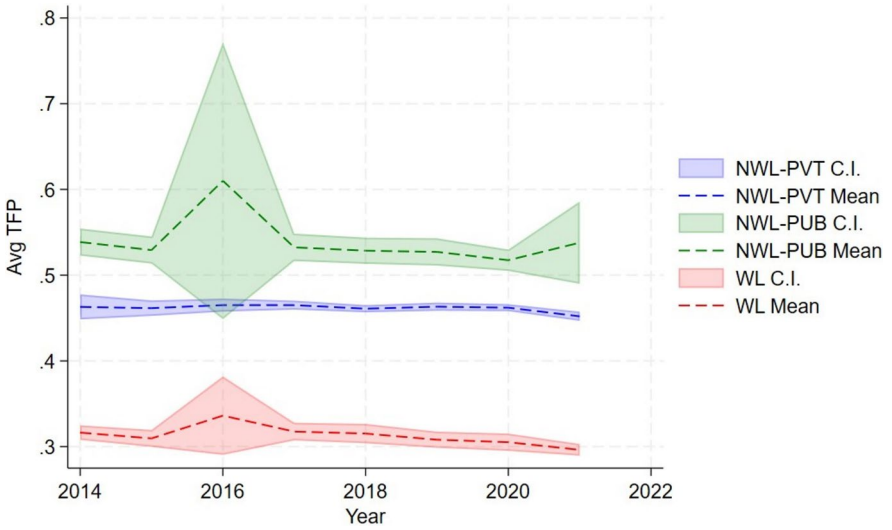

Fig. 14 Average TFP of firms funded by 2014–2020 programming period

NWL-PUB firms. The specification includes firm size, measured by log total assets, the log number of below-threshold CIGs, the log total value of below-threshold CIGs, province fixed effects, and sector fixed effects. Kernel propensity score matching is then applied imposing common support.

Table 33 reports covariate balance before and after matching. The matching procedure substantially reduces observable differences between WL-ANAC and NWL-PUB firms. The standardized bias falls from 29.9 to − 0.7% for log assets, from − 7.8 to 0.3% for the

Table 25 Production function estimates using Wooldridge estimator

	NWL-PVT	NWL-PUB	WL
Labor	0.190***	0.201***	0.208***
	(0.0046)	(0.0143)	(0.0121)
Capital	0.0211***	0.0263***	0.0327***
	(0.0035)	(0.0098)	(0.0103)
Materials	0.0021*	0.0057	0.060**
	(0.0012)	(0.0037)	(0.0029)
Observations	60,461	8011	8073

All regressions include firm age, calendar year dummies, province fixed effects, and sector fixed effects

Statistical significance is denoted as follows: $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$

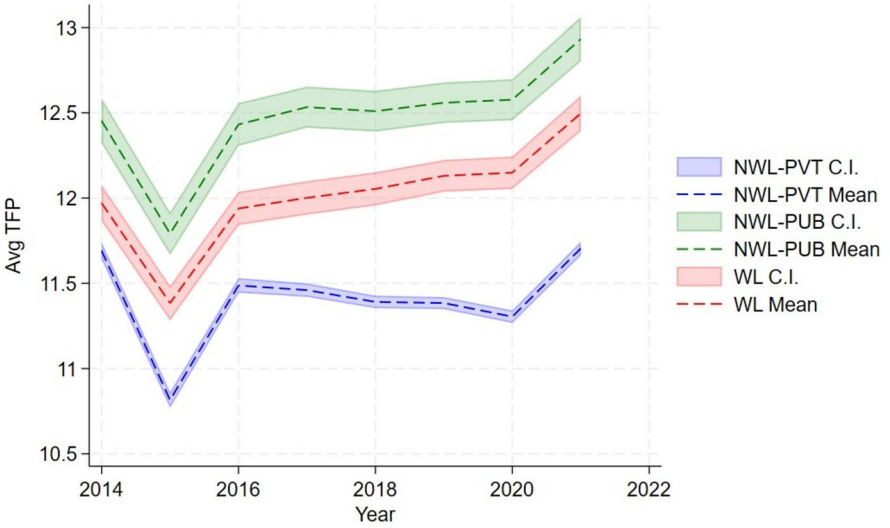

Fig. 15 Average TFP using Wooldridge Estimator

log number of below-threshold CIGs, and from − 10.2 to 0.5% for the log value of below-threshold CIGs. Overall balance also improves sharply: the mean bias falls from 16.0 to 0.5, the pseudo-R^2 from 0.019 to 0.000, and Rubin's B from 32.1 to 2.3.

Figure 20 reports the propensity-score distributions before and after matching. Before matching, WL-ANAC firms are shifted to the right relative to NWL-PUB firms. After matching, the reweighted distribution of NWL-PUB firms closely overlaps with that of WL-ANAC firms, confirming improved common support.

Figure 21 reports average measured TFP for WL-ANAC and matched NWL-PUB firms. The productivity ranking is consistent with the baseline evidence: even after matching on observable procurement exposure, NWL-PUB firms continue to display higher measured TFP than comparable WL-ANAC firms.

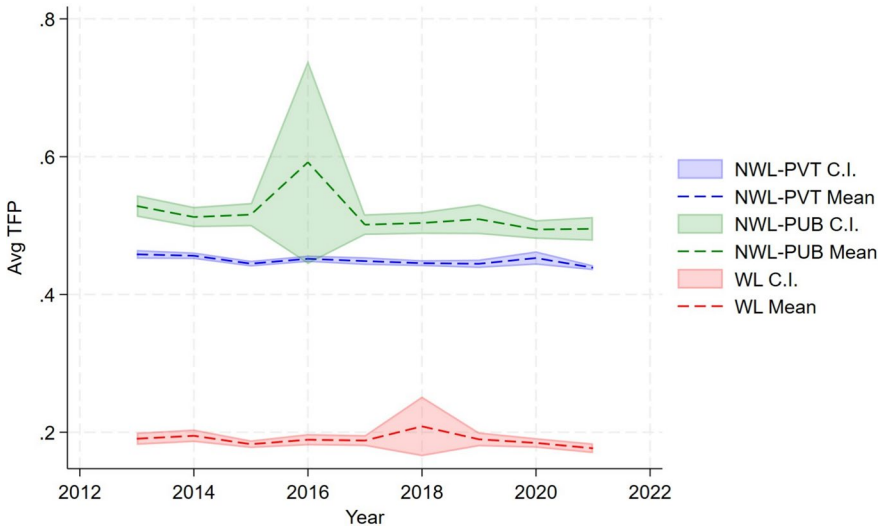

Fig. 16 Average TFP of firms never funded

Table 26 TFP differences under full and size-balanced comparison samples

Comparison	Coefficient	Std. error	*p*-value
Panel A. Full sample NWL-PUB vs. WL 0.062			
		0.010	0.000
NWL-PVT vs. WL	0.037	0.008	0.000
NWL-PUB vs. NWL-PVT	0.025	0.009	0.004
Panel B. Size-balanced comparison sample NWL-PUB vs. WL 0.042			
		0.011	0.000
NWL-PVT vs. WL	− 0.001	0.014	0.917
NWL-PUB vs. NWL-PVT	0.044	0.013	0.001

The dependent variable is log TFP. WL is the omitted category in the baseline specification. Panel A reports estimates from the full sample. Panel B reports estimates from a size-balanced comparison sample that retains all WL and NWL-PUB firms and randomly restricts NWL-PVT firms to a subsample equal in size to the WL group. The comparison between NWL-PUB and NWL-PVT is obtained from the same specification by testing the difference between the corresponding estimated coefficients. All specifications include firm age, firm size, liquidity, capital intensity, leverage, return on assets, calendar year dummies, province fixed effects, and sector fixed effects. Standard errors are clustered at the firm level

Overall, the matching exercise shows that the WL–NWL-PUB productivity gap is not mechanically driven by differences in observable below-threshold procurement exposure. This evidence should nevertheless be interpreted cautiously. Matching improves comparability along observed characteristics, but it does not address

Table 27 EBITDA and institutional alignment: full sample and heterogeneity by Mafia intensity

	(1) Full sample	(2) Low-IMP provinces	(3) High-IMP provinces
NWL-PVT	332.93*	195.47	387.19*
	(178.75)	(269.11)	(224.47)
NWL-PUB	245.63***	76.11	301.09***
	(90.49)	(99.26)	(113.38)
Observations	75,197	21,581	53,615
Firms	14,417	4264	10,153
Controls	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Province FE	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes

The dependent variable is EBITDA. The omitted category is WL-certified firms. Low-IMP provinces include Messina, Ragusa, and Siracusa; high-IMP provinces include all remaining Sicilian provinces. All regressions include firm size, liquidity, capital intensity, leverage, as well as calendar year dummies, province fixed effects, and sector fixed effects. Robust standard errors clustered at the firm level are reported in parentheses

Statistical significance is denoted as follows: *$p<0.1$, **$p<0.05$, ***$p<0.01$

Table 28 ROA and institutional alignment: full sample and heterogeneity by Mafia intensity

	(1) Full sample	(2) Low-IMP provinces	(3) High-IMP provinces
NWL-PVT	1.41***	2.01***	1.16***
	(0.30)	(0.59)	(0.35)
NWL-PUB	1.46***	0.89	1.57***
	(0.37)	(0.77)	(0.43)
Observations	74,140	21,208	52,932
Firms	14,379	4248	10,131
Controls	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Province FE	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes

The dependent variable is return on assets (ROA). The omitted category is WL-certified firms. Low-IMP provinces include Messina, Ragusa, and Siracusa; high-IMP provinces include all remaining Sicilian provinces. All regressions include firm size, liquidity, capital intensity, leverage, as well as calendar year dummies, province fixed effects, and sector fixed effects. Robust standard errors clustered at the firm level are reported in parentheses

Statistical significance is denoted as follows: *$p<0.1$, **$p<0.05$, ***$p<0.01$

Table 29 Operating margins by institutional group

	EBITDA/sales
NWL-PVT	− 1.387*** (0.368)
NWL-PUB	− 2.741*** (0.404)
Controls	Yes
Year FE	Yes
Province FE	Yes
Sector FE	Yes
Observations	86,594
Clusters	16,067

The omitted category is WL firms. The dependent variable is EBITDA over sales. Controls include firm size, liquidity, capital intensity, leverage, ROA, and firm age. Standard errors clustered at the firm level are reported in parentheses

Statistical significance is denoted as follows: ***$p < 0.01$

Table 30 Production function estimates of WL-PUB, WL-PVT, and NWL-PUB

	WL-PUB	WL-PVT	NWL-PUB
Labor	0.297***	0.236***	0.231***
	(0.0062)	(0.0090)	(0.0121)
Capital	0.257***	0.282***	0.296***
	(0.0005)	(0.0013)	(0.0012)
Materials	0.758***	0.738***	0.703***
	(0.0155)	(0.0009)	(0.0019)
Observations	5063	2627	7381

All regressions include firm age, firm size, liquidity, capital intensity, leverage, return on assets, as well as calendar year dummies, province fixed effects, and sector fixed effects

Statistical significance is denoted as follows: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

selection on unobserved determinants of WL status, such as managerial quality, risk preferences, relational networks, expected access to above-threshold contracts, or latent exposure to informal governance.

14.4 WL status, productivity, and Mafia intensity

A further concern is that WL enrollment may reflect negative selection into certification. In particular, less productive firms may choose, or be induced, to obtain WL certification in order to preserve access to public procurement opportunities, especially in high-Mafia intensity areas where institutional scrutiny is stronger and procurement opportunities above the regulatory threshold may be more relevant.

To explore this possibility, we estimate logit and probit models in which the dependent variable equals one for WL firms and zero for NWL-PUB firms. The

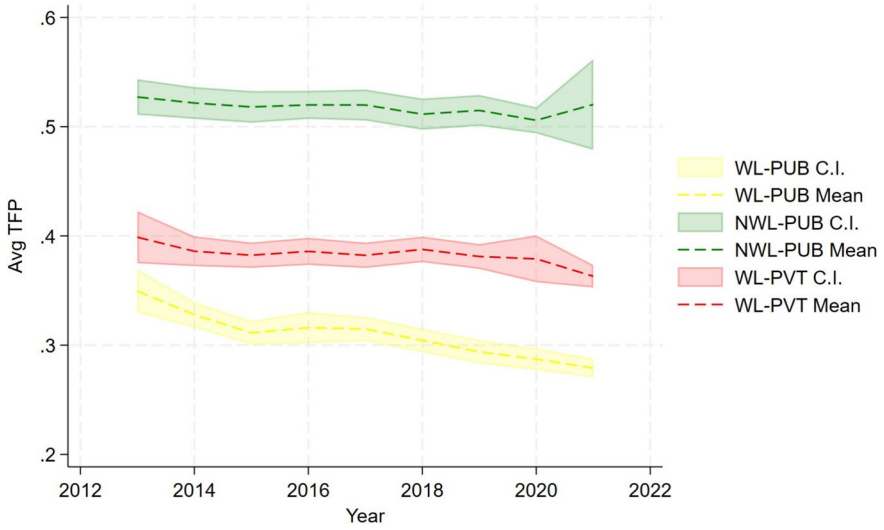

Fig. 17 TFP of WL-PUB, NWL-PUB, and WL-PVT firms

Table 31 Production function estimates, firms segmented by size

	Small			Medium		
	NWL-PVT	NWL-PUB	WL	NWL-PVT	NWL-PUB	WL
Labor	0.201***	0.232***	0.276***	0.898***	0.162***	0.143***
	(0.0016)	(0.0078)	(0.0117)	(0.0079)	(0.0149)	(0.0089)
Capital	0.296***	0.324***	0.282***	0.239***	0.425***	0.520***
	(0.0009)	(0.0004)	(0.0034)	(0.0012)	(0.0038)	(0.0016)
Materials	0.742***	0.674***	0.742***	0.768***	0.565***	0.474***
	(0.0012)	(0.0016)	(0.0082)	(0.0008)	(0.0011)	(0.0015)
Observations	51,675	6715	7054	2756	511	593

All regressions include firm age, firm size, liquidity, capital intensity, leverage, return on assets, as well as calendar year dummies, province fixed effects, and sector fixed effects

Statistical significance is denoted as follows: *$p<0.1$, **$p<0.05$, ***$p<0.01$

sample is restricted to procurement-active firms. NWL-PVT firms are excluded because they are not observed in ANAC procurement records and therefore do not constitute the relevant comparison group for this exercise. The specifications include firm size, firm age, below-threshold procurement value, the number of below-threshold CIG procedures, sector fixed effects, and the interaction between TFP and the high-IMP indicator. We then compute the average marginal effect of TFP separately for low- and high-IMP provinces.

Table 34 reports the results. The marginal effect of TFP on the probability of being WL rather than NWL-PUB is negative in both low- and high-IMP provinces, but it is not statistically significant in either the logit or the probit specification.

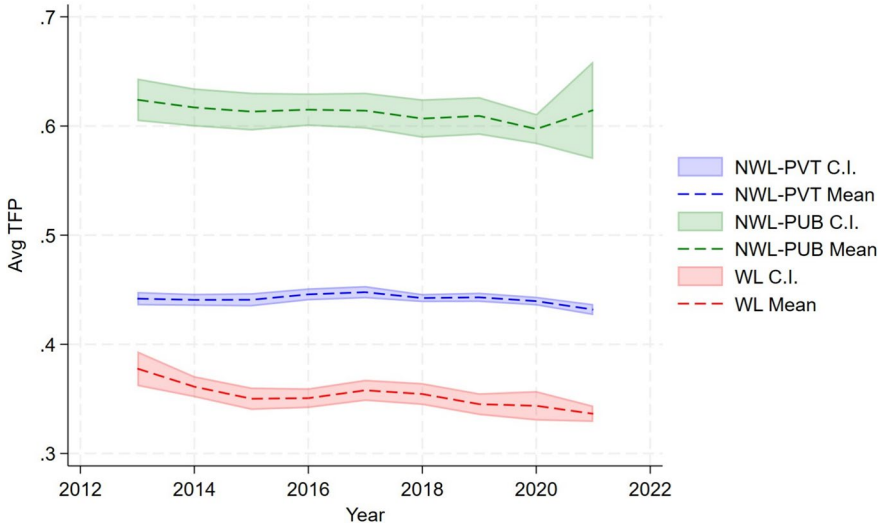

Fig. 18 TFP of WL, NWL-PUB, and NWL-PVT, small firms

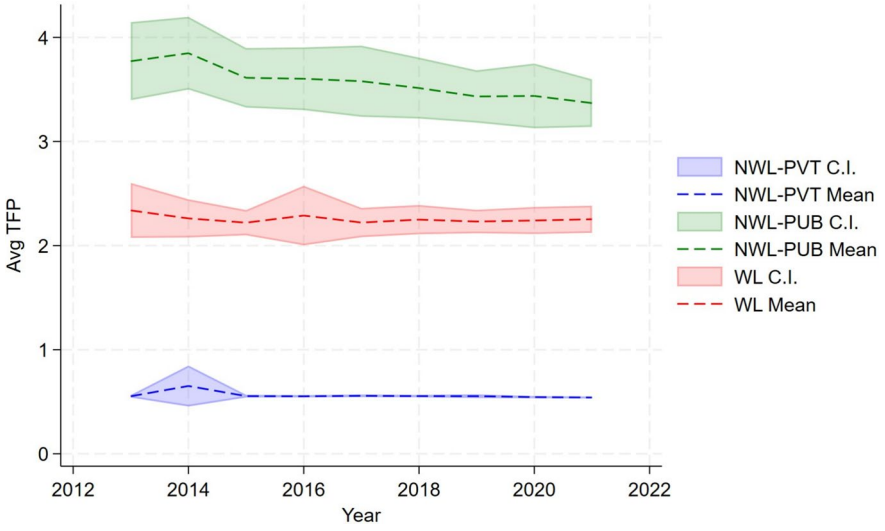

Fig. 19 TFP of WL, NWL-PUB, and NWL-PVT, medium firms

Moreover, the estimated marginal effect is not larger in high-IMP provinces. This evidence does not support the interpretation that lower-productivity firms are systematically more likely to be WL rather than NWL-PUB, nor that such negative selection into certification is stronger in high-Mafia-intensity areas.

Table 32 Propensity score model

	Dependent variable: WL-ANAC firm Coefficient robust s.e.	
Total assets	0.183***	(0.029)
Number of below-threshold CIGs	2.969**	(1.398)
Value of below-threshold CIGs	− 0.527***	(0.196)
Province fixed effects	Yes	
Sector fixed effects	Yes	
Observations	2399	
Pseudo R^2	0.0848	
Area under ROC curve	0.6985	

The table reports the logit model used to estimate the propensity score. The treated group consists of WL firms observed in ANAC procurement records, while the control group consists of NWL-PUB firms. The reported covariates are expressed in logarithmic form using the transformation $\log(x+1)$. Below-threshold CIGs refer to public procurement contracts below the €150,000 anti-Mafia documentation threshold. Province and sector fixed effects are included but not reported. Robust standard errors are reported in parentheses

Significance levels: ***$p<0.01$, **$p<0.05$, *$p<0.10$

Table 33 Covariate balance before and after kernel propensity score matching

	Mean		Std. bias		*t*-test	
Variable	Treated	Control	Before	After	*p* before	*p* after
Total assets	7.118	6.662	29.9	− 0.7	0.000	0.885
Number of below-threshold CIGs	0.006	0.017	− 7.8	0.3	0.067	0.929
Value of below-threshold CIGs	0.039	0.149	− 10.2	0.5	0.018	0.875
Mean bias			16.0	0.5		
Median bias			10.2	0.5		
Pseudo R^2			0.019	0.000		
LR test *p*-value			0.000	0.965		
Rubin's *B*			32.1	2.3		

The table reports covariate balance before and after kernel propensity score matching. The treated group consists of WL-ANAC firms, while the control group consists of NWL-PUB firms. The covariates are expressed in logarithmic form using the transformation $\log(x+1)$. Below-threshold CIGs refer to public procurement contracts below the €150,000 anti-Mafia documentation threshold. Standardized bias is reported in percentage points. Post-matching statistics use the kernel weights generated by the matching procedure

14.5 Additional evidence on OpenCoesione project-scale exposure

This appendix reports additional evidence on whether the productivity ranking across firm types is driven by differences in the scale of the OpenCoesione projects with which firms are associated. For each firm, we compute the average total value

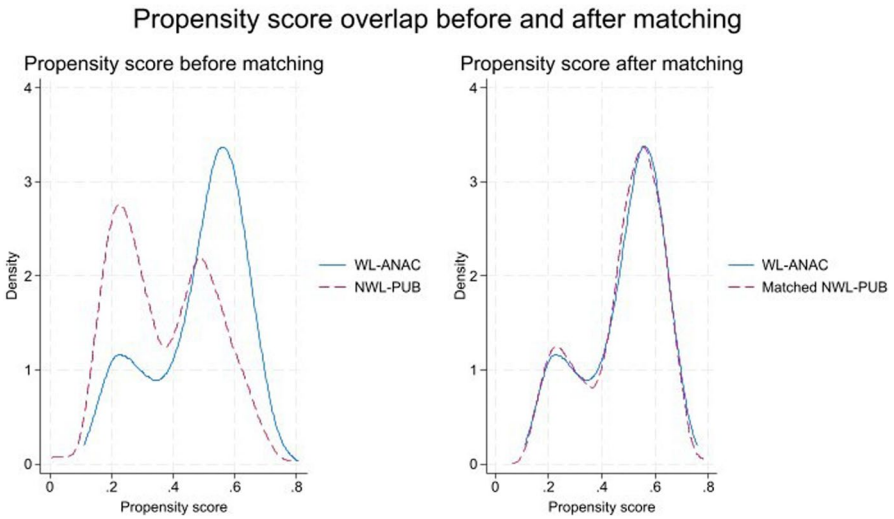

Fig. 20 Propensity score overlap before and after kernel matching. The figure reports kernel density estimates of the propensity score before and after matching. The treated group consists of WL-ANAC firms. The control group consists of NWL-PUB firms. In the post-matching panel, NWL-PUB firms are weighted using the kernel weights generated by the matching procedure

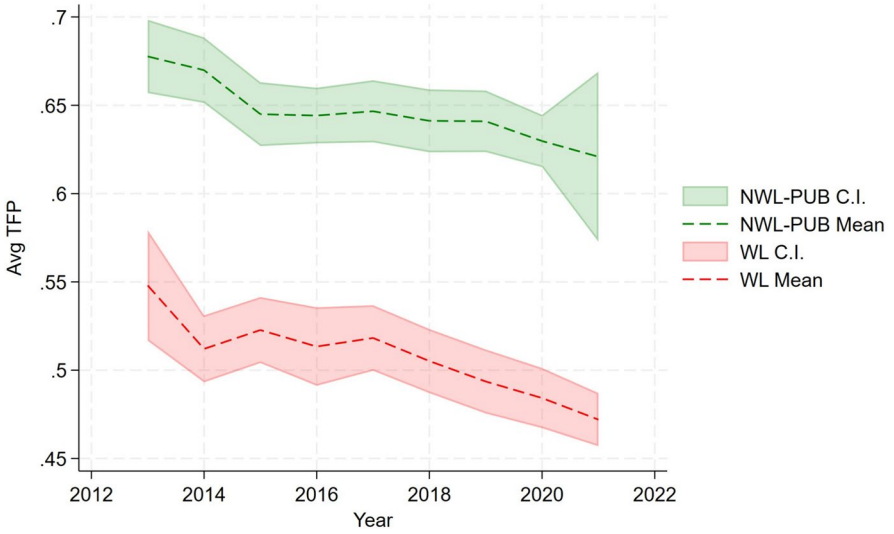

Fig. 21 Average measured TFP of matched WL-ANAC and NWL-PUB firms. Note. The figure reports average measured TFP for WL-certified firms observed in ANAC procurement records and matched NWL-PUB firms. Matching is based on firm size, total awarded below-threshold contract value, number of below-threshold CIG procedures, province, and sector. Shaded areas report 95% confidence intervals

of the OpenCoesione projects in which the firm appears and split the sample according to whether this value is below or above the sample median.

Table 34 Marginal effect of TFP on WL status by IMP area

	Logit	Probit
Low-IMP provinces	− 0.0563	− 0.0542
	(0.0482)	(0.0495)
High-IMP provinces	− 0.0442	− 0.0419
	(0.0289)	(0.0272)
Controls	Yes	Yes
Sector fixed effects	Yes	Yes
Observations	1535	1535

The table reports average marginal effects of TFP on the probability of being WL rather than NWL-PUB, separately for low- and high-IMP provinces. The dependent variable equals one for WL firms and zero for NWL-PUB firms. Logit and probit models include firm size, firm age, below-threshold procurement value, the number of below-threshold CIG procedures, sector fixed effects, and the interaction between TFP and the high-IMP indicator. Robust standard errors are reported in parentheses. Low-IMP provinces are Messina, Ragusa, and Siracusa; high-IMP provinces include the remaining Sicilian provinces

$^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.10$

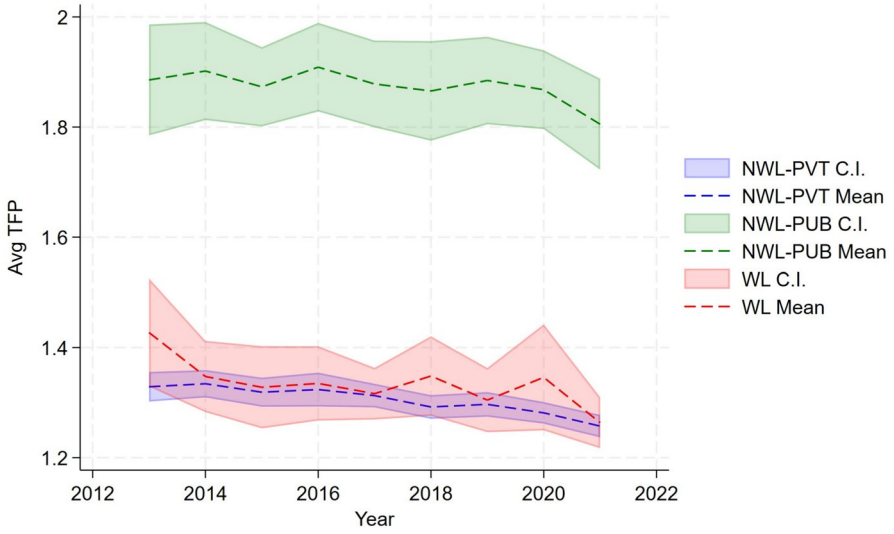

Fig. 22 Average measured TFP by firm type: firms associated with lower-scale OpenCoesione projects

This exercise should not be interpreted as comparing firms receiving smaller or larger amounts of funding. OpenCoesione project values refer to the overall financial envelope of monitored interventions and may involve multiple beneficiaries, implementing bodies, contractors, or procurement procedures. The exercise is therefore intended to capture project-scale exposure rather than firm-level funding intensity or procurement-level competition.

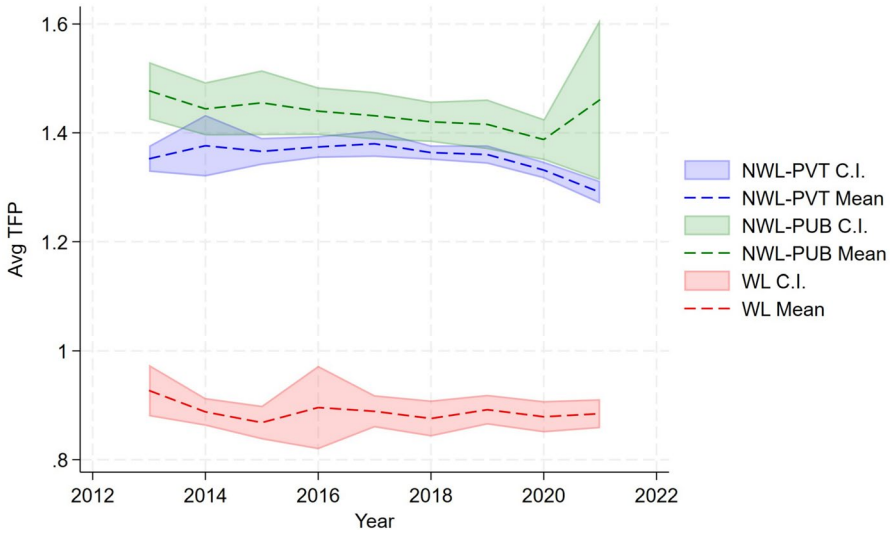

Fig. 23 Average measured TFP by firm type: firms associated with higher-scale OpenCoesione projects

Figures 22 and 23 report average measured TFP by firm type for firms associated with lower- and higher-scale OpenCoesione projects, respectively. In both subsamples, NWL-PUB firms exhibit higher measured TFP than WL firms. The qualitative ranking is therefore preserved after stratifying firms by project-scale exposure.

14.6 Local market thickness

A further alternative explanation is that the observed productivity differences may reflect differences in local market competitiveness. In particular, WL firms may operate in thinner markets, possibly related to larger or more specialized contracts, whereas firms facing denser local markets may be exposed to stronger competitive pressure and therefore display higher measured productivity.

To explore this possibility, we construct a proxy for local market thickness. For each firm-year observation, we assign the number of active firms operating in the same province–sector–year cell, N_{pst}, where p denotes province, s sector, and t year. We then use $\log(N_{pst})$ as a measure of the density of potential competitors in the relevant local market. The available data do not allow us to observe the number of bidders in each procurement procedure or firm-level market shares. This measure should therefore be interpreted as an indirect proxy for local competitive density.

We split the sample into low- and high-thickness markets according to the median of $\log(N_{pst})$ and compare average residual TFP across firm groups. Table 35 shows that the baseline productivity ranking is not driven by WL firms being concentrated in thinner local markets. NWL-PUB firms display higher average measured TFP than WL firms in both low- and high-thickness markets. In low-thickness markets, average residual TFP is − 0.810 for NWL-PUB firms and − 0.861 for WL firms. In high-thickness markets, the corresponding values are − 0.819 and − 0.907.

Table 35 TFP by firm type and local market thickness

Firm group	Low market thickness			High market thickness		
	Mean TFP	SD	Obs.	Mean TFP	SD	Obs.
NWL-PVT	− 0.742	0.404	33,675	− 0.760	0.448	31,177
WL	− 0.861	0.473	3726	− 0.907	0.528	5027
NWL-PUB	− 0.810	0.408	4533	− 0.819	0.463	3982
Total	− 0.760	0.413	41,934	− 0.784	0.462	40,186

TFP is computed as the residual from the production function estimates. Local market thickness is measured as the logarithm of the number of active firms operating in the same province–sector–year cell, $\log(N_{pst})$. Low and high market thickness are defined according to whether $\log(N_{pst})$ is below or above the sample median. Since TFP is measured as a residual in logs, less negative values correspond to higher measured productivity

Table 36 Compliance costs required to explain the NWL-PUB–WL TFP gap

Channel	WL input elasticity	Required log input increase	Required input increase (%)
Labor	0.246	0.741	109.8
Capital	0.243	0.750	111.8
Materials/services	0.758	0.241	27.2

The observed NWL-PUB–WL TFP gap is calibrated as $\Delta = \ln(1.20) = 0.182$. The table reports the input increase that would be required for WL firms to mechanically generate this TFP gap through higher compliance-related input use, holding output constant. The required log input increase is computed as $\Delta / \hat{\beta}_j^{WL}$, where $\hat{\beta}_j^{WL}$ denotes the WL-specific input elasticity from the baseline production function estimates. The percentage increase is computed as $\exp(\Delta / \hat{\beta}_j^{WL}) - 1$

Therefore, differences in local market thickness do not mechanically explain the productivity gap documented in the baseline analysis.

14.7 Compliance-cost calibration (See Table 36)

15 Appendix 9: List of high-risk sectors for Mafia infiltration

Article 1, paragraph 53 of the Anti-Corruption Law and the amended version of Law 40/2020, Article 4-bis, paragraph 2, identify the following activities as being at the highest risk of Mafia infiltration (See Table 37):

Table 37 Sectors identified by Italian Law 190/2012 as high risk

Code	Sector description
(a)	Extraction, supply, and transport of soil and inert materials
(b)	Packaging, supply, and transport of concrete and bitumen
(c)	Cold rental of machinery
(d)	Supply of wrought iron
(e)	Hot freight
(f)	Road transport on behalf of third parties
(g)	Construction site security services
(h)	Funeral and cemetery services
(i)	Catering, canteen management, and food services
(j)	Environmental services (waste collection, transport, treatment, disposal, remediation)

Acknowledgements This paper is part of the research project "The Assessment of Regional Development Policies in Italy through a new Database (1950s–2000s)" PRIN 2022.

Author contributions All the authors contributed equally to the manuscript.

Funding Open access funding provided by Università degli Studi della Campania Luigi Vanvitelli within the CRUI-CARE Agreement.

Data availability Data on firms awarded with the White List are publicly available on the websites of the Italian Prefectures. Firm-level financial data from AIDA are subjected to a proprietary agreement between Bureau van Dijk and Università degli Studi di Napoli Federico II, and cannot be shared directly by the authors.

Declarations

Conflict of interest The authors declare no competing interests.

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