

INSTITUTIONAL COMMITMENT AND ECONOMIC REVIVAL: EVIDENCE FROM PALACE-BUILDING IN RENAISSANCE ROME

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ABSTRACT. I study the recovery of the Roman economy following the papacy’s absence (1309-1377), specifically, an era of palace-building resulting in the construction of over 35% of palaces built in Roman history. Using a novel dataset, I show that the late-15th-century palace-construction boom was triggered by credible institutional commitment. Two reforms (1475, 1480) allowed prelates to bequeath their possessions and reduced costs for all patrons, causing a significant increase of prelate palace-building. Initial prelate investment guaranteed the papacy would remain in Rome long-term, which eventually incentivized laymen to invest. I disentangle the effect of commitment to long-term presence from contemporaneous papal presence to show that the irreversibility of institutional change is a necessary condition for successful intervention.

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1. INTRODUCTION

In early-modern Europe, palace-building was an engine of economic growth and a symbol of urban prosperity. Italian city-states – including Florence, Venice, Milan, Urbino, Ferrara – saw their renaissance skylines mature by the early-to-mid fifteenth century. Palace-building was enshrined as a civic activity in mercantile republics, a courtly display of strength in principalities, an homage to an old tradition all across the peninsula. Yet, Rome’s palace-building boom arrived unusually late – beginning only in the late fifteenth century when palace-building in other Italian city-states had already passed its zenith.¹ The sudden and enduring surge in construction in the late fifteenth century remains a historical and economic puzzle: what was the cause of Rome’s delayed palace-building?

I argue that the turning point was a shift in patrons’ beliefs about the future of Rome, specifically vis-à-vis the papacy. Early-modern Rome was, in many ways, a company town. The prosperity of the city, and patrons’ willingness to invest in its future, were dependent on their beliefs about whether the papacy would remain in Rome long-term. The papacy returned to Rome from Avignon in 1378, following a seven-decade absence from the city, yet for nearly a hundred years little was built. The conceivably temporary return of the popes to Rome only became credibly permanent a century later, due to two papal reforms, issued in 1475 and 1480, and it is following these reforms that Rome’s restoration began in earnest. By allowing ecclesiastical officials to bequeath property (1475) and by easing restrictions on urban land acquisition for the purpose of palace-construction for all patrons (1480), the reforms created both the incentive and the capacity to invest in Roman real estate. More importantly, the reforms generated a self-perpetuating mechanism binding the papacy to Rome: high-ranking ecclesiastical officials personally financially invested in the city’s real estate would never support candidates inclined to leave the city. The irreversible commitment to long-term presence, in turn, gave rise to a century-long construction boom that reshaped Rome’s economy. By contrast, none of the previous historical shocks or policy interventions had a self-perpetuating mechanism, and so lacked the credible longevity responsible for the success of the papal reforms.²

I use a novel hand-coded dataset linking palace-construction and patron identities over the course of more than 200 years to quantify the Roman palace-building boom and test the proposed mechanism. I pair a seminal map of Rome with a manual data classification effort, allowing me to trace investment patterns at the level of individual projects, with granular tracking of patron classes and construction details. I document that between 1470 and 1599

¹See Section 3 and especially Figure 2 for a discussion of Roman palace-building compared to other Italian city-states.

²The mechanism I describe here is, therefore, fundamentally different from temporary financial relief or a single pope signalling his good intentions via an ambitious building agenda. Optimism about a single pope gives little reason to have faith in his successors.

– within roughly a century after the reforms – 31% of all recorded Roman *palazzi*³ erected from antiquity to the 21st century were constructed, and 42% saw construction or major renovation. Of these, 84% are today extant, and an additional 8% are partially preserved.⁴ Figure 1 highlights the dramatic change in investment patterns after the papal reforms: in just over a century, a city suffering from decay – caused largely by institutional dereliction and impotence – became a Renaissance metropolis.

To establish a causal link between the reforms and the ensuing construction boom, I exploit the selective nature of the 1475 reform: the papal bull⁵ allowed high-ranking ecclesiastical officials (prelates) to bequeath their inheritance to an appointed heir, dropping their effective tax-rate on inheritance from 100% to 0%, while laymen continued to face no inheritance constraints. The 1480 papal bull, in turn, allowed for easier land acquisition for the purpose of palace-construction for all patrons. Taken together, these papal bulls gave the incentive (to one group) and capacity (to the whole population) to engage in palace-construction. I use a difference-in-differences design to compare investment by prelate and lay patrons before and after the reforms, treating the two papal bulls as a single institutional change and setting the cutoff at 1470 to avoid any possibility of anticipation effects.⁶ I estimate that the reforms increased per-capita new palace projects among prelates by roughly 307% relative to their pre-reform mean. In absolute terms, this corresponds to about 4.33 additional palace projects per decade among prelates. The magnitude and timing of this effect cannot be explained by contemporaneous papal presence, general wealth trends, or citywide demand shocks.

Indeed, a de facto tax-cut and cost-reduction alone would likely be insufficient to explain the rise of palace-building: in a precarious political and economic environment, having no meaningful guarantee that the papacy would remain in Rome long-term, patrons were hesitant to invest in local real estate. I show that the 1475-80 reforms had such a dramatic effect on Rome’s recovery precisely because of their perceived longevity: the reforms transformed the papacy’s return from a temporary political event into a credible institutional commitment by means of a recursive incentive constraint. Before the reforms, cardinals could not transmit wealth to heirs and therefore had little reason to invest in illiquid, immovable assets. After the two reforms, they could, and quickly developed a personal interest in the papacy remaining in Rome. A crucial institutional detail rendered the 1475 and 1480 papal bulls self-sustaining: cardinals elect popes and popes appoint cardinals. Prelates heavily

³Edifices usually serving as residences. To abstract from patterns driven by nomenclature, I broaden the category to include all plausibly-inheritable real estate according to historians’ records; see section 4.

⁴These figures are conditional on the availability of data. The unconditional rates (including as non-extant landmarks for which present condition is not reported) are 82% and 8%.

⁵A papal bull is a charter issued by the Pope. The term derives from the seal (*bullā*) used to attest to the authenticity of the document. Such bulls were a common way for popes to issue public decrees, and ranged in content from executive legislation to theological commentary. They are traditionally referred to by the first few words of the Latin text.

⁶Sixtus IV, who instituted the reforms, was elected in 1471 – just after the 1470 cutoff.

invested in Rome would never elect a pope who would leave the city or who would annul this papal bull, devaluing their own investments.⁷ A pope who wanted to stay in Rome would not promote to a cardinalate a bishop averse to his agenda. Future generations would – in recursive fashion – be bound by the same incentive constraints.

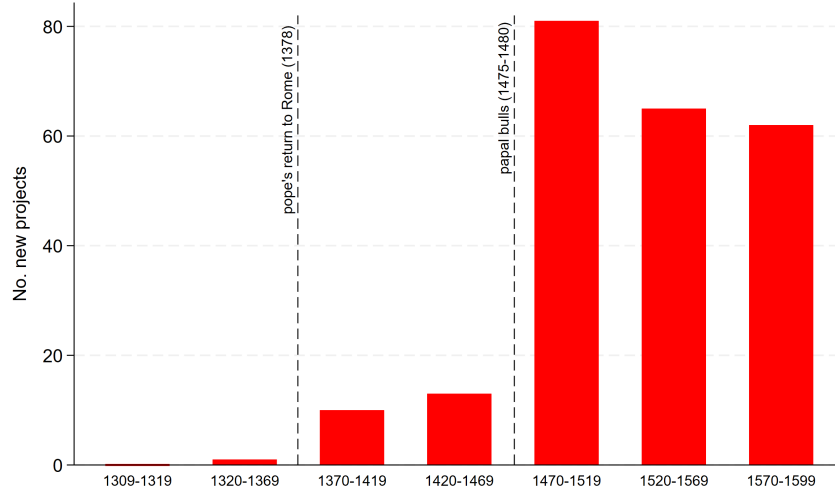


FIGURE 1. Number of new palace-building projects

This figure presents the total number of new projects in palace-building by 50-year intervals, from the start of the Avignon Papacy (1309-1377) until the end of the sixteenth century. It is clear that, though the pope’s return to Rome in 1378 did correspond to a modest increase in investment, it alone cannot explain most of the recovery. Indicated by vertical lines are the return of the pope to Rome (1378), and the hypothesized cause of the change in investment patterns: the 1475 and 1480 papal bulls, which constituted a dramatic reform of inheritance laws. (The 1309-1319 bin is truncated; its cutoff reflects the start of papal absence from Rome.)

I furnish evidence consistent with an informational spillover and learning about the papacy’s commitment to remain in Rome. I document that the papal bull had a real effect on long-term papal presence in Rome. Post-reforms, papal absences decreased by 81.5%, and discretionary papal absences (which were plausibly interpretable as signals of the pope’s unwillingness to be in Rome) disappeared altogether. This supports the interpretation that pre-reforms, the papacy’s presence in Rome was plausibly temporary and easily-reversible, and became truly permanent only after the reforms. Moreover, I find that contemporaneous papal presence, before or after the reforms, did not matter for investment decisions; only the credibility of permanent presence mattered. It follows that, pre-papal-bull, the pope’s presence was not a meaningful predictor of future presence, and post-papal-bull, any papal absences were understood to be temporary.

⁷In fact, post-1379, only cardinals have been elected popes, though, in principle, any Catholic man is eligible for the role.

I also document a pattern of investment illustrative of a gradual diffusion of updated beliefs: I show that, as laymen increasingly believed in long-term papal presence by observing past prelate investment, they increased their investment commensurately.⁸ In the first 50 years following the implementation of the papal bull, 10 new prelate projects in one decade translate into 7.3 additional new lay projects in the subsequent decade. After this pivotal half-century, during which about 80% of cardinals started an investment project, the commitment mechanism was meaningfully in place, and lay beliefs were fully updated to reflect the guarantee of papal presence. Past prelate investment stopped having an effect on future lay investment thereafter. Conversely, past pooled investment is not a predictor of future investment, neither for the population as a whole, nor for the laity. That the effect is so limited in scope and time is inconsistent with generic spillover channels, and suggests that lagged prelate investment conveyed information about the papacy’s long-term presence in Rome, which was uniquely beneficial for laymen.

Finally, consistent with the hypothesis of patrons’ increased confidence in the city’s long-term future, project ambition – as measured via novelty – also increased post-reform among both patron groups. In the first 25 years after the papal bull, the number of novel projects increased eight-fold, while projects aimed at the refurbishment of existing palaces only tripled. The increased ambition was most pronounced among lay patrons, who benefited only from the guarantee of long-term papal presence in Rome.

This paper seeks to contribute to two main literatures. First, it adds to the literature on the economic history of early-modern Europe by providing the first quantitative city-level study of Rome’s palace boom. Despite the historical significance of the papacy, the Papal States, and the city itself, Rome’s urban development remains understudied (especially compared to Florence or early-modern states North of the Alps), mostly due to data scarcity. The significance of the 1475 and 1480 papal bulls (“etsi universis” and “etsi de cunctarum civitatum”, respectively),⁹ introduced by Pope Sixtus IV (r. 1471-84), vis-à-vis palace-building has been echoed in the conjectures of several historians’ works but has never been formally articulated or tested.¹⁰ The second literature bears on institutions, commitment and development. Several influential theoretical works have identified that the good intentions of institutions do not always manifest in good economic outcomes (Rodrik, 2000),

⁸This suggests that all estimates of the direct effect of the papal bull obtained via a dynamic comparison of prelates and laymen ought to be taken as a lower bound on the true effect.

⁹A papal bull is a charter issued by the Pope. The term derives from the seal (*bulla*) used to attest to the legitimacy and authenticity of the document. Such bulls were a common way for popes to issue public decrees, and ranged in content from executive legislation to theological commentary. They are traditionally referred to by the first few words of the Latin text.

¹⁰I first discovered mention of these papal reforms in Bartlett (2013) and am grateful to the author for introducing me to this reform and to the subject of Rome’s revival. The papal bull hypothesis is perhaps most formally articulated in a footnote of Frommel (1988).

posited uncertainty as a cause of urban underdevelopment (Titman, 1985)¹¹, and proposed the irreversibility of institutional change as a necessary condition for successful intervention (Acemoglu, 2012; Greif, 2006; North, 1990; Roland, 2004). Such conjectures have proven difficult to test empirically due to simultaneity problems and confounding variables: the substance and longevity of policy are generally inextricably tied.

In this paper, I exploit a unique economic recovery in late 15th-century Rome, a setting in which it is possible to disentangle the effects of institutional change and the irreversibility thereof.¹² The Roman setting offers a unique laboratory for tests of how investment appetites and economic outcomes respond to institutional credibility and the perceived permanence of policy, which are not necessarily feasible with more modern data due to insufficiently long time-horizons and a preponderance of confounding variables. Real estate investment, due to its illiquidity and construction duration, is a potent litmus test of public confidence in the city's long-term prospects.

The paper proceeds with a survey of the relevant literature (section 2) and of the papal bulls in their historical context (section 3). Section 4 introduces the data. The conceptual framework and corresponding hypotheses are outlined in section 5. Section 6 presents the empirical results, which are then discussed in Section 7. Section 8 presents historical evidence on the contemporaneous environment and instability, Romans' attitudes to papal presence, and voting patterns of prelates, and argues that these were meaningfully reshaped by the reforms. Section 9 concludes.

2. LITERATURE REVIEW

The relationship of institutions to economic growth has received abundant attention from economists; particularly influential works include Acemoglu et al. (2005), Acemoglu and Robinson (2008), Greif (2006) and North (1990).¹³ A number of papers, including Nunn (2008) and Dell (2010), show empirically that a deterioration of institutional quality – caused, in particular, by short-termist or extractive attitudes – has long-lasting harmful effects on economic development.

¹¹The uncertainty in Titman (1985) pertains primarily to the future value and use of the land, which is perfectly commensurate with Rome's reliance on the papacy. The author even shows that government interventions aimed at encouraging real estate development can have limited or even adverse effects if they do not address the uncertainty that forestalled the development in the first place.

¹²The emphasis on credibility and reputation as determinants of effective policy intervention can be traced back, at least, to Fellner (1976, 1979), Kydland and Prescott (1977) and Barro and Gordon (1983a,b) in the context of monetary policy, and has since proliferated to a wide variety of literatures, including those on development and urban revival.

¹³For a broader survey of sources of economic development, see Mokyr (1990), which describes the scholarly consensus that growth has historically been attributable to one of four factors: gains from trade and specialization, technological change, capital accumulation, and efficiency growth (the latter primarily due to attenuated misallocation of resources). The explanation posited in this paper fits well with the notion of efficiency growth: the prohibition on clerical bequests and the lack of long-term institutional commitment on the part of the papacy stifled opportunities for investment and hence growth.

Successful institutional interventions have also been documented, though causal identification of mechanisms remains more elusive. North and Weingast (1989) demonstrate the role of constitutional changes following the Glorious Revolution, while Stasavage (2002) shows how political representation enhanced sovereign credibility in early-modern Europe. State capacity and (fiscal) credibility are explored by Drelichman and Voth (2014) in Spanish sovereign debt markets; by Cantoni et al. (2024) through administrative innovations in the Holy Roman Empire; and by Besley and Persson (2009) through an analysis of state investments in fiscal and legal capacity. In a theoretical work, Acemoglu and Robinson (2006) highlight the contribution of democratic institutions, characterized by their credibility and by aligned incentives among the elites and the governed.¹⁴

Thus, while a causal link between specific kinds of destructive institutional behaviour and negative economic outcomes is well-established, it remains difficult to empirically identify a mechanism explaining the success of certain institutions and the failure of others to stimulate economic growth. The challenge arguably owes, at least in part, to the asymmetry of institutional credibility: trust is easier lost than (re-)gained,¹⁵ and institutional practices which could positively contribute to credibility frequently co-occur, so necessary conditions are difficult to identify.

I derive one particular conjecture from a few seminal works on the subject (Acemoglu, 2012; Greif, 2006; North, 1990; Roland, 2004): that the irreversibility of institutional change is a necessary condition for successful intervention. I exploit the papal return to Rome to test one conjecture in particular. In the theoretical literature (Aoki, 2001, 2011; Greif, 2006; Schotter, 1981), institutions are often thought of as equilibria and analyzed in game-theoretic fashion; “irreversibility” is, therefore, naturally understood as precluding profitable deviation.

The present study benefits from a unique historical setting to overcome the simultaneity issue and isolate the effect of the irreversibility of the pope’s return: a century elapsed between the return of the papacy and the reform of inheritance laws¹⁶ that arguably rendered impossible another papal departure.¹⁷ Consistent with the game-theoretic notion of

¹⁴Commitment and institutions are also discussed, in the context of policy-implementation, in a theoretical work by Bassetto et al. (2024).

¹⁵See, e.g., Nunn and Wantchekon (2011), which shows that effects of deteriorated trust in individuals and institutions persist for centuries.

¹⁶Research on inheritance typically considers effects on inequality by examining the role of marginal changes to inheritance taxes. (See Piketty and Zucman (2015) for a survey.) This paper makes no comment on marginal effects, due to the non-marginal nature of the reform, but suggests that bequests are a necessary condition for real-estate investment. Of course, the peculiarity of the setting is such that I make no claim of external validity for a modern context beyond the intuition that inheritance and long-term beliefs are a motivation for investments at long time-horizons. (See Botticini and Siow (2003) and Botticini (1999) for a discussion of strategic considerations related to property transfer. The authors propose dowries, in Renaissance Italy among other settings, as an optimal form of premortem bequests in view of the heterogeneity in incentives among sons and daughters.)

¹⁷That the reform had a more limited scope (only prelates’ inheritance constraints were affected) than set of beneficiaries (lay and prelate patrons responded favourably) – in combination with analysis ruling out

forward induction,¹⁸ perceived irreversibility obtains from a recursive incentive constraint on prelates charged with electing future popes: prelate palace construction is irrational unless prelates also intend to exercise their voting powers to ensure that the pope remains in Rome; otherwise, their real-estate holdings will lose all value.

This paper also contributes to the literature on the papacy and its effect on European economic development. No institution has been more influential in medieval and early-modern European political, economic and social affairs than was the Catholic Church.¹⁹ In existing scholarship, the importance of the papacy has been inferred from the consequences of its absence in cities affected by the Reformation. The institutional vacuum left by the withdrawal of the papacy from Protestant German cities was typically filled by local secular actors: Cantoni et al. (2018) characterize the implications of the Reformation on German universities and human capital; Dittmar and Meisenzahl (2020) also find the development of secular infrastructure in post-Reformation Germany. The return of the papacy to Rome offers an exceptional opportunity to consider the effect of the papacy on economic development directly.

3. THE PAPAL BULLS AND THEIR HISTORICAL CONTEXT

3.1. Rome Compared to Other Cities. The papacy’s withdrawal to the south of France (1309-1377) brought Roman life to a halt. Contemporaries likened the derelict city to a “great stable for sheep” and a “cadaver.”²⁰ The return of the papacy to Rome changed little: the city continued to struggle.

Meanwhile, an architectural renaissance begun in other Italian city-states. Trachtenberg (1997) places the peak of Florentine palace-building c.1400–1530, the eras of Medici power and civic humanism, and Goldthwaite (1980) defines 1300–1500 as the golden age of Florentine urban domestic architecture more broadly. Tafuri (1989) argues that renaissance palace-building is best-framed in a long continuum from Byzantine prototypes to renaissance reinterpretations in the 15th–16th centuries. Venice developed a stable palace typology in the 13th century and the main urban palace-building boom started as early as the 14th century (Howard, 2002).

spillovers – furthermore lends credibility to the view that effects are attributable to long-term commitment to institutional presence, not to the de facto tax cut per se.

¹⁸The natural counterpart to backwards induction, forward induction defines rationality by considering past play as optimal conditional on future behaviour. Most pertinent to this setting is Battigalli and Siniscalchi (2002), which models how players revise beliefs in the face of unexpected actions by others, such as surprising institutional changes; other foundational works in the forward induction literature include Cho and Kreps (1987), Govindan and Wilson (2009), Kohlberg and Mertens (1986), Man (2012) and Vida and Honryo (2021).

¹⁹Such was the importance of the Church in the early-modern European economy that Buringh et al. (2020) proposed Church constructions in the so-called Age of Cathedrals as a proxy for overall construction and economic development.

²⁰Both epithets are due to humanist orator Aurelio Brandolini, as quoted in Blondin (2005).

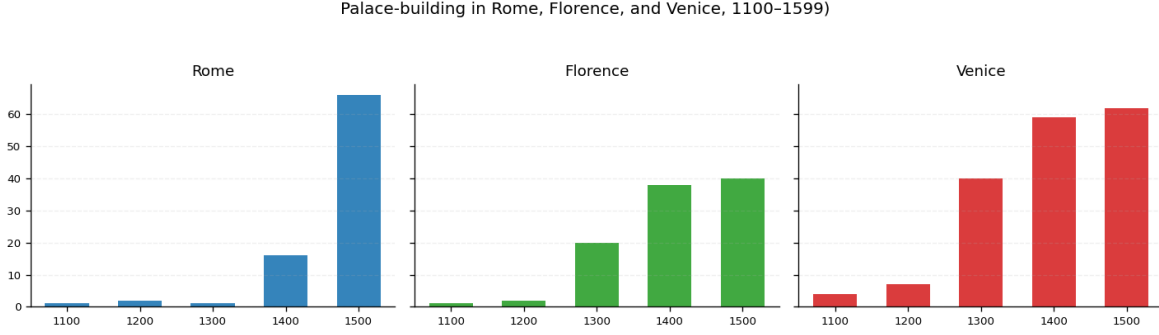


FIGURE 2. Palace-building in Italian City-States

With data obtained from the Beni Culturali's ArCO, I plot palace-building eras in three major Italian city-states by century of construction. The trend is clear: palace-building begins considerably later in Rome, and the pattern is much sharper as well.

Conversely, Frommel (1973) demonstrates that the true Roman "palazzo" emerged very late, between 1480 and 1550. Frommel explicitly contrasts Rome with Tuscany, arguing that Roman palace-building was a Renaissance phenomenon. Furthermore Krautheimer (1980) presents an account of medieval Rome as a city without a strong tradition of urban domestic palaces.

By collecting data from ArCO (*Architettura della Conoscenza*), a repository of cultural heritage records, developed by the Italian Ministry of Culture, I obtain a high-level empirical corroboration of these arguments. Figure 2 presents palace-construction in Rome, Florence and Venice from 1100 to 1599. Consistent with abundant scholarly work on the matter, it is clear that palace-building comes to Rome much later than to other city-states.

3.2. The Papal Bulls. Sixtus IV's 1475-1480 ingenious papal bulls exploited self-interest, graft, and preferment²¹ within the Church to fuel the rebuilding of the city. Prior to 1475-1480, prelates took advantage of papal coffers, but were unable to produce a legitimate heir due to clerical vows of celibacy and were constrained in their investment by regulation. The obligation to bequeath all of their possessions to the Church was meant to temper their appetites. Rather than encourage austerity, however, such constraints inadvertently promoted the most frivolous forms of conspicuous consumption. As they could leave nothing

²¹A big element of papal power was the right to nominate, and to transfer, from one to another office outside of Rome. So preferment was a common way to accumulate wealth: a cardinal could simultaneously be the bishop of Ravenna, the abbot of some wealthy monastery. He could then install a vicar to do the work on-site and cull the income. Graft, too, was wide-spread: prelates made a habit of hiring nephews and otherwise of using the offices of the Church to their advantage. Hallman (1985) traces the businesses of churchmen from 1494 to 1563, including the sale of offices, an essential part of clerical income, and various cases of financial abuse. See Ago (1990) for a discussion of prelates as a source of wealth for their families, albeit in a later time-period (during the Baroque era).

to family, prelates spent papal wealth on feasts, hunts, and entertainment, and made few meaningful investments in the Roman economy (Bartlett, 2013).

Frommel (1988, p. 48, footnote 14) breaks down the two-bull initiative: “Sixtus’ two famous bulls were meant to stimulate the building of sumptuous palaces, and showed the strong influence of nepotism. The bull of 1475 allowed prelates to leave a palace or country house near Rome to relatives even if it had been built with income from the church; the second bull, of 1480, enabled builders of sumptuous palaces to incorporate adjacent land or houses.” (See also (Müntz, 1878, pp.180-187) and Spezzaferro (1981).)

There was no mandatory tax on inheritance at the time,²² and land acquisition costs were considerably reduced. Prelates had a reason to invest in the city; their initial investment then bound the papacy to Rome, which, in turn, gave rise to lay investment.

Popes are elected by the College of Cardinals, and, from 1379, have come only from the College itself. Thus, for there to be a pope who decides to leave Rome (or otherwise act against the best interests of the city), the sentiment would, in principle, have to be tolerated by a majority of electors.²³ Cardinals with significant investment in the city’s real estate would clearly be reluctant to move and would not lend their support to a pope who did so, and few candidate-popes could even conceivably have different incentives, given that popes were chosen from among cardinals. A pope elected on the promise to remain would not, in turn, appoint cardinals opposed to his agenda. The reform thus gave rise to an endogenous and recursive incentive constraint: the more invested in the city cardinals became, the less likely was the papacy’s departure.

4. DATA

Rome lacks the systematic cadastral records that survive for many of her neighbours. The compilation of the first comprehensive database of Roman construction projects with economically-relevant classifications is one of the main empirical contributions of this paper. I construct a panel dataset of palace-construction projects in Rome between 1309 and 1599 at the project-patron level. Each observation corresponds to a single investment project at a specific palace site. I classify every project, first, by its type (new construction or refurbishment of an existing palace), and, second, by its patron’s status (prelate vs lay). The classification is hand-coded; 43.7% of projects required supplementary historical materials to complete. Details, examples, and full source references are reported in the Online Appendix.

Giambattista Nolli’s extraordinarily-precise 1748 catographic survey of Rome, digitized in 2005 by a team of architectural historians (Tice et al., 2021), contains the architectural

²²Custom, however, obliged bequests to include some donations, especially to charitable or religious organisations (e.g., confraternities). See, e.g., Cohen (2025) for a microhistorical account of a specific instance of the practice in Rome, and Jr. (2012) for a broader discussion of the economic and cultural significance of inheritance and associated behavioural patterns in Renaissance Italy.

²³While surprises were possible in principle, cardinals had every reason to vet nominated colleagues carefully to prevent this, and had a corrective mechanism (i.e., the next election) at their disposal.

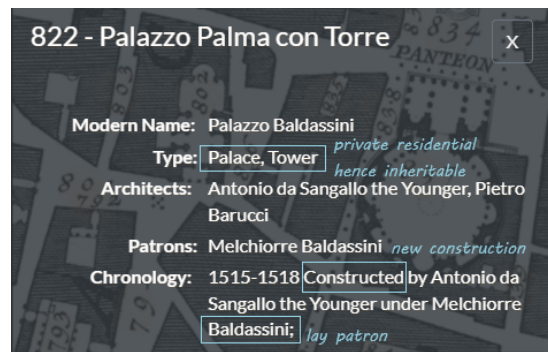


FIGURE 3. Giambattista Nolli's "La pianta grande di Roma" (c. 1748)

history from antiquity to the 21st century of some 1300 landmarks across Rome. I extract information on the name, type, patrons, and construction timeline of each landmark (among other variables) for each palace-site.²⁴

4.1. Classification. I classify projects as built (new construction) or rebuilt (refurbishment, restoration, or major acquisition). Patron type distinguishes prelates (those bound by inheritance constraints before 1475) from laymen. Classification occurs at the project level: a single palace can host multiple projects with patrons of different types. (Within the difference-in-difference sample period, there are no projects jointly financed by laymen and prelates, ensuring that the treatment and control groups are disjoint. Joint financing occurs outside the sample period, notably there is one co-financed project in 1541 and one in 1590.) I resolve ambiguous cases using external archival, and primary and secondary historical sources. I document each classification decision and source – in addition to explaining the construction of category definitions – in the Online Appendix. Figure 4 contains an example of classification of an entry.

²⁴To avoid nomenclature-sensitive results, I include all plausibly-inheritable real estate: villas, towers, etc.



(A) Nolli map excerpt annotated with classification details



(B) Baldassini's tomb in Chaalis Abbey, France (Image from Wikipedia Commons)

FIGURE 4. An Example of data classification: the Palazzo Baldassini

Palazzo Baldassini – in those days, the Palazzo Palma con Torre – is, the Nolli map entry tells, “constructed by Antonio da Sangallo the Younger under Melchiorre Baldassini” between 1515 and 1518. Now, Sangallo the Younger is a fashionable architect: his are Palazzo Farnese (completed later by Michelangelo), Santa Maria di Loreto, Villa Madama (following the death of Raphael), even parts of St. Peter’s Basilica. To hire an architect of this calibre, Melchiorre Baldassini can be no ordinary patron. But just who he is remains a mystery. The furtive Baldassini declines all requests for closer acquaintance and takes his secret to the grave. Rather literally, in fact. It is his tomb that reveals the answer. A marble effigy sleeps peacefully on a bed of books; a Latin inscription pays homage to an illustrious career as a jurist. Then comes a paper by S  n  chal (1999) marvelling at a surprising discovery in Chaalis of the tomb of one Melchiorre Baldassini, one of the most eminent Roman legal scholars of the early 16thC. The mystery is solved, the patron identified as a layman, the project classified. (In general, I consider a patron’s occupation sufficient grounds to identify a patron as prelate or lay. All classifications retained in the final dataset are unambiguous; the very few projects for which it was not possible to produce compelling direct evidence of a patron’s status have been dropped from the final dataset.)

After dropping isolated and sporadic mentions of rent or palace dereliction²⁵ and nine unclassifiable projects without credible dating, I obtain a dataset with 222 projects at 139 distinct palace sites. Table 1 presents an overview.

4.2. Population Controls. Because the number of potential prelate patrons is much smaller and more slowly varying than that of lay elites, it is necessary to control for population sizes. Importantly, I show population growth to be continuous and explicitly control for population levels, which rules out the possibility that the palace-construction boom is simply driven by a demographic shock.

For prelates, I compile annual counts of living cardinals from the Consistories of Cardinals, the official papal records of appointments, between 1305 and 1700, paired with their mortality dates. The identified population – living cardinals already in office – represent

²⁵In reality, such events ought not to be sparse, but the digitized Nolli map’s coverage thereof is not systematic enough to be exploitable; the map’s focus is on significant construction events influencing a site’s architectural history.

<i>Sample: Nolli Map</i>	All			Prelates		Laity		
	all records	1378-1599	1378-1469	1470-1599	1378-1469	1470-1599	1378-1469	1470-1599
<i>Panel A: Roman construction</i>								
No. map mentions	5025							
No. sites	1319							
No. active palace sites	328	161	28	151	12	50	16	101
Currently extant	251	134	22	127	10	43	12	84
Partially extant	25	13	4	10	0	4	4	6
Demolished	56	13	2	13	2	3	0	10
<i>Panel B: Inheritable projects</i>								
No. inheritable projects		230	22	208	10	77	12	131
No. palaces built (sites)		120	15	105	8	26	7	79
No. palaces reconstructed (sites)		114	9	105	3	53	6	52
<i>Panel C: Inheritable project lengths (years)</i>								
min length		1	1	1	1	1	1	1
max length		152	101	152	51	101	101	152
mean length		22.83	40.86	20.92	18.8	9.73	59.25	27.50
median length		1	44.5	1	9.5	1	51	1

TABLE 1. Summary Statistics: Project Characteristics

Sites are precise geographic identifiers (akin to a street address). A “palace” pools together all plausibly-inheritable real estate. Condition status (extant, partially extant, demolished) refers to the current condition of a site and is sometimes missing in the data. A “map mention” is any entry in the digitized map with an event (start-)date. Palaces are often built and later reconstructed, so entries in Panel B need not be additive. Precise definitions (e.g., of the distinction between “built” and “reconstructed” projects, of “inheritability,” etc.) are presented in Table 5 and discussed further in s.??.

the population of ecclesiastical officials sufficiently high-ranking and wealthy as to be the relevant treatment group of the inheritance reforms vis-à-vis palace-construction.

For laymen, as no notion of hereditary nobility or systematic identifier of wealth exists in the Roman setting, I use records of high-ranking civic magistrates from 1305 to 1865 from the *Lista d’Oro della Magistratura Capitolina* furnished by the Accademia Moroniana (De Dominicis, 2009). These officials are robustly-documented and politically influential, and hence form a conservative proxy for Rome’s powerful lay elite. Underestimating the lay population biases results against finding a treatment effect, and implies all estimates are to be taken as a lower bound.

The Online Appendix describes the construction of the annual population indices and robustness to alternative definitions.

4.3. Papal Absences. Using a variety of secondary historical sources (mostly papal biographies), I manually construct an index of papal absences 1378-1599. I also identify the reason for each, thus allowing for a delineation of “exogenous absences” (e.g., due to plagues or diplomatic missions), not interpretable as a signal of a pope’s waning appetite to remain in Rome. Variable definitions, sources, and classification decisions are recorded in the Online Appendix.

4.4. Panel Construction.

4.4.1. *Data cleaning: the reigning pope’s relatives and measurement error.* Lest results be driven by growing inner-circle nepotism, I collect data on whether patrons are close relatives (up to cousinry, including nephews) of the reigning pope at the time of the project’s inception. Controlling for projects sponsored by a close relative of the reigning pope removes irregularities from the data (as, plausibly, close papal relatives of either patron class face systematically different incentive and information constraints than do prelates and laymen not part of the ruling family) and ensures that a broad and meaningful trend is identified.

Some projects suffer from measurement error: indicated by round start-dates (1400, 1500), exactly-century-long duration, and extremely terse one-word descriptions, these projects are clearly indicative of data paucity. I address this issue in several ways: by removing or controlling the projects of exactly a century with the dates 1400-1500 and 1500-1600, or by smoothing the start date of these projects across the stated active period.

4.4.2. *Identification level.* At first glance, it seems natural to measure investment at the patron-year level. However, producing interpretable estimates immune to selection bias would require observation of the entire hypothetical-patron class, including non-investors. This is not feasible with Roman data. Furthermore, repeat investments coming from a single individual are extremely rare: if a patron invests in one year, it is nearly impossible that he would ever build again. As project occurrence is nearly one-to-one with individual patron identities, it is effectively costless to pass to project-level analysis, and, in so doing, to avoid explicitly modelling the impossibility of repeated events per patron.²⁶ Instead, I track palaces over time. (The implicit assumption that all hypothetical palaces are eventually constructed is far more innocuous than the assumption that all hypothetical patrons eventually build.) Appendix A derives the equivalence of the two approaches up to a weighted regression (conditional on accurate population weights and no repeat projects per patron), and all estimates are presented accordingly.

From the project-level records, I construct a balanced panel, where each observation is identified by palace site ID i ; patron type $s \in \{\text{lay, prelate}\}$; and year $t \in \{1378, \dots, 1599\}$. That is, each palace-site-patron-type combination appears in every year of the sample, and the variable “investment” takes the value 1 if a project is started in that year and 0 otherwise. (Note that non-projects are true zeroes.)

5. A CONCEPTUAL FRAMEWORK

It is well-established that demand for palazzi was high and ubiquitous across Italy throughout the renaissance (Goldthwaite, 1993, 1982), but, conditional on a general willingness to build, patrons must actively find Rome in particular a desirable location for

²⁶Formally, a patron-year specification would require an event-history or a hazard model for the first construction event. Given that repeat investments are essentially nonexistent and that non-investors are unobserved, the simpler cross-sectional project-level formulation is more transparent and parsimonious.

long-term investment. Even if no other city were suitable, the outside option of not investing in local real estate remains. A compelling mechanism must, therefore, explain (1) why investment in Roman palace-construction was stagnant before the late fifteenth century but flourished afterwards, and (2) both why there was a response among laity and prelates, and why it was different across the two groups.

The recursive commitment mechanism explains the pre-reform economic stagnation, which persisted despite a number of economic shocks. The return of the papacy to Rome c. 1378 had had a muted effect because there was no reason to believe this to be a permanent return: the Schism began with the very next pope. Other positive shocks to the financial incentives had little effect on investment as they failed to inspire confidence in the future of the city. The overall potency of the 1475 and 1480 papal bulls, conversely, is due to the meaningful commitment they cultivated on behalf of the papacy.

Importantly, commitment is quite distinct from a simple signal of Sixtus IV's personal intent to keep the papacy in Rome or to otherwise pursue policy favourable to the city's growth – given the relatively short tenure of any single pope, such a signal would not be very meaningful²⁷ – but an assurance that the costs for any future pope attempting to leave the city would be prohibitively high. The mechanism I propose is also not one of signaling in the standard informational sense of revealing an unobserved exogenous state or type (e.g., an institution's predetermined willingness to remain in the city). Instead, prelate investment altered the papacy's incentives by raising the costs of leaving Rome: the reforms created a feedback loop in which the private interests of the ecclesiastical elite constrained future popes' behaviour via elections. Lay patrons inferred this realignment of incentives by observing prelate investment, and rationally concluded that the papacy's presence in Rome had become self-perpetuating.

The core generalizable insight is that personal investment by elites can transform an unenforceable promise into self-enforcing institutional commitment. Indeed, this is a story that may sound familiar to inhabitants of many old cities: elites take advantage of state coffers or local resources, but, in exchange, take a stake in the city's future and begin to invest their wealth into local projects.²⁸

This conceptual framework is summarized in Figure 5 and the testable hypotheses the mechanism generates are as follows.

²⁷There were good popes who tried to revitalize the city before Sixtus IV, too. Were signaling to be enough, one would have to explain the strange differential effects. On the other hand, a lack of long-term commitment is plausibly the reason that the seven decades of the Avignon Papacy never gave rise to significant private palace-building in Avignon. Just as there was a fear of the papacy leaving Rome once more, there had been an understanding that the sojourn in Avignon might be a temporary affair.

²⁸See also (Acemoglu and Robinson, 2008) for a theoretical rationalization of the phenomenon.

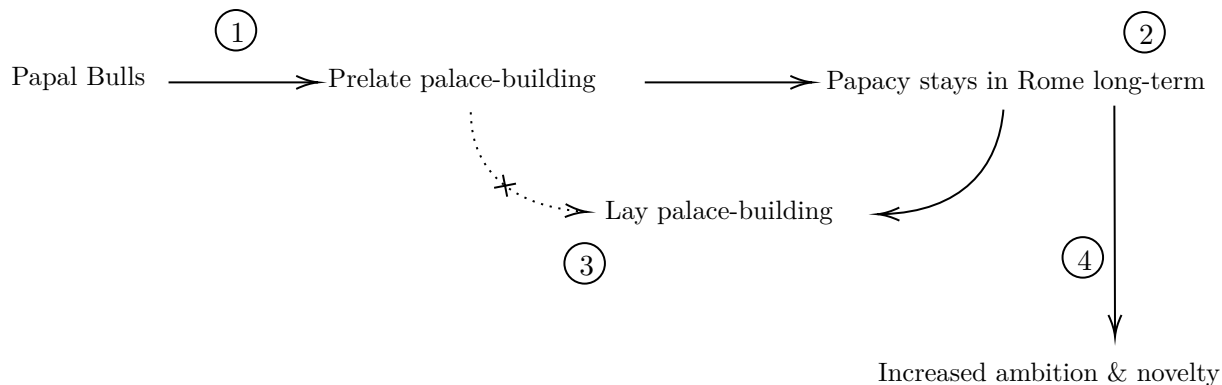


FIGURE 5. Self-perpetuating commitment to long-term papal presence via elite investment

Labels correspond to Hypotheses 1-4 and corroborating evidence is presented in s.6.1-6.4. In short: (1) The papal bull should have a (treatment) effect on incentivizing prelate palace-building. (2) There should be a real effect on papal absences from Rome, and patrons should respond to the guarantee of long-term absence. (3) Lay palace-building should be explained by “learning” of the guarantee of papal presence. (4) The irreversibility of papal presence in Rome should result in increased project ambition, as captured by novelty.

In order that the proposed mechanism have any explicatory power, it is important that the papal bulls have a real effect on prelate investment.²⁹

Hypothesis 1. Incentive for Prelates: *After the reforms, investment must increase more, in relative terms, among prelates than among laymen.*

In addition to establishing a causal relationship between the introduction of the reforms and the economic recovery, a difference-in-difference result is useful for highlighting the commitment mechanism: the lag between the two groups further underscores that mere cost reduction channels (i.e., some direct effect of the 1480 reform) is insufficient to explain the observed pattern: indeed, the 1475 bull completely equalized the two in terms of financial incentives, and the 1480 bull relaxed financial constraints in the same way. Yet the response between the two groups was different. Using subsequent tests, I argue that this difference is explained by lay patrons’ apprehension regarding the papacy’s long-term presence – and that the gap closed when as laymen updated their beliefs. It had been quite obvious to all patrons that, should the papacy remain and flourish, the city, too, would prosper. But equally obvious was the risk that another departure would prove as devastating as it had been in the early fourteenth century. The memory of the Avignon papacy and, above all, the unallayed fear of its reprisal, were enough to stifle all appetite for investment.

²⁹Estimating the true real effect, insofar as I claim that the laymen – who are the natural comparison group – will eventually benefit from the reform via the generated commitment, is complicated. The results I obtain represent lower bounds on the true effects, as the response among the laity can only bias downwards the estimation. Comparisons to investors outside Rome would be even more problematic, due to substantial differences in settings and institutions.

Thus, the reforms encouraged prelates to build in Rome, and to make the city their permanent home and that of their families. Once cardinals were invested in the city, the financial future of the ecclesiastical ruling class and the economic well-being of Rome became inextricably linked. By forward induction, cardinals with real-estate holdings in the city would never vote for a pope who would leave Rome, nor would they allow this legislation to be repealed.³⁰ The commitment was uniquely robust to papal turnover.³¹ This was a rare quality for papal policy to boast: executive legislation enacted by one pope could, in principle, be repealed by his successors with relative ease.³² Indeed, the papacy never left again.

In short, since cardinals are charged with electing future popes, and are themselves appointed by popes, their investment in the city became a long-term guarantee that the papacy would remain in Rome. The promise of long-term presence in Rome was sufficient to inspire confidence in the future and to foster a belief in the profitability of real-estate investment. Laity began to invest in the city as well.

For completeness, one should also note that Sixtus IV, via his early policy and the bulls in question (as well as the investment decisions of his beloved nephew), had sent an unambiguous signal that he himself had no desire to leave Rome. The self-perpetuating mechanism of prelate investment and long-term papal presence was launched.³³

To test this, I must, therefore, confirm the salience of long-term papal presence to investment decisions, and show that the papal bull changed investors' views on the permanence of the papacy's sojourn in Rome. If the commitment really is meaningful, these updated beliefs should furthermore be accurate; that is, political incentives post-reforms must in fact constrain the papacy to remain in Rome in a more meaningful way than before.³⁴

Hypothesis 2. Real Commitment:

- (1) *The number of papal absences should decrease post-reforms, relative to the pre-reform trend.*

³⁰While popes' powers are not constrained by formal mechanisms as in modern democratic states and though suffrage was not universal in early-modern Rome, that the pope was elected aligned incentives between the prelate elites and the laity in a way similar to that discussed in Acemoglu and Robinson (2006) for democratic institutions.

³¹Roland (2004) and North (1990) are theoretical works which bear on on institutional persistence and on the ways in which informal constraints reinforce formal rules, respectively.

³²Popes were, in many ways, elected princes and were not officially bound by precedent, by early-career (pre-pontificate) stances, or even by preferences of their closest advisors. Clement V, for instance, revoked support of the Templars, leading to the dissolution of the order c. 1312 (Barber, 2006). Likewise noteworthy was Pius II's rebuke of conciliar theory c.1460, despite conciliar movements being a common practice in which he had personally been involved and which facilitated his own ascent to the papal throne (Izbicki (2006), Oakley (2003)).

³³See Greif (2006) and North (1990) for theoretical analysis of how institutions create self-reinforcing incentive structures.

³⁴In other words, it would not be enough to produce evidence that patrons' beliefs changed but were misguided, as the core of the mechanism pertains to the real incentives of the prelate governing class.

- (2) *Papal absences from Rome should have no effect on investment once a control for the implementation of the papal bull (i.e., a post-reform interaction term) is included.*

Hypothesis 2.2 is much stronger than just arguing that papal absences post-reforms should have no effect on investment.³⁵ I claim also that papal absences should not have a significant effect on investment pre-reforms, too – not because papal presence was not important for Rome per se, but because contemporaneous presence, in the absence of institutional commitment, was not an indicator of the economically-salient variable: the continued presence of popes in Rome centuries to come. If long-term papal commitment is critical enough, a post-reform dummy alone should absorb any effect of papal absence or presence.

As per the flowchart in Figure 5, it will be particularly important to establish the effects in Hypothesis 2 for laymen, in order to suggest that papal commitment drives the changes. It is furthermore crucial to show that the laity responds to the prelate reaction to the bull due to the induced papal commitment (to exclude all effects merely being driven by the across-the-board cost-reductions of the 1480 papal bull), and also that past investment in general does not matter (to exclude a general spillover channel). This suggests the following hypothesis:

Hypothesis 3. Belief Diffusion: *Lay investment should respond favourably to past prelate investment for a brief period post-reforms, but should otherwise not be affected by past prelate, lay or pooled investment.*

The anticipated short time horizon of the effect is quite important: it distinguishes between the aforementioned commitment channel and some kind of spillover channel. (One could have in mind an alternative hypothesis about past construction driving down costs for new patrons – for example, due to complementarities, or because the required labour force would then already be present in the local market – and thus that early reform-induced prelate investment would make future investment for all patrons more affordable.) In particular, as the mechanism takes effect and it becomes clear that the College of Cardinals is indeed bound to the city, prelate investment should stop being a sign of increased commitment of the papacy and should fail to predict lay investment long-term.

An effect unrestricted by time-horizon or patron-class would be more consistent with a spillover channel. A short-term effect with such restrictions, conversely, is strongly indicative of the proposed commitment mechanism. (Given the small population of prelates of whom there are about 40 in any year in the late 15th century, on average, and who represent, at most, a quarter of the plausible patron class (cf Figure 8), it is also unlikely for there to be a significant spillover from prelate construction, and no spillover from comparable lay palace-building.)

³⁵This could, for instance, be a consequence in a belief that absences post-reforms are sure to be transitory, due to the papacy's commitment to remain in Rome, whereas there was no guarantee absences pre-reforms would not become permanent.

A combination of increased confidence and reduced land acquisition costs should also manifest at the intrinsic margin with the nature of projects pursued: more ambitious projects should become (relatively) more prominent post-reforms.

Hypothesis 4. Optimism: *Post-reforms, there should be an increase – among both patron-types – of new construction, relative to projects aimed at refurbishment of existing sites. These changes should be driven primarily by the laity.*

(Of course, the increased novelty of projects would have been partly facilitated by the reduced costs of land acquisition, but the latter alone are insufficient: ambition, optimism and confidence are still a necessary condition for embarking on a new construction project of a palace – especially one for which patrons have to incur commensurately higher costs due to a project’s novelty.)

6. RESULTS

This section tests the hypotheses outlined in the conceptual framework. In particular, I examine (1) whether the papal reforms had a real effect on prelate investment, relative to laymen; (2) whether the reforms had effects on long-term papal presence and whether long-term papal presence mattered for patrons investment decisions; (3) whether the growing commitment of the papacy to remain in Rome (as engineered via prelate investment) was gradually absorbed by the laity; and (4) whether project ambition post-reform increased. I take 1470 as the conservative start of the “treatment period” to avoid any within papal reign anticipation effects as Sixtus IV began his tenure in 1471.

6.1. Hypothesis I: Real effect of the papal bull. I first establish that the papal bulls had a real treatment effect by means of a difference-in-difference analysis of annual new projects at the location-year-patron group level. I estimate the following regression model:

$$\mathbb{1}_{i,s,t}^{\text{new project}} = \alpha + \beta_1 \mathbb{1}_{t \geq 1780} + \beta_2 \mathbb{1}_{s=\text{prelate}} + \beta_3 \mathbb{1}_{t \geq 1470} \times \mathbb{1}_{s=\text{prelate}} + \gamma X_{i,s,t} + \varepsilon_{i,s,t}, \quad (1)$$

for $i \in \{\text{palace sites}\}$, $s \in \{\text{lay, prelate}\}$, $t \in \{1400, 1401, \dots, 1499\}$. The parameter α is the constant term. $X_{i,s,t}$ include the fixed effects (including 10-year time effects) and various controls: indicators for whether the project is started by a reigning pope’s relative and for plausible instances of measurement error (century-long projects with century start-and end-dates), and continuous variables for time elapsed since a previous project at the same site and the length of the previous project, and an indicator for the group identity of the previous patron; see Table 5 for a complete description.

The estimated regression results are reported in Table 2. Results remain robust to the inclusion of controls and fixed effects (including at the location \times year and location \times patron-type levels). The baseline specification (Column 1) and subsequent specifications consistently estimate the average treatment effect of the papal bull on the treated prelate class post-1470 as a 398% increase in the probability of construction at the average site per

year, relative to the pre-1470 levels. (The ATT ranges from 307% to 369% with the inclusion of dummies for the reigning pope's relatives and century-long projects.) This is equivalent to an additional palace-construction project every two years (more precisely, 4.326 new projects per decade). For robustness, I repeat the test with a logit model and recover nearly identical results: there is an average treatment effect on the treated of .26pp (compared to .29pp in the OLS difference-in-difference design), or a roughly 350% increase in the probability of construction at an average site in a given year. Logit results are reported in Table 6.

	(1)	(2)	(3)	(4)	(5)	(6)
	new proj	new proj	new proj	new proj	new proj	new proj
papal bull=1	-0.000283 (0.000478)	0.0000891 (0.000449)	-0.000511 (0.000419)	-0.000139 (0.000386)		
prelate patron=1	-0.000223 (0.000359)	0.000149 (0.000324)	-0.000372 (0.000345)	2.15e-08 (0.000309)		
papal bull=1 \times prelate patron=1	0.00296** (0.00114)	0.00259** (0.00113)	0.00220** (0.000857)	0.00183** (0.000842)	0.00183*** (0.000605)	0.00165*** (0.000596)
lay population						-0.0000695*** (0.0000268)
prelate population						0.0000427 (0.0000383)
has prev proj=1						0.622** (0.285)
has prev proj=1 \times years since prev project						0.00620 (0.0165)
has prev proj=1 \times years since prev project ²						-0.0000444 (0.000113)
Constant	0.000968*** (0.000257)	0.000596*** (0.000205)	0.000968*** (0.000257)	0.000596*** (0.000205)	0.000562*** (0.0000744)	0.00491*** (0.00171)
Century-long project dummy	—	✓	—	✓	✓	✓
Reigning pope's relative dummy	—	—	✓	✓	✓	✓
Location ID \times patron-type FE	—	—	—	—	✓	✓
Location ID \times 10-year time FE	—	—	—	—	✓	✓
Observations	35624	35624	35624	35624	35624	35624
Adjusted R2	0.000557	0.122	0.195	0.317	0.319	0.384

Standard errors in parentheses
* $p < .10$, ** $p < .05$, *** $p < .01$

TABLE 2. New Projects Difference-in-difference (1378-1499)

This table presents regression results for the difference-in-difference analysis of new project (i.e., at the start-year level) for the years 1378-1499. The dependent variable in all specifications is a dummy variable for a new investment project in a given year, at a palace-site, by the given patron type (lay or prelate). Location fixed effects refer to the identifiers assigned to a palace-sites by Nolli in his map (these are sufficiently granular as to uniquely identify a palace location – one can think of them as a street address). Years since previous project measure time elapsed since the conclusion of the last investment project at the same palace-site. As dummies for century-long projects and reigning pope's relatives are perfect predictors of a new project (because the data set is at the project level, so one never observes a 1 for a century-long project which never took place), I do not display the coefficients: they are uninterpretable (and indistinguishable from 1). All clustering is performed at the location ID \times patron-type level, the level on which treatment is administered.

Next, I decompose the treatment effect over time by 10-year intervals (with decades defined as 1460-1469, 1470-1479, etc.). I include dummy variable controls for century-long projects and those sponsored by relatives of contemporaneously reigning popes. Clustering is shown at the location \times patron-type and decade level. Figure 6(c) presents the dynamic difference-in-difference findings. There is no pre-trend; the decades after the reform are characterized by considerably higher prelate investment, especially 1490-1499.

A few decades after the reforms, there is a “catching-up” effect, suggestive of long-term convergence. To see this, it is important to control for population sizes directly (otherwise the difference in levels, driven by population sizes, becomes obfuscatory); passing to per-capita measures, this trend of convergence becomes clear and is presented in Figure 6(d).

All of the aforementioned difference-in-difference results are to be taken only as lower bound estimates of the true effects of the papal bulls. As I argue throughout the paper, lay investment increases post-reforms, as lay patrons benefited from the papacy’s commitment, secured by reform-induced prelate investment. These confounding effects are mitigated by the constrained time-horizon of the analysis, but are likely still present. However, they can only bias downwards the estimate of the effect of the bulls, and so do not threaten the validity of findings. The exclusion restriction is verified in the sample: I allow, in principle, for both prelate and lay patrons to build simultaneously at a given site in a given year, which happens, but outside the sample period (in 1541 and 1590).

6.2. Hypothesis II: Papal absences, the papal bull, and investment. I collect data on papal absences from Rome and study whether absences correspond to lower investment. A complete description of all papal absences is provided in the Online Appendix . I repeat all of the ensuing analysis at two levels: focusing on all patrons’ investment, and restricting to lay patrons only. The latter isolates patrons who benefit most from persistent papal presence. I report findings for laymen in the main text of the paper, and reserve the pooled regressions for the appendix; results are unchanged.

I first establish that the papal bull has a real effect on whether the papacy stays in Rome: the number of years of papal absences significantly decreases post-1470 (Column 1 of Table 3), such that the probability of absence in a given year drops by 81.5% (or, equivalently, by 18.84 p.p.). So-called “endogenous” absences – that is, those that are, in any way, discretionary and plausibly interpretable as a signal of the pope’s waning willingness to remain in Rome vanish post-1470 altogether.

I next test whether contemporaneous papal presence itself might be a plausible driver of investment. That is, I test the alternative hypothesis that papal presence per se matters for palace-construction even controlling for the introduction of commitment, and I find no evidence in favour of this explanation. The negative relationship between papal absence and investment disappears with the inclusion of a control for commitment to long-term papal presence in Rome, as captured by the introduction of the papal bull (Columns 3 and 5). It

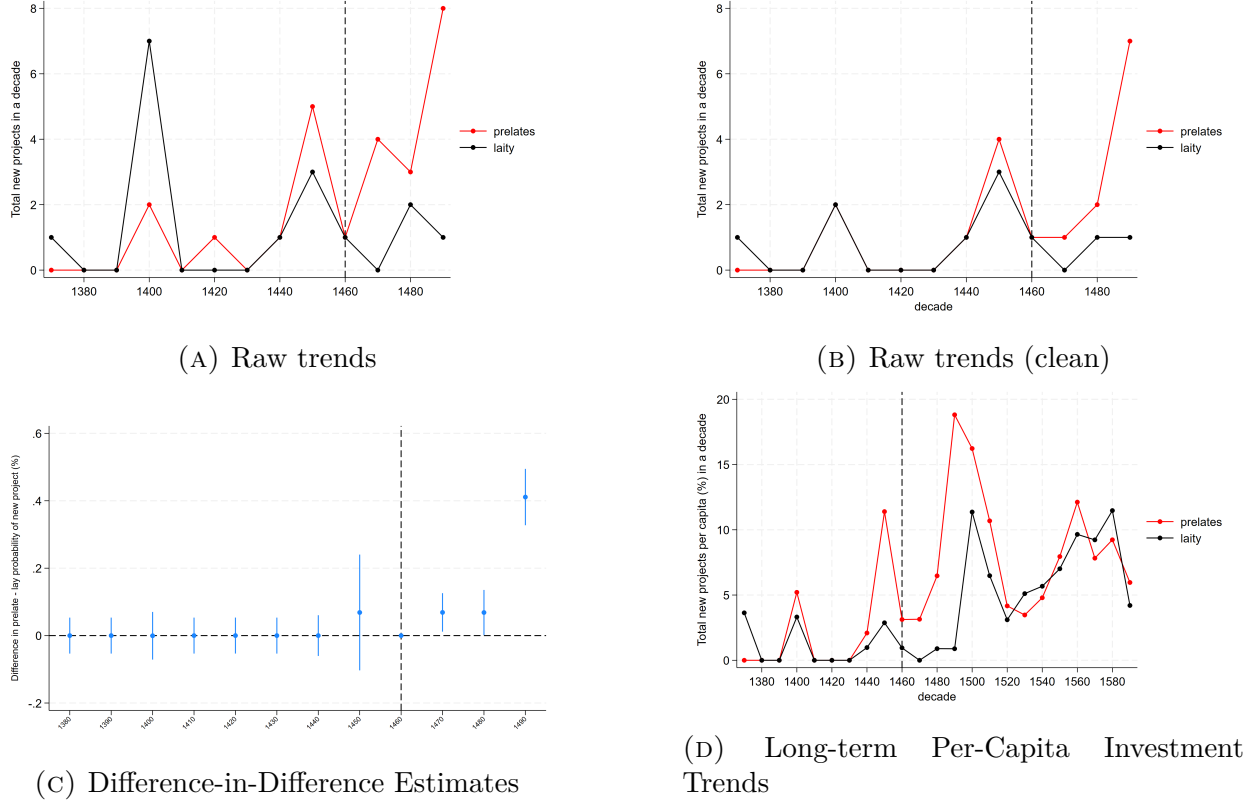


FIGURE 6. Prelate vs Lay Investment

Figure 6a displays the raw data on total new prelate and lay projects by their respective start years; Figure 6b presents the same data with century-long projects as well as those started by reigning popes' relatives removed. Dynamic difference-in-difference estimates (corresponding to the specification in Column 4 of Table 2 – that is, with dummy variable controls for century-long projects and those by reigning popes' relatives – and but with standard errors clustered by location ID \times patron-type and decade) are shown in Figure 6c. Figure 6d contains the long-term trends of per-capita investment: the number of projects started in that decade by the average population of the relevant patron group in that decade. With the additional assumption (borne out in the data) that each patron does not build more than once in his lifetime, the figure is interpretable as a participation rate. There is convergence in these participation rates in the latter portion of the 16th century, following a “catching-up” effect. (The “blip” in the pre-trend in 1450 among prelates is purely due to differences in population sizes: the raw data in Figures 6(a, b)) reveals that the gross numbers of projects are nearly identical.

follows that, pre-1470, patrons were not naïve enough to take the pope's contemporaneous presence as a guarantee that he – and, more importantly, his successors – would remain in the city long-term. Conversely, post-reforms, patrons had reason to believe that the papacy as an institution was bound to Rome long-term; the location of a single pope, therefore, did not matter. Thus, I argue that it is not contemporaneous institutional presence that drives the increase in investment post-reforms, but specifically commitment to long-term presence.

To ensure that results are not driven or diluted by political tensions extra muros, I repeat the exercise but include periods of externally-contested papal authority (during which antipopes outside of Rome challenge the reigning pontiff's authority) in Table 7.³⁶ External challenges to papal authority follow the same pattern as normal papal absences: their effect on investment vanishes with the inclusion of a post-1470 dummy; they also do not change the effect of local papal absences in joint analysis, as desired (Columns 4-9 of Table 7). In table 7, as in Table 3, I consider the effects of all absences together and endogenous (discretionary) ones separately.

³⁶Results are also not affected by the inclusion, into periods of contested rule, the 1453 plot of the humanist Stefano Porcari to overthrow the popes and establish a republic. He was caught and hanged before violence could erupt. (Not reported as effects of interest are identical.)

	No. Absences		Investment (lay)			
	(1) endog.	(2) all	(3) new proj.	(4) new proj.	(5) new proj.	(6) new proj.
post-1470	-0.398*** (0.103)	-0.212*** (0.048)		0.006*** (0.002)		0.006*** (0.002)
endogenous absence			-0.005*** (0.001)	-0.001 (0.001)		
endogenous \times post-1470				0.000 (.)		
papal absence					-0.004*** (0.001)	-0.001 (0.001)
papal absence \times post-1470						-0.002 (0.002)
Constant	-30.618* (15.999)	0.250*** (0.045)	0.005*** (0.001)	0.001* (0.001)	0.005*** (0.001)	0.001* (0.001)
year	0.040* (0.021)					
year_2	-0.000* (0.000)					
N	222	222	32,412	32,412	32,412	32,412
Adjusted R2	0.175	0.094	0.000	0.002	0.000	0.002
Years absent 1378-1479	22	23	22	22	23	23
Years absent 1470-1599	0	5	0	0	5	5

Standard errors in parentheses

* $p < .10$, ** $p < .05$, *** $p < .01$

TABLE 3. The effect of papal absence from Rome on per-capita investment

Papal absences include all meaningful stays of the pope outside Rome, due, for instance, to flights during invasions of Rome, wars waged on foreign soil and treaty negotiations that requires the pope's presence elsewhere. Endogenous absences are those interpretable as a plausible sign of the pope's waning willingness to remain in Rome long-term – e.g., a disagreement between (a subset of) Romans and the pope, the purchase and active construction of property in another city (with the pope present to oversee the construction) – are isolated in the variable “endogenous.” Regressions in Column 1-2 are run at the year-level (robust standard errors), and at the palace-year level in Columns 3-6 (standard errors clustered by palace). This exercise is repeated in Table 7 to consider effects on investment across patron-types, as well as periods of contested papal authority (as measured by the presence of antipopes – competing popes – elsewhere).

6.3. Hypothesis III: The Effect of past prelate investment. If the increased lay investment post-reform is induced by increased confidence that the papacy will remain in Rome, which is driven by prelate construction, then past prelate investment should be a predictor of future lay investment for a brief period after the reforms. The brevity of the relationship attests to the role of past prelate investment for laymen: it matters only insofar as it generates the papacy's commitment to stay in Rome in an observable way, and does not itself carry intrinsic economic value.

I will test this by running the regression in Equation 2, both in a dynamic and static set-up for projects by their start-year:

$$\begin{aligned}
\text{inv_dw}_{i,t}^{\text{lay}} = & \alpha + \beta_0 \mathbb{1}_{t \geq 1470} \times \text{prev_prelate_investment}_{t-\text{mod}(t,10)-10} \\
& + \beta_1 \mathbb{1}_{t \geq 1470} \times \text{prev_lay_investment}_{t-\text{mod}(t,10)-10} \\
& + \beta_2 \mathbb{1}_{t \geq 1470} \\
& + \beta_3 \text{prev_prelate_investment}_{t-\text{mod}(t,10)-10} \\
& + \beta_4 \text{prev_lay_investment}_{t-\text{mod}(t,10)-10} \\
& + X_{i,t} + \varepsilon_{i,t}
\end{aligned} \tag{2}$$

with control variables (such as location fixed effects) in $X_{i,t}$. The variable $\text{prev_prelate_investment}_{t-\text{mod}(t,10)-10}$ captures the total³⁷ per capita investment by prelates in the city in the previous decade, and analogously for $\text{prev_lay_investment}_{t-\text{mod}(t,10)-10}$. In the dynamic specifications, $\mathbb{1}_{t \geq 1470}$ is replaced by a set of indicator variables for half-centuries (with the interval 1420-1469 omitted as the reference category).

For previous prelate investment to be a predictor of future lay investment post-1470, in the estimation of Equation 2, we need:

$$\hat{\beta}_{\mathbb{1}_{t \geq 1470} \times \text{prev_prelate_investment}_{t-\text{mod}(t,10)-10}}^L > 0 \tag{3}$$

but only for a short period after 1470.

However, past lay investment should not have a discernible differential effect on post-1470 investment according to this channel. Thus, we should observe:

$$\hat{\beta}_{\mathbb{1}_{t \geq 1470} \times \text{prev_lay_investment}_{t-\text{mod}(t,10)-10}}^L = 0. \tag{4}$$

By decomposing Equation 2 to have time-varying coefficients (at the half-century level due to the preponderance of zeroes in the data), one can verify whether the effect of past prelate investment on future lay investment decreases over time. Indeed, this is confirmed in Table 4, where the effect is pronounced during the first 50 years post-papal-bull and negligible otherwise. (Table 8 contains the full regression output.)

³⁷Calculated as the sum.

A back-of-the-envelope calculation suggests that, between 1470 and 1519, 10 additional projects in the past decade by prelates correspond to 7.3 additional lay projects city-wide in the subsequent decade (Table 4). During the same half-century, a similar back-of-the-envelope calculation reveals that a 1p.p increase in per-capita projects by prelates in one decade is associated with an additional 24.5 projects city-wide in the next decade.³⁸

The high sensitivity of laymen’s responses to past prelate investment hints at a low prior probability assigned by laymen to the papacy remaining in Rome long-term. Otherwise, had prelate investment only confirmed what laymen already believed, it could not have elicited a strong response, whose magnitude diminishes as patrons’ beliefs in long-term papal presence increases.

That the effects vanish at longer time horizons and that they are not present at all for the prelate patron-class (see, e.g., Table 4) grants further credibility to the commitment channel. This finding cannot be explained by a wealth spillover.

To directly rule out general spillover effects driving the change c.1470-1480, I consider the predictive power of past investment pooled across patron types in Table 9 for new projects. There is no positive effect of past investment on future investment over time,³⁹ neither for all patrons (pooled), nor for laymen in particular.

In fact, even the static variable measuring lagged lay investment is never a positive predictor of later lay investment (see Table 8).⁴⁰ Together, these findings are inconsistent with an explanation on the basis of spillovers, both in explaining investment in general, and as pertains to the the change post-reforms.

6.4. Hypothesis IV: An increase in project ambition. The increased commitment of the papacy to remaining in Rome ought to have had an effect on patrons’ confidence and risk tolerance. I provide some illustrative evidence consistent with increased patron ambition. To this end, I consider changes in project characteristics over time. An increase in “building” (entirely new projects) rather than “rebuilding” (contributions to existing palaces)⁴¹ could be taken as evidence of a shift in patrons’ risk-tolerance for profitable investments. Building something completely new likewise requires a less transactional or less short-term

³⁸Interpreting the per-capita figure as a participation rate hinges on the empirically valid assumption that patrons do not engage in repeat projects; without the assumption, one could still view projects per capita as a measure of intensity.

³⁹The coefficient on the interaction term of lagged investment \times post-1470 time effects is insignificant.

⁴⁰On the contrary, in some specifications, there is even a brief negative effect, 1570-1599. The effect is not very strong, and should not be interpreted as conclusive evidence of a between-patron substitution effect. It seems mechanical, as building a palace in one decade reduces one’s appetite for building a palace in the next decade. When investment rates are sufficiently low, this within-patron substitution effect is diluted, but when construction rates are sufficiently high, it can be observed. (A heuristic: if patrons are willing to build at most once every two years, a year with no construction may or may not be followed by a more active year, while a year with high investment will necessarily be followed by one in which investment is low.) This within-patron substitution is not very interesting in and of itself, but it is further evidence that positive spillovers are not the primary driving force.

⁴¹See Table 5 for a thorough classification guide.

	(1) new proj	(2) new proj	(3) new proj
lagged prelate projects	-0.001** (0.000)	-0.001*** (0.000)	-0.000 (0.001)
1370-1419 \times lagged prelate projects	0.006 (0.006)	0.006 (0.006)	0.017 (0.014)
1470-1519 \times lagged prelate projects	0.005*** (0.001)	0.005*** (0.001)	0.004*** (0.001)
1520-1569 \times lagged prelate projects	0.000 (0.001)	0.000 (0.000)	-0.000 (0.001)
1570-1599 \times lagged prelate projects	-0.000 (0.001)	-0.000 (0.001)	-0.002 (0.001)
lagged lay projects	0.002*** (0.001)	0.002*** (0.001)	0.001 (0.001)
1370-1419 \times lagged lay projects	-0.004* (0.002)	-0.004* (0.002)	-0.006 (0.004)
1470-1519 \times lagged lay projects	-0.003*** (0.001)	-0.003*** (0.001)	-0.002* (0.001)
1520-1569 \times lagged lay projects	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)
1570-1599 \times lagged lay projects	-0.002*** (0.001)	-0.002*** (0.001)	-0.000 (0.001)
Constant	0.001** (0.000)	0.001* (0.000)	0.007 (0.007)
50-year time FE	✓	✓	✓
Location ID FE	—	✓	✓
Full controls	—	—	✓
N	32412.000	32412.000	32412.000
Adjusted R2	0.006	0.004	0.320

Standard errors in parentheses

* $p < .10$, ** $p < .05$, *** $p < .01$

TABLE 4. Previous investment affecting future investment (1378-1599)

This table presents the dynamic coefficients of interest for regressions testing the effects of the previous decade's investment on the subsequent decade's investment by lay patrons. 50-year fixed effects are included in all regressions, and controls in some, as per table labels. (Full control specifications include variables tracking average lay and prelate populations in the corresponding 50-year interval, a dummy variable for the presence of previous projects at the same site, the same dummy interacted with the number of years elapsed since the previous project at the same site, and the same year measure but squared.) All of the coefficients are recorded in Table 8. Clustering in all regressions is performed at the location-ID level. 1420-1469 is the omitted category. To recover back-of-the-envelope calculations estimating the effect of one decade's investment on the next, it is enough to multiply the corresponding coefficient by the number of active investment sites (146).

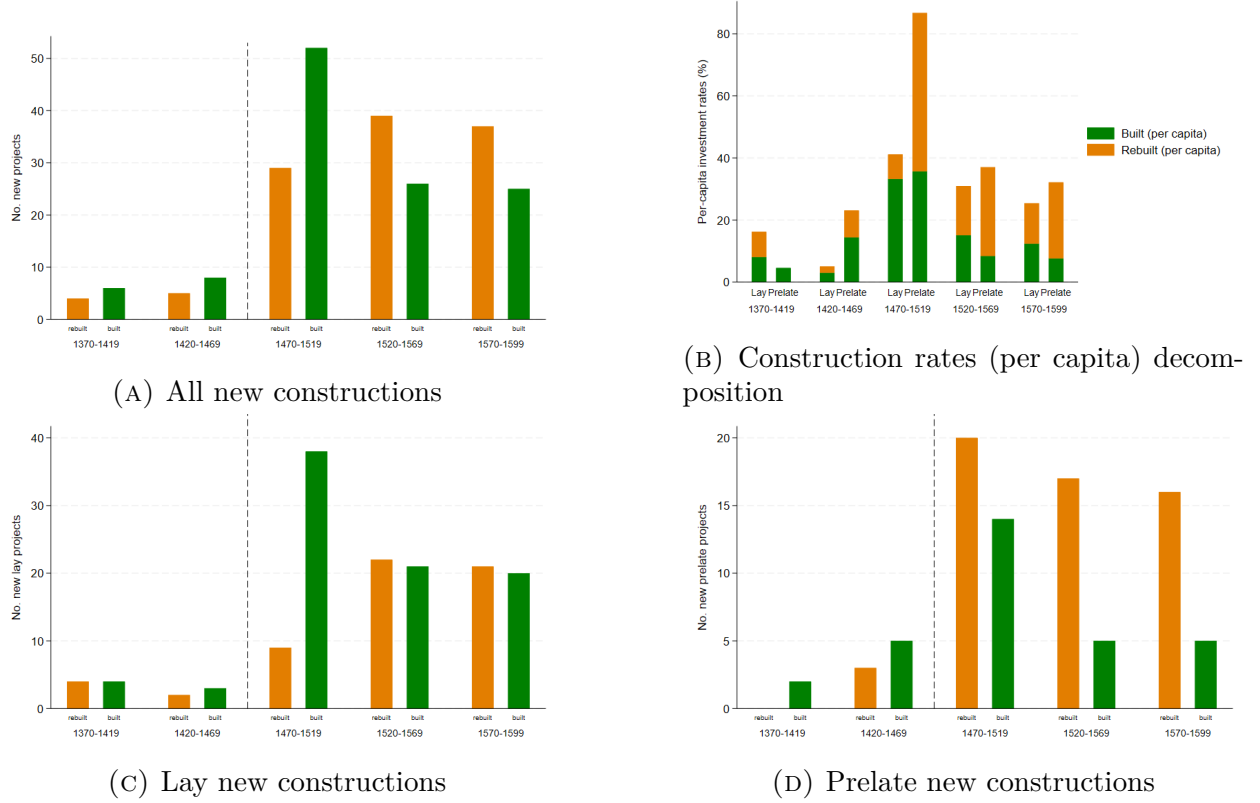


FIGURE 7. Palace-building decomposed by project novelty

“Built” projects are those that see some fundamentally novel construction, while “rebuilt” projects entail a reconstruction or refurbishment of an existing palace. Refer to Table 5 for a more detailed classification.

relationship with the city than does an acquisition or reconstruction of an existing site due to the additional risk and complicated nature of a completely new project. Patrons of “new” projects incur (non-financial) costs associated to various bureaucratic constraints (e.g., the procurement of building permits, superfluous for contributing to existing palaces).

The decompositions of investment rates by project type are presented in Figure ???. The data confirms that, while there is no considerable difference between patrons’ pre-1470 project choices, post-1470, there was an increase in per-capita rates of new construction (“building”) projects. The disproportionate increase was driven primarily by the laity; prelates did not exhibit a marked preference change and increased investment in both types of projects rather homogeneously. This is consistent with the hypothesis that risk-tolerance and optimal investing time-horizons are positively affected by the papal bull – and that laymen are responding positively to the prospect of the papacy staying in Rome long-term.

7. DISCUSSION

7.1. Limitations and Alternative Explanations.

7.1.1. *Who was doing the committing, and how does “commitment” generalize?* The notion of commitment proposed in this paper does not rely on Sixtus IV being selfless or far-sighted (– once again emphasizing the distinction to be drawn with a classic signalling channel, where discerning the pope’s true motivations or “type” would be critical). Even if his ambitious building programs were all for his own self-aggrandizement (as were those of his predecessors), even if his own nepotism was the goal of the reform, the proposed mechanism worked for the whole elite. The key requirement is that the 1475–80 reforms altered the incentives of prelates, not that the pope intended a citywide revival. The reforms then tied prelates’ private wealth to the city, and through the recursive appointment–election cycle, bound future popes to Rome.

While this paper focuses on commitment generated by the papacy, the mechanism itself is more general. Commitment here extends far beyond the motivations or capacity of any individual leader. In fact, the Roman context suggests that a fundamental advantage of institutions – and unavailable to any given statesman – is exactly in the robustness to leadership turnover. Credible, long-term commitment is generated when individual actors’ incentive constraints are recursively-binding, and this, in turn, creates the stability necessary for economic growth. The logic of recursive incentive constraints is common to all governance types where one generation has sway over the politics of the next, including hereditary monarchies (where leaders seek to preserve stability and hence familial power) and democracies (where self-sustaining democratic norms constrain governments). Similarly, incentive-alignment of the personal interests of elites with the broader population appears in many contexts, from economic history to executive compensation via company equity.

7.1.2. *What exactly was being committed to? Institutional presence vs quality.* Throughout the paper, I emphasize the credibility of long-term papal presence as the relevant variable for patrons’ investment. One may nonetheless ask whether the quality of governance changed – for instance, if the ecclesiastical elite would have incentives more aligned with the city’s population as a result of their real estate holdings – and whether that result in policy more conducive to economic growth and palace-building.

There is no clear prediction. On the one hand, a land-owning political elite might have more reason to enact policy advantageous to lay residents than a potentially-transitory governing class with no stake in the city’s future. On the other hand, the increased opportunities for personal profit could have created perverse incentive and led to policies designed to make prelates wealthier at the expense of laymen.⁴²

⁴²For instance, family names start to repeat much more in Cardinal Consistories starting from the mid-16thC: there seems to be an emergent quasi-dynastic prelate elite, much more hereditary than in it had been in the past. This paper does not take a stance on whether this was good or bad for Rome. Modern political theories, however, might suggest a preference for more meaningful turnover.

These ambiguous effects would have been as difficult for contemporaries to anticipate as they are for historians to now assess.⁴³ The observable and incontrovertible – and hence salient – change was presence. Indeed, were favourable governance alone to be a sufficient condition for lay palace-construction, the period of the papal sojourn in Avignon, during which laymen could rule the city with few external constraints, ought to have seen significant lay palace-building.

Thus, while measurement of governance quality in Renaissance Rome is extremely challenging and lies beyond the scope of this paper, the empirical patterns strongly suggest that (credible belief in) long-term papal presence was the key variable for investor expectations.

7.1.3. *Could the papal bull have been purely nominal? Why did it have any real effects?* A further concern is that prelates may already have avoided inheritance restrictions through informal transfers or corruption, rendering the papal bulls nominal in practice. Though some circumvention is plausible, it was unlikely to be quantitatively meaningful. Large sums of money were difficult to steal and hide, and the most common way to help relatives was via job procurement. Most importantly, pre-reform investment among laymen was similarly low: even if there was a flow of money from cardinals to beloved nephews – and even if those nephews resided in Rome – the funds were seldom allocated to Roman palazzo construction.

Given the fact that entry into and ascent in the Church were costly and time-consuming, that Francesco della Rovere did not become Pope on the promise to enact the reforms, and that pre-trends in the data show no evidence of anticipatory behaviour, there are compelling grounds for a causal interpretation of the post-reform changes. Furthermore, the magnitude of the estimated treatment effect is inconsistent with a purely nominal reform. Even under a conservative reading that allows for some pre-existing circumvention, the papal bulls materially changed the incentives of prelates to invest in real estate and which corresponds to real observed change in their investment patterns.

7.1.4. *Were there wealth spillovers after all?* If the papacy was so crucial to the Roman economy that a mere promise of its long-term presence was enough to incentivize investment, one may ask whether papal presence could have also generated economic activity itself. In other words, instead of prelate investment actively generating commitment and laymen learning this and updating their behaviour commensurately, could the papacy’s presence in Rome make laymen wealthy directly, after which they invested their new wealth in palaces?

Two comments are in order. First, the sharp increase in investment is inconsistent with a slow-moving income channel. So, even if wealth generation is involved, there is still some discontinuity attributable to the papal bulls. A wealth effect triggered by the expectation of

⁴³Sixtus IV did much to revive the city, but was perpetually embroiled in nepotism-related scandals. Leo X was popular and a great spender, but he accused a group of cardinals of plotting to kill him, and he created cardinals in such a flock that he may have diluted the prestige of the cardinalate. It is difficult to label a pope as “good” or “bad.”

permanent papal presence leaves the core mechanism intact and merely adds an intermediate step: reforms lead to prelate investment, which leads to papal commitment, which perhaps bolsters economic activity, which in turn leads to lay investment. The possibility of an intermediate step of wealth-creation does not change the fundamental importance of the papacy's long-term commitment.

Second, the socioeconomic profile of lay palace patrons makes a pure wealth channel unlikely. Lay palace-building families were not stonemasons, shopkeepers, or other middle-class professions who stood to benefit the most from increased economic activity. They typically made their fortune from landholdings outside Rome, dynastic marriages, or simply brought their wealth from other cities (Brentano, 1991). Thus, while increased activity may have broadened the urban economy, it is unlikely to have been the proximate cause of lay palace-building.

7.2. Why inheritable investment?

7.2.1. *Eliciting long-term attitudes.* Palaces were illiquid, costly, and designed to remain within a family, as a primary store of wealth and sign of power, for many generations. Outside options existed: Rome had an active rental market; the city had an unusually transitory elite, and every new pope, every new cardinal, every ambassador and wealthy immigrant wanted lodgings – but very few, before the reforms, built new ones (Fragnito, 1993). So, the choice to invest in a palace for any patron reveals their confidence in the city's future economic prospects in a way that investment in liquid or movable assets would not.

7.2.2. *Prevalence.* A palazzo served many purposes. It was not just a residence. It was a family heirloom; a symbol of power and wealth; an impressive reminder to friends and a warning to enemies; a fortress and a hub of economic activity. That it also happened to be the investment of choice throughout the Renaissance (see Goldthwaite (1993)) underscores the ambition – and consequently the potency – of the 1475-1480 papal bulls. Palaces also played a vital role in commercial and rental markets long after their construction was over, with floors reserved for vendors (including storefronts and storage) and tenants. Narrative evidence is abundant in confirming that early-modern Romans delighted in opportunities to spend illustrious sums of money on projects they thought would advantage their family for generations (Nussdorfer (1997), Goldthwaite (1993)).

7.2.3. *Economic Significance.* Unlike the occasional Church commission, which brought, at best, sporadic economic activity, sustained investment in real estate meant a steady income for artisans, stonemasons, builders, and skilled and unskilled labourers at all stages of the construction process (Goldthwaite, 1993; Bartlett, 2013)). Palace-building was, in other words, one of the primary economic engines of the Renaissance.

Especially for a city with almost no industry and whose most meaningful export was the sale of indulgences and mediation,⁴⁴ consistent labour demand was a promise of long-term economic activity – and a hope for a natural corrective to the demographic problems that plague a city with a minimal natural birthrate. Partner (1980) and Bartlett (2013) even suggest that the construction boom in the late fifteenth century and early sixteenth century led to an influx of workers from Lombardy settling in the city. Expectations of stable future employment lured entire families to Rome. Temporary spikes in labour demand induced, at best, temporary relocation of workers, and seldom led to mass migrations of wives and children.⁴⁵

A definition of “private” residence would map poorly onto early-modern urban life. Conversely, inheritability is a historically meaningful, verifiable criterion. It captures precisely the asset class at the heart of the reforms and the credibility mechanism. The Online Appendix discusses in greater detail early-modern use and understanding of space, as well as the choice of definitions employed in the construction of the data.

7.3. How robust is the distinction between prelate and lay? Lee (1983) notes that, in the fifteenth century, most cardinals came from outside Rome, and were, therefore, easily distinguishable from the powerful lay families. Until the Sack of Rome (1527), these are two largely distinct groups.

Eventually, family-rise and palace-building became a two-brother effort: one layman for marriage and begetting an heir; the other – clerical, for career advancement, even the cardinalate. Two such cases appear explicitly in my data (one in 1541, one in 1590) and likely become even more prominent later. Beyond the time-interval in question, selection into the prelate treatment group does become endogenous, available on a costly opt-in basis, which is another reason to constrain difference-in-difference analysis to before the Sack of Rome. (In fact, this suggests another dimension of wisdom to the policy: it is plausible that the bull allowed the papacy to simultaneously foster economic growth in the city and attract representatives of powerful families – or otherwise more competent workers – to join its ranks.)

7.4. Survivorship bias & data imperfections. As with any historical study, missing data and survivorship bias are legitimate concerns. Two features of the setting mitigate these issues: the comprehensiveness of the digitized map, and the continuity of data.

⁴⁴There was a market for masses, dedicated prayers, for Romans as for visitors, and another kind of indulgences: an absolution from solemn vows. So petitioners would come to Rome to litigate for absolution and remission. Rome exported justice, too: it was a court of last appeal (Southern, 1961), and – earlier than many monarchies – Rome exported its capacity to arbitrate and rule on cases, for instance in the *Sacra Romana Rota*, the highest ecclesiastical tribunal in the Church, which handled cases from across Europe (Salonen, 2016). See also Blastenbrei (2006), Fosi (1993) and Fosi (2011) for examples of seminal historical accounts of criminal justice in sixteenth century papal Rome.

⁴⁵For more on Lombard workers in Rome, see, for example, Pineiro (2020) and Fregna (1990).

Although the *Pianta Grande di Roma* depicts the city as Nolli saw it in 1748, the accompanying scholarly entries document what stood on each site before and after the mapped structure. They are, therefore, sufficient to reconstruct the cityscape of Rome in any year of interest. For major palaces and renovation projects, owing to the meticulous work of scholars who curated the data, the digitized map’s coverage is as complete as one could reasonably hope. Of course, limitations naturally persist: minor alterations (e.g., interior refurbishments) are not systematically recorded, and some structures (particularly those currently extant) surely have more readily available data than others. These omissions do not threaten the analysis: the former are beyond the scope of the present paper (which concerns itself with ambitious, historically-significant investment projects), and the latter does not jeopardize identification as current condition is not a predictor of patron identity. That is, I check whether current existence is a predictor of a project having a prelate patron, and the relationship is negative and statistically-insignificant (a Pearson correlation of -0.046, and a regression coefficient of -0.074 with p-value 0.472 even after controlling for the passage of time).

Moreover, there is no evidence that record preservation or scholarly attention changed discretely around the 1475–80 reforms – and hence no reason to suspect that results are driven by a discontinuity at the data level. To test this directly, I collect all mentions of events from the Nolli map: investment projects, demolitions and disasters, churches, fountains, parks, streets, special events, idiosyncratic notes about famous inhabitants – any entry, in short, for which a date is available. I examine the evolution of these entries over time. While mentions in the map increase gradually over time, there is no discontinuity at 1470. A placebo regression discontinuity design, shown in Figure 9 and Table 10, confirms smooth trajectories in levels and growth rates (i.e., in a logarithmic scale). For additional robustness, I also check that the “ambient” data availability is smooth: I exclude inheritable projects and check that there is no meaningful cutoff c.1470 either. The placebo RDD analysis confirms that the data do not exhibit a sharp break in information availability that could generate spurious treatment effects – which ought to assuage concerns of results being driven by survivorship bias.

It is, therefore, reasonable to assume that data limitations are roughly symmetric across patron groups and smooth around the 1470 cut-off. Thus, these concerns should not jeopardize the integrity of the quantitative analysis.

Other maps of Rome (e.g., the 1551 Bufalini map, the 1593 Tempesta map, the 1668 De Rossi map, the 1676 Falda map, and the 1697 Barbey map)⁴⁶ do not provide a viable substitute: they lack geometric accuracy, are often stylized townscapes, and, due to various inaccuracies, have never benefited from the systematic digitization effort afforded to the Nolli

⁴⁶Scholarly work involving any of the other maps has not been nearly as comprehensive. See StudiumUrbis (2019) for a discussion of the maps of Rome of the sixteenth and seventeenth centuries.

map. Deferring to the wisdom of historians, I follow this established practice of treating the Nolli map as the authoritative source.

8. HISTORICAL EVIDENCE FOR THE MECHANISM

In this section, I furnish qualitative historical evidence in favour of the commitment channel. I address three questions central to the mechanism. First, I examine the political environment in Rome after the end of the Avignon Papacy to argue that other positive “shocks” had not translated into economic revival before the reforms due to pervasive instability. Second, I document that uncertainty around papal presence was highly salient to contemporaries: even in 1378, just after the return of the papacy to the city, Romans appreciated the risk of renewed departure and even rioted to influence that year’s papal conclave (i.e., election). Finally, I draw on evidence from the conclaves immediately preceding and following the reforms to show that the commitment mechanism swiftly became binding, and to ascertain the exogeneity of the reforms. These questions are important for the mechanism, but bear on contemporaneous attitudes and political constraints — dimensions that are not directly testable with surviving historical data.

8.1. Why Did Past Attempts at Urban Revival Fail?

8.1.1. *Continued political instability post-Avignon.* During the Western Schism (1378-1417), there were multiple simultaneous popes in Rome, Avignon, and later Pisa, each of whom claimed to be the true pope and excommunicated the others. It was impossible to know who the true pontiff was, or where the papacy would come to reside.⁴⁷ Consolidating internal political authority was itself a challenge as local families were, at first, reluctant to cede control; tensions were eventually quelled following the reinstatement of the ancient practice of house-destruction as severe legal punishment by Pope Paul II (r.1464-1471) and probably last-exercised early in the tenure of Sixtus IV (Raedt, 2022). Rome was trapped in a vicious cycle of economic decay and political instability.

Decades of political manipulation for personal gain and a sequence of unpopular popes further eroded trust in the papacy long after the end of the Schism. Popes’ attempts to revitalize the city were perceived – rightly or wrongly – as halfhearted, or as self-serving and outright exploitative. Fear that the pope could still take off at any moment and move back to Avignon or elsewhere, plunging Rome back into one of her darkest chapters, manifested in an unwillingness to make any meaningful long-term investment in the city. Romans’ skepticism was justified: some popes did have extended sojourns outside Rome,⁴⁸ and most popes who stayed still made a clear priority of pursuing projects for their own aggrandizement or sought

⁴⁷In fact, despite the ensuing turmoil and various attempts to return the papacy to France, Gregory XI was the last French pope to date, excluding the antipopes of the Schism.

⁴⁸Out of his 16-year-long papacy (1431-1447), Eugenio IV spent over nine years away from Rome. See also Table 3 for more on papal absences from Rome.

to find ways to help their families.⁴⁹ Frommel (1988) identifies this egoism, particular in its degree to Rome,⁵⁰ as a major contributor to Rome’s infrastructure’s falling considerably behind that of cities like Florence, Siena, and Venice. The prevalent ethos was one of opportunistic short-termism.⁵¹

8.1.2. *Unsuccessful past attempts at revival: positive shocks were not enough.* In such an environment of uncertainty, even positive economic shocks generated little reaction, as evidenced by two important case-studies: the economic activity associated to Jubilees and the failed attempt at transforming Corsignano.

Lured to the city by promises of absolution, pilgrims would flock to Rome at most every quarter-century for Papal Jubilees. Large sums of money spent on the city’s temporary beautification were never recovered: pilgrims left just as they had come; rent prices fell back to pre-Jubilee levels within months (Curcio (1986)).

Papal attempts to suggest investment in other cities were likewise in vain: Mack (1987) finds that Pius II (r. 1458-64) wished to turn Corsignano into a papal city, renamed Pienza in his own honour, and tried to encourage palace-construction in the would-be summer residence town. Very few patrons followed suit, and the pope’s death put a swift end to that investment campaign. In short, positive economic shocks were not enough to secure Rome’s revival; in the absence of credible longevity of policy, hypothetical investors did not build palaces.

8.1.3. *Was Sixtus IV different?* Sixtus IV, unlike his predecessors, displayed a deep care for the development of Rome from his first days as pope. He took up the improvement of the city’s infrastructure: roads, bridges, hospitals, churches (Blondin, 2005; Ackerman, 1982; Madonna and Cerioni, 1983; Buddensieg, 1983).

Sixtus IV intentionally broadcast his ambition vis-à-vis urban revival. In the 1480 papal bull, the pope articulated his vision that Rome merited and required restoration because of its exceptional position as “the city consecrated to our lord Jesus Christ by the glorious blood of the martyred apostles Peter and Paul [...] and because the most high established

⁴⁹It is worth noting that a majority of popes prior to the early 16th century had come from unassuming backgrounds. Promotion to the papal mandate quite late in life allowed only for a few years to pursue an agenda. Unsurprisingly, the priority for men of humble origins was their own legacy and the immortalization of their name, not the amelioration of the city.

⁵⁰Frommel (1988) also points out that such a pronounced obsession with glory-seeking projects on the part of rulers could not have been sustained in republics nor in principalities with dynastic rule, and, therefore, constituted a problem whose severity was unique to Rome. This further highlights the optimality of the Roman setting for the investigation of stakeholder behaviour in the context of commitment problems.

⁵¹With the exception of Sixtus IV, Nicholas V (r.1447-1455) was the 15th-century pope most recognized for his dedication to public infrastructure. On his deathbed, Nicholas said his effort to modernize the city, notably the Capitol and the Vatican palace, was “not for ambition, nor pomp, nor vainglory, nor fame, nor the eternal perpetuation of my name, but for the greater authority of the Roman church and the greater dignity of the Apostolic See”(Westfall, 1974, pp.33, 94-101, 129-165, quoted in Frommel (1988)). But Frommel (1988) is quick to point out that Nicholas V, like his predecessors, only embarked on a public campaign after having been in power for many years – having, first, satisfied his own private ambitions.

in it the principate of his bishop and the capital of the Christian religion, and because he chose in it the seat of his vicar, to which the faithful gather in large numbers from all parts of the world” (papal bull translated in (Fernandez, 2003, p.233); see (Richardson, 2009, p.301-302) discussing (?, p.179-180)). The public was aware of and responded favourably to these changes: Torch (2024) finds that correspondence between two prominent humanist contemporaries, Bussi and Gaza, exalted Sixtus IV’s patronage and governance as the virtues of a prince “we often wished for.” In other words, it was clear to Romans that this pope actively sought to revitalize the city.

8.2. Roman Attitudes to Uncertainty Surrounding the Papacy’s Long-term Presence. The Avignon Papacy⁵² (1309-1377) demonstrated that Romans could not afford to lose the pope, and that they could not trust him either. When Gregory XI passed away in March of 1378 some two months after returning the papacy to Rome – having defied the French king and the largely-French College of Cardinals – Romans took to the streets.

“We want a Roman pope, or at least an Italian,” the mob threatened, “or else you will die!” A heckler added the vivid description: “If you cardinals don’t give us one, we will make your heads as red as your hats” (Baumgartner, 2003). The cardinals gave in and elected an Italian pope, hoping to coerce him into resigning shortly thereafter. But resign Urban VI did not. He had a violent and unpredictable temper, and, by October of the same year, the cardinals elected another pope who, after an unsuccessful attempt to depose Urban VI, retreated to Avignon with his coterie. The Western Schism had begun.

During the Schism (1378-1417), there were multiple simultaneous popes in Rome, Avignon, and later Pisa, each of whom claimed to be the true pope and excommunicated the others. It was impossible to know who the true pontiff was, or where the papacy would come to reside.⁵³ Consolidating internal political authority was itself a challenge as local families were, at first, reluctant to cede control; tensions were eventually quelled following the reinstatement of the ancient practice of house-destruction as severe legal punishment by Pope Paul II (r.1464-1471) and probably last-exercised early in the tenure of Sixtus IV (Raedt, 2022). Rome was trapped in a vicious cycle of economic decay and political instability.

8.3. Political Environment and incentives: Evidence from papal conclaves.

8.3.1. *The election of Sixtus IV.* Why and how was Sixtus IV elected? This is an important question to answer, both from the perspective of understanding the contemporaneous political environment, and because causal identification of the mechanism will rely on the exogeneity of the papal bulls.

⁵²The Avignon Papacy was christened, by poet Francesco Petrarca (1304-1374), the “Babylon Captivity,” drawing an evocative comparison between the papacy’s sojourn in France and the forced relocation of Judeans to Babylonia after the siege of Jerusalem in 597 BC (and again after the destruction of Jerusalem and Solomon’s Temple in 587 BC).

⁵³In fact, despite the ensuing turmoil and various attempts to return the papacy to France, Gregory XI was the last French pope to date, excluding the antipopes of the Schism.

The 1471 papal conclave was contentious. The two biggest lobbies were the French-aligned faction and the Orsini faction, but neither was large enough to ensure their preferred cardinals could win in such a fraught political environment. The initial front-runners in early scrutinies (voting rounds) were already compromise picks, but too closely associated to political interests that made them unpalatable to others: Roverella from Ferrara could not gain the support of Roman and French cardinals, and Calandrini was opposed by anti-Florentine elements for his ties to the Medici. In these early scrutinies, Francesco della Rovere amassed few votes. But once it became clear that Roverella, Calandrini and other established candidates could not secure enough votes, della Rovere emerged as a sort of “universal second choice” – and hence compromise pick. A foreigner with no connections to princely houses and baronial entanglements, a scholar and pious man, he elicited no strong opposition from anyone. The scales finally tipped in della Rovere’s favour, in fact, when a few influential cardinals cast votes they had previously “reserved” consistent with a slow process of building a mutually-acceptable coalition (Pastor, 1936, p.197-208).⁵⁴

Pastor (1936, p.204-205) thus describes the atmosphere in Rome after the conclave: “The election of Cardinal Francesco della Rovere caused great joy throughout Rome, especially, Nicodemus informs us, because the well-known piety and holiness of his life led all to hope that he would be an excellent Pastor for the Church and for the Christian Faith everywhere. Francesco, like Nicholas V, owed his elevation to the purple to his reputation as a learned theologian and a man of blameless like.”

There was no reason, in short, to suspect that Francesco della Rovere was made pope to enact specific reforms concerning palace-building. Much of his domestic policy were a surprise to his contemporaries – as was, in fact, his very election.

8.3.2. *Post-reform shift in political realities and prelates’ incentives.* Did the papal bulls then create a self-propagating incentive structure? Evidence that cardinals came to support Sixtus IV’s agenda is present even in the very next papal conclave. Sixtus IV passed away in 1484, just a few years after introducing the papal bulls, and Cardinal Giovanni Battista Cibo (Pope Innocent VIII) was elected his successor. His candidacy had been championed by a cardinal-nephew of Sixtus IV – Cibo was thus positioned as the natural heir to Sixtus

⁵⁴The beginnings of Sixtus IV’s reign supported the image of a compromise candidate. He quickly made peace with Naples and Venice. “This Pope evidently intends to be on good terms with everyone,” wrote the Marquess of Mantua’s ambassador (Pastor, 1936, p.214). The lack of traditional faction and hence pliability, openness to all factions, and desire for universal appeal was probably why della Rovere’s candidacy was the one eventually supported by the Duke of Milan (despite initial lobbying by the French faction for their preferred candidate Cardinal d’Estouteville), a relationship which nonetheless soured shortly thereafter. In Rome, “Sixtus IV commenced his reign by conferring favours on the Cardinals, and in this proceeding formed such a contrast to his predecessor that, as an Ambassador wrote, every one felt as if they were in a new world” (Pastor, 1936, p.210). This he did even at considerable cost to himself, giving away offices and papal riches in ways that were unexpected and unprecedented.

IV's agenda – and opposed by the de facto pro-Neapolitan faction,⁵⁵ who had lobbied for a rival-candidate (Burkle-Young, 2022). The College of Cardinals was careful to elect popes with an eye to preserving Sixtus IV's legacy and to avoiding negative foreign influence.

The one (unsuccessful) attempt to put an end to this policy lasted for a few short years in the late 17th century; the pope who launched the venture and even started a war on nepotism (which temporarily collapsed palace-building) to this day boasts a reputation as one of the least popular in the entire history of the papacy (Krautheimer, 1985).

9. CONCLUSION

This paper provides the first quantitative evidence on the origins of Rome's palace-building boom and identifies an institutional mechanism linking papal reforms to real estate investment. The 1475–80 papal bulls, by making property owned by high-ranking ecclesiastical officials inheritable and easing land acquisition, created both the incentive and the capacity for investment. Due to their investments in the city, prelates personally benefited from the papacy's continued presence in Rome, which rendered papal departure prohibitively costly and precluded the appointment of successors inclined to leave the city. Via this self-reinforcing incentive constraint (à la North (1990) and Greif (2006)), papal presence in Rome became irreversible. The irreversibility, in turn, gave rise to the beliefs necessary for a citywide construction boom. A series of tests underscore that the effectiveness of reforms depends on the credibility of their permanence – a distinction difficult to observe in most modern settings. The 1475–80 papal bulls had such a striking effect precisely because they rendered papal presence irreversible, while the return of a single pope to Rome, a century earlier, did not.

Early-modern Rome represents a unique and natural laboratory for the study of political economy, institutional economics, and urban growth. Many events that appear concurrently in contemporary settings (e.g., stakeholder presence and commitment, improvement in institution quality and the credibility thereof) are staggered here, and allowing effects to be disentangled. It is now clear, for instance, that the mere presence of the powerful stakeholder did little for Rome until there was a sign that the stakeholder's and city's futures were inextricably tied. Somewhat paradoxically, while the Church arguably became more prone to nepotism, more susceptible to the existence of a hereditary political elite, Roman institutions appreciated in credibility – to the benefit of the economy. The paper thus furnishes rare empirical evidence for a proposition advanced by Acemoglu and Robinson (2006): enduring institutions arise when those with power find permanence in their own interest. In this sense,

⁵⁵According to Burkle-Young (2022), one faction prioritized the advancement of papal power, and another supported a pan-Italian alliance, the Italian League. A consensus emerged among non-Venetian cardinals that Sixtus IV's adherence to the Peace of Bagnolo, to curb the influence of Venice, was to be preserved: cardinals' choice of faction reflected mostly their preference vis-à-vis the power and influence to be afforded to the papacy and Rome at the expense of the Kingdom of Naples. In the end, cardinals adopted a pro-Roman view, electing the candidate likely to prioritize Roman geopolitical interests.

palace-building in renaissance Rome illustrates that credible institutional commitment was an engine of early-modern growth.

Several research avenues remain unexplored in the Roman context. There is reason, for instance, to suspect that private investment drove future patronage; elites who suddenly no longer had a transactional or transitory relationship with the city were more likely to become philanthropists (motivated, surely, by concerns of public appeal and politics). Families would also attempt to curry favour with popes via various commonalities (e.g., shared migrant origins, etc.). All of this would likely manifest in investment behaviour at politically-salient moments, such as at times of papal turnover. Likewise, the dusk of palace-building would benefit from further analysis. Among the most important contributors is likely primogeniture, a practice of making firstborn sons the sole heirs of family property, implemented via *fidecommesso* contracts. An attempt to consolidate inheritance and take advantage of convex returns, the strategy was extremely risky: with daughters sent to nunneries and surplus sons to the Church, the custom inadvertently led to the extermination of noble families. While the demographic consequences are well-established by historians, the effects on palace-construction and the economy more broadly have not been studied.⁵⁶

Rome was rebuilt. Not in a day, not by decree. But by individual patrons with renewed confidence in Rome, the papacy's commitment to long-term presence in the city, and the future. It is, perhaps, no wonder that eulogies drew parallels between a famed Emperor and the pope who "made Rome from a city of brick into stone just as Augustus of old had turned the stone city into marble" (Raffaello Maffei, quoted by Partridge (1996, p.21)).

REFERENCES

- Acemoglu, Daron (2012) *Introduction to Modern Economic Growth*, Princeton: Princeton University Press.
- Acemoglu, Daron, Simon Johnson, and James A. Robinson (2005) "Institutions as a Fundamental Cause of Long-run Growth," in Aghion, Philippe and Steven N. Durlauf eds. *Handbook of Economic Growth, Vol. 1A*, Chap. 6, 385–472: Elsevier.
- Acemoglu, Daron and James A. Robinson (2006) *Economic Origins of Dictatorship and Democracy*, Cambridge: Cambridge University Press.
- (2008) "Persistence of Power, Elites, and Institutions," *American Economic Review*, 98.
- Ackerman, James S. (1982) "Rome in the Renaissance: The City and the Myth," in Ramsey, Paul A. ed. *Papers of the Thirteenth Annual Conference of the Center for Medieval and Early Renaissance Studies*, New York.
- Ago, Renata (1990) *Carriere e clientele nella Roma barocca*: Einaudi.

⁵⁶Primogeniture can, for example, simultaneously account for the rapidly-diminishing number of palaces (via the extinction of powerful families) and the gargantuanism and illustriousness of the palaces that were built (via consolidated wealth).

- Aoki, Masahiko (2001) *Toward a Comparative Institutional Analysis*: MIT Press.
- (2011) *Institutions as Cognitive Media Between Strategic Interactions and Individual Beliefs*: Cambridge University Press.
- Barber, Malcom (2006) *The Trial of the Templars*: Cambridge University Press.
- Barro, Robert J and David B Gordon (1983a) “A positive theory of monetary policy in a natural rate model,” *Journal of political economy*, 91 (4), 589–610.
- (1983b) “Rules, discretion and reputation in a model of monetary policy,” *Journal of monetary economics*, 12 (1), 101–121.
- Bartlett, Kenneth (2013) *A Short History of the Italian Renaissance*, Toronto: University of Toronto Press.
- Bassetto, Marco, Zhen Huo, and José-Victor Rios-Rull (2024) “Institution Building without Commitment,” *American Economic Review*, 114 (11), 3427–3468.
- Battigalli, Pierpaolo and Marciano Siniscalchi (2002) “Strong Belief and Forward Induction Reasoning,” *Journal of Economic Theory*, 106 (2), 356–391.
- Baumgartner, Frederic J. (2003) *Behind Locked Doors: A History of the Papal Elections*: Palgrave Macmillan.
- Besley, Timothy and Torsten Persson (2009) “The Origins of State Capacity: Property Rights, Taxation, and Politics,” *American Economic Review*, 99 (4), 1218–44.
- Blastenbrei, Peter (2006) “Violence, arms and criminal justice in papal Rome, 1560-1600,” *Renaissance Studies*, 20 (1), 68–87.
- Blondin, Jill E. (2005) “Power Made Visible: Pope Sixtus IV as “Urbis Restaurator” in Quattrocento Rome,” *The Catholic Historical Review*, 91 (1), 1–25.
- Botticini, Maristella (1999) “A Loveless Economy? Intergenerational Altruism and the Marriage Market in a Tuscan Town, 1415-1436,” *The Journal of Economic History*, 59 (1), 104–121.
- Botticini, Maristella and Aloysius Siow (2003) “Why Dowries?” *The American Economic Review*, 93, 1385–98.
- Brentano, Robert (1991) *Rome before Avignon: A Social History of Thirteenth-Century Rome*: University of California Press.
- Buddensieg, Tilman (1983) “Die Statuenstiftung Sixtus’ IV. im Jahre 1471,” in *Römisches Jahrbuch für Kunstgeschichte*, XX, 54–72, Roma: Bibliotheca Hertziana.
- Buringh, Eltjo, Bruce M. Campbell, Auke Rijpma, and Jan Luiten van Zanden (2020) “Church building and the economy during Europe’s ‘Age of the Cathedrals’, 700-1500CE,” *Explorations in Economic History*, 76.
- Burkle-Young, Francis A. (2022) “Papal elections in the Fifteenth Century: The election of Pope Innocent VIII (1484).”
- Cantoni, Davide, Jeremiah Dittmar, and Noam Yuchtman (2018) “Religious competition and reallocation: The political economy of secularization in the protestant reformation,” *The Quarterly Journal of Economics*, 133 (4), 2037–2096.

- Cantoni, Davide, Cathrin Mohr, and Matthias Weigand (2024) “The Rise of Fiscal Capacity: Administration and State Consolidation in the Holy Roman Empire,” *Econometrica*, 92 (5), 1439–1472.
- Cho, In-Koo and David M. Kreps (1987) “Signaling Games and Stable Equilibria,” *The Quarterly Journal of Economics*, 102 (2), 179–221.
- Cohen, Thomas (2025) “Magdalena, Deaf and Mute, makes her Roman Will,” *Renaissance Quarterly*, 87 (4), 1–37.
- Curcio, Giovanna (1986) “I processi di trasformazione edilizia,” in Massimo Miglio, Diego Quaglioni Concetta Ranieri, Francesca Niutta ed. *Un Pontificato ed una città: Sisto IV (1471-1484)*, 706–732, Roma: Istituto storico italiano per il medioevo.
- De Dominicis, Claudio (2009) “Membri del Senato della Roma pontificia. Senatori, Conservatori, Caporioni e loro Priori e Lista d’oro delle famiglie dirigenti (secc. X-XIX),” <https://www.accademiamoroniana.it/indici-e-repertori-biografici/>.
- Dell, Melissa (2010) “The Persistent Effects of Peru’s Mining Mita,” *Econometrica*, 78 (6), 1863–1903.
- Dittmar, Jeremiah E. and Ralph R. Meisenzahl (2020) “Public Goods Institutions, Human Capital, and Growth: Evidence from German History,” *Review of Economic Studies*, 87 (2), 959–996.
- Drelichman, Mauricio and Hans-Joachim Voth (2014) *Lending to the Borrower from Hell: Debt, Taxes, and Default in the Age of Philip II*: Princeton University Press.
- Fellner, William (1976) “Towards a reconstruction of macroeconomics: Problems of theory and policy,” *American Enterprise Institute for Public Policy Research*.
- (1979) “The credibility effect and rational expectations: implications of the Gramlich study,” *Brookings Papers on Economic Activity*, 1979 (1), 167–189.
- Fernandez, Henry Dietrich (2003) *Bramante’s Architectural Legacy in the Vatican Palace: A Study in Papal Routes*, Ph.D. dissertation, University of Cambridge.
- Fosi, Irene (1993) “Justice and its Image: Political Propaganda and Judicial Relativity in the Pontificate of Sixtus V,” *The Sixteenth Century Journal*, 24, 75–95.
- (2011) *Papal Justice: Subjects and Courts in the Papal State, 1500-1750*: Catholic University of America Press, translated by Thomas V. Cohen.
- Fagnito, Gigliola (1993) “Cardinals’ Courts in Sixteenth-Century Rome,” *The Journal of Modern History*, 65 (1), 26–56, 10.1086/244607.
- Fregna, Roberto (1990) *La Pietrificazione del Denaro: Studi sulla proprietà urbana tra XVI e XVII Secolo*: CLUEB.
- Frommel, Christoph Luitpold (1973) *Der römische Palastbau der Hochrenaissance*, Tübingen: Wasmuth, 2 vols.
- (1988) “Papal Policy: The Planning of Rome during the Renaissance,” in Rotberg, Robert I. and Theodore K. Rabb eds. *Art and History: Images and Their Meaning*, 39–65, Cambridge: Cambridge University Press.

- Goldthwaite, Richard (1982) *The Building of Renaissance Florence: An Economic and Social History*: John Hopkins University Press.
- (1993) *Wealth and the Demand for Art in Italy, 1300-1600*: John Hopkins University Press.
- Goldthwaite, Richard A. (1980) *The Building of Renaissance Florence: An Economic and Social History*, Baltimore: Johns Hopkins University Press.
- Govindan, Srihari and Robert B. Wilson (2009) “A Formal Approach to Forward Induction Reasoning in Extensive Form Games,” *Econometrica*, 77 (1), 1–28.
- Greif, Avner (2006) *Institutions and the Path to the Modern Economy: Lessons from Medieval Trade*, Political Economy of Institutions and Decisions, Cambridge: Cambridge University Press.
- Hallman, Barbara McClung (1985) *Italian Cardinals, Reform and the Church as Property, 1492-1563*: University of California Press.
- Howard, Deborah (2002) *Venetian Architecture, 1450–1540*, New Haven: Yale University Press.
- Izbicki, Thomas M. (2006) *Reject Aeneas, Accept Pius: Selected Letters of Aeneas Sylvius Piccolomini (Pope Pius II)*: Catholic University of America Press.
- Jr., Samuel Cohn (2012) “Renaissance attachment to things: material culture in last wills and testaments,” *Economic History Review*, 65 (3), 984–1004.
- Kohlberg, Elon and Jean-François Mertens (1986) “On the Strategic Stability of Equilibria,” *Econometrica*, 54 (5), 1003–1037.
- Krautheimer, Richard (1980) *Rome: Profile of a City, 312–1308*, Princeton: Princeton University Press.
- (1985) *The Rome of Alexander VII, 1655-1667*: Princeton University Press.
- Kydland, Finn E and Edward C Prescott (1977) “Rules rather than discretion: The inconsistency of optimal plans,” *Journal of political economy*, 85 (3), 473–491.
- Lee, Egmont (1983) “Foreigners in Quattrocento Rome,” *Renaissance and Reformation / Renaissance et Réforme, New Series / Nouvelle Série*, 7, 135–146.
- Mack, Charles R. (1987) *Pienza: The Creation of a Renaissance City*: Cornell University Press.
- Madonna, Maria Luisa and Anna Maria Cerioni (1983) “Momenti della politica edilizia e urbanistica dello Sato Pontificio nel '400. L'exemplum della Piazza del Comune a Viterbo,” in Cannata, Roberto and Caludio Strinato eds. *Il Quattrocento a Viterbo*, 23–89, Roma: De Luca Editore.
- Man, Priscilla T. Y. (2012) “Forward Induction Equilibrium,” *Games and Economic Behavior*, 75 (1), 265–276.
- Mokyr, Joel (1990) *The Lever of Riches: Technological Creativity and Economic Progress*: Oxford University Press.

- Müntz, Eugène (1878) *Les arts à la cour des papes pendant le XVe et le XVIe siècle : recueil de documents inédits tirés des archives et des bibliothèques romaines*, 9: E. Thorin.
- North, Douglas (1990) *Institutions, Institutional Change and Economic Performance*: Cambridge University Press.
- North, Douglass C. and Barry R. Weingast (1989) “Constitutions and Commitment: The Evolution of Institutions Governing Public Choice in Seventeenth-Century England,” *The Journal of Economic History*, 49 (4), 803–832.
- Nunn, Nathan (2008) “The Long-Term Effects of Africa’s Slave Trades,” *The Quarterly Journal of Economics*, 123 (1), 139–176.
- Nunn, Nathan and Leonard Wantchekon (2011) “The Slave Trade and the Origins of Mistrust in Africa,” *American Economic Review*, 101 (7), 3221–52.
- Nussdorfer, Laurie (1997) “The Politics of Space in Early Modern Rome,” *Memoirs of the American Academy in Rome*, 42, 161–186.
- Oakley, Francis (2003) *The Cociliarist Tradition: Constitutionalism in the Catholic Church 1300-1870*: Oxford University Press.
- Partner, Peter (1980) *Renaissance Rome, 1500-1559: A Portrait of a Society*: University of California Press.
- Partridge, Loren (1996) *The Art of Renaissance Rome, 1400-1600*, New York: Prentice Hall.
- Pastor, Ludwig (1936) *The History of the Popes: From the Close of the Middle Ages*, 4: B Herder Book Company.
- Piketty, Thomas and Gabriel Zucman (2015) “Wealth and inheritance in the Long Run,” in Atkinson, Anthony and François Bourguignon eds. *Handbook of Income Distribution*, Vol. 2B, chapter 15, 1303–1368: Elsevier.
- Pineiro, Manuel Vaquero (2020) “I lavoratori dell’edilizia a Roma tra XV e XVI secolo,” in *Vivere la Città*: Viella.
- Raedt, Nele De (2022) “Papal and municipal authority in the city: house-destruction as a legal punishment in Renaissance Rome,” *UrbanHistory*, 1–17.
- Richardson, Carrol (2009) *Reclaiming Rome: Cardinals in the Fifteenth Century*: Brill Academic Publishers.
- Rodrik, Dani (2000) “Institutions for High-Quality Growth: What They Are and How to Acquire Them,” *Studies in Comparative International Development*, 35 (3), 3–31.
- Roland, Gérard (2004) “Understanding Institutional Change: Fast-Moving and Slow-Moving Institutions,” *Studies in Comparative International Development*, 38 (4), 109–131.
- Salonen, Kirsi (2016) *Papal Justice in the Late Middle Ages: The Sacra Romana Rota*, Abingdon, UK: Routledge, 10.4324/9781315599359.
- Schotter, Andrew (1981) *The Economic Theory of Social Institutions*: Cambridge University Press.
- Southern, Richard W. (1961) *The Making of the Middle Ages*: Yale University Press.

- Spezzaferro, Luigi (1981) “« Place Farnèse : urbanisme et politique »,” in École française de Rome ed. *Le Palais Farnèse. Vol. I*, 84–123, Rome: École française de Rome.
- Stasavage, David (2002) “Credible Commitment in Early Modern Europe: North and Weingast Revisited,” *Journal of Law, Economics, and Organization*, 18 (1), 155–86.
- StadiumUrbis (2019) “Rome Maps Stadium Urbis,” <http://web.archive.org/web/20190719013002/http://www.stadiumurbis.org/rome-maps/>, July, Archived on web.archive.org.
- Sénéchal, Philippe (1999) “Le tombeau de Melchiorre Baldassini retrouvé à Chaalis,” *Revue de l’Art*, 124 (1), 56–61, 10.3406/rvart.1999.348446.
- Tafuri, Manfredo (1989) *Venice and the Renaissance*, Cambridge, MA: MIT Press, Translated by Jessica Levine.
- Tice, James, Nicola Camerlenghi, Erik Steiner, Giovanni Svevo, Allan Ceen, and Giovanni Svevo (2021) “Interactive Nolli Map Website 2.0,” <https://web.stanford.edu/group/spatialhistory/nolli/>.
- Titman, Sheridan (1985) “Urban Land Prices Under Uncertainty,” *The American Economic Review*, 75 (3), 505–514.
- Torch, Barry (2024) “Do I Have a Book for You! The Friendship of Theodore Gaza, Giovanni Bussi, and a Gifted Book,” in Christopoulos, John and John Hunt eds. *Making Stories in Early Modern Italy and Beyond: Essays in Honour of Elizabeth S. Cohen and Thomas V. Cohen*, 31–47, Toronto: Centre for Renaissance and Reformation Studies: Essays and Studies (59).
- Trachtenberg, Marvin (1997) *Dominion of the Eye: Urbanism, Art, and Power in Early Modern Florence*, Cambridge: Cambridge University Press.
- Vida, Péter and Takakazu Honryo (2021) “Strong Forward Induction in Monotonic Multi-Sender Signaling Games,” *Games and Economic Behavior*, 126, 265–290.
- Westfall, Carroll William (1974) *In This Most Perfect Paradise*: Pennsylvania State University Press.

VARIABLE	DESCRIPTION
DATA OBTAINED FROM THE MAP	
ID	Location ID on the Nolli Map; a unique identifier of a (palace-)site
Name	Name when Nolli was making the map (c. 1736-48)
Modern Name	Name in the 21 st century
Type	Landmark type in its “final” form (e.g., palazzo, street, academy, church, etc.)
Architects	All (prominent) architects engaged with connections to building over its “lifetime”
Patrons	All (prominent) patrons engaged with connections to building over its “lifetime”
Start year	First year of project
End year	Last year of project
Current condition	Condition in 21st century, if available
Description	Description of event (furnished by historians)
MANUAL CLASSIFICATION OF EVENTS	
All investment (= active project)	A dummy variable capturing an instance of real estate investment.
Built	The building was built/some institution was established for the first time, or very significant construction took place. ^a
Rebuilt	Work was done on an existing building (reconstruction, improvement, etc.). ^b
Inheritable	Records whether or not the construction associated to the project was inheritable (e.g., a residential palazzo). Need not reflect current state.
Prelate patron	Records whether there is a patron who is a high-ranking ecclesiastical official overseeing the particular project.
Reigning pope’s relative	The patron is a close relative of the reigning pope at the time of the project’s inception.
Supplementary notes	A record of additional sources consulted, separate from Nolli map, used to classify the entry.
CONSTRUCTED VARIABLES	
Prelate population	The number of active prelates, as per the Cardinal consistories.
Lay population	The number of active laymen, as per the Lista d’Oro.
Since last project ^c	Number of years since the last project at the same site (and higher-order polynomial terms).
Previous project length ^c	Total length of the previous project at the same site (and higher-order polynomial terms).
Project length	Number of years in which project is active (and higher-order polynomial terms).
Century-long project	Plausible measurement error: project is exactly a century long, with start- and end-dates exactly at the turn of a century.

TABLE 5. Description of variables

^a For example, if, on the territory, there was a palace, and they added a military fort, that merits the “built” tag because the purpose of the added infrastructure is different. Adding a chapel or cloister to an existing church is best classified as an “improvement” rather than as new construction.

^b “All investment” is a union of “built” and “rebuilt” projects.

^c Censored variables. In quantitative analysis, these are modulated by a dummy variable (“has a previous project”).

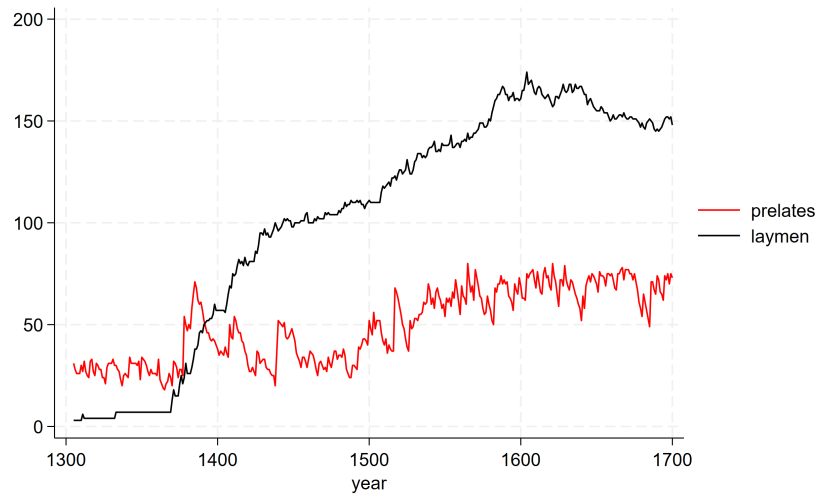


FIGURE 8. Prelate and Lay populations

The number of cardinals remains quite constant over time: their population is a reflection of the needs of the papacy. The number of powerful laymen grows with the overall prosperity and size of Rome. Prelate populations are taken from cardinal consistories; lay populations are derived from occupants of high-ranking civil service positions.

	(1)	(2)	(3)	(4)
papal bull=1	-0.000328 (0.000744)			
prelate patron=1	-0.000214 (0.000524)	-0.000321 (0.000787)	-0.000779 (0.000881)	-0.000779 (0.000881)
papal bull \times prelate patron=1	0.00392 (0.00331)	0.00584 (0.00490)	0.00586 (0.00501)	0.00586 (0.00501)
c1	0 (.)	0 (.)	0 (.)	0 (.)
lay population			-0.000359*** (0.000136)	-0.000359*** (0.000136)
prelate population			0.0000186 (0.0000868)	0.0000186 (0.0000868)
10-year time dummies	—	✓	✓	✓
Observations	35040	23360	20434	20434
Adjusted R2				

Standard errors in parentheses

* $p < .10$, ** $p < .05$, *** $p < .01$

TABLE 6. Logit difference-in-difference analysis of papal reforms

The table presents average marginal effects (dy/dx) from logit regressions of the difference-in-difference. Standard errors, reported in parentheses, are clustered at the location \times patron-type level, same as treatment is administered. All continuous variables are evaluated at their sample means. The Average Treatment Effect on the Treated (ATT) is a roughly .26pp increase in the probability of additional new prelate projects at the average palace-site post reforms – constituting a 350% increase in relative terms.

	Investment (all)						Investment (lay)	
	(1) new proj.	(2) new proj.	(3) new proj.	(4) new proj.	(5) new proj.	(6) new proj.	(7) new proj.	(8) new proj.
post-1470		0.005*** (0.001)		0.005*** (0.001)		0.004*** (0.001)		0.006*** (0.002)
endogenous absence	-0.003*** (0.001)	-0.001 (0.001)						
endogenous \times post-1470		0.000 (.)						
antipope					-0.004*** (0.000)	-0.000 (0.001)	-0.005** (0.002)	0.000 (0.001)
antipope \times post-1470						0.000 (.)		0.000 (.)
papal absence			-0.003*** (0.001)	-0.001 (0.001)		-0.001 (0.001)		-0.001 (0.001)
absence \times post-1470				-0.002** (0.001)		-0.002* (0.001)		-0.002 (0.002)
Constant	0.004*** (0.001)	0.001* (0.000)	0.004*** (0.001)	0.001** (0.000)	0.005*** (0.000)	0.001* (0.001)	0.006*** (0.001)	0.001** (0.001)
N	64,824	64,824	64,824	64,824	64,824	64,824	32,412	32,412
Adjusted R2	0.000	0.001	0.000	0.001	0.001	0.001	0.001	0.002
Years antipopes 1378-1479	-	-	-	-	58	58	58	58
Years antipopes 1470-1599	-	-	-	-	0	0	0	0
Years absent 1378-1479	22	22	23	23	-	23	-	23
Years absent 1470-1599	0	0	5	5	-	5	-	5

Standard errors in parentheses

* $p < .10$, ** $p < .05$, *** $p < .01$

TABLE 7. The Effects of periods of contested rule on investment

Papal absences include all noteworthy stays of the pope outside Rome, due, for instance, to political exile or assassination attempts. “Endogenous papal absences” isolate the absences plausibly interpretable as signals of the pope’s waning willingness to remain in Rome. The variable “antipope” measures whether the (Roman) pope’s authority is contested in a particular year by a rival claim to his office – that is, by the existence of an antipope elsewhere. Regressions are run at the year-level, with each observation corresponding to a palace-location pair. All clustering is performed at the palace (location-ID) level.

	(1) new proj	(2) new proj	(3) new proj	(4) new proj	(5) new proj	(6) new proj
lagged prelate projects	-0.00109** (-2.66)	-0.00109*** (-3.18)	-0.000467 (-0.63)			
1370-1419 \times lagged prelate projects	0.00628 (1.09)	0.00628 (1.11)	0.0174 (1.22)			
1470-1519 \times lagged prelate projects	0.00479*** (6.04)	0.00479*** (6.27)	0.00369*** (4.38)			
1520-1569 \times lagged prelate projects	0.000382 (0.75)	0.000382 (0.84)	-0.0000438 (-0.06)			
1570-1599 \times lagged prelate projects	-0.0000519 (-0.10)	-0.0000519 (-0.09)	-0.00154 (-1.68)			
lagged lay projects	0.00187*** (2.89)	0.00187*** (3.46)	0.00128 (1.19)			
1370-1419 \times lagged lay projects	-0.00369* (-1.88)	-0.00369* (-1.93)	-0.00619 (-1.47)			
1470-1519 \times lagged lay projects	-0.00264*** (-4.06)	-0.00264*** (-4.85)	-0.00194* (-1.84)			
1520-1569 \times lagged lay projects	-0.000916 (-1.17)	-0.000916 (-1.31)	-0.000584 (-0.54)			
1570-1599 \times lagged lay projects	-0.00223*** (-3.18)	-0.00223*** (-3.44)	-0.000235 (-0.21)			
lagged prelate proj per capita				-0.0317*** (-3.12)	-0.0317*** (-3.94)	-0.0152 (-0.99)
1370-1419 \times lagged prelate proj per capita				0.0129 (0.28)	0.0129 (0.33)	0.0448 (0.51)
1470-1519 \times lagged prelate proj per capita				0.168*** (4.47)	0.168*** (4.52)	0.134*** (4.40)
1520-1569 \times lagged prelate proj per capita				-0.00709 (-0.41)	-0.00709 (-0.46)	-0.00765 (-0.55)
1570-1599 \times lagged prelate proj per capita				-0.0393 (-1.17)	-0.0393 (-0.91)	-0.136*** (-3.34)
lagged lay proj per capita				0.163*** (3.39)	0.163*** (4.29)	0.103 (1.64)
1370-1419 \times lagged lay proj per capita				-0.171*** (-3.14)	-0.171*** (-3.77)	-0.126* (-1.73)
1470-1519 \times lagged lay proj per capita				-0.213*** (-4.30)	-0.213*** (-5.34)	-0.148** (-2.40)
1520-1569 \times lagged lay proj per capita				-0.0430 (-0.56)	-0.0430 (-0.60)	-0.0265 (-0.38)
1570-1599 \times lagged lay proj per capita				-0.260** (-2.30)	-0.260* (-1.88)	0.186 (1.66)
Constant	0.000716** (2.34)	0.000716* (1.73)	0.00738 (1.11)	0.000679** (2.47)	0.000679* (1.77)	0.00204 (0.40)
location ID FE	—	✓	✓	—	✓	✓
_cons	✓	—	—	✓	—	—
N	32412	32412	32412	32412	32412	32412
Adjusted R2	0.00600	0.00361	0.320	0.00563	0.00325	0.320

t statistics in parentheses

* $p < .10$, ** $p < .05$, *** $p < .01$

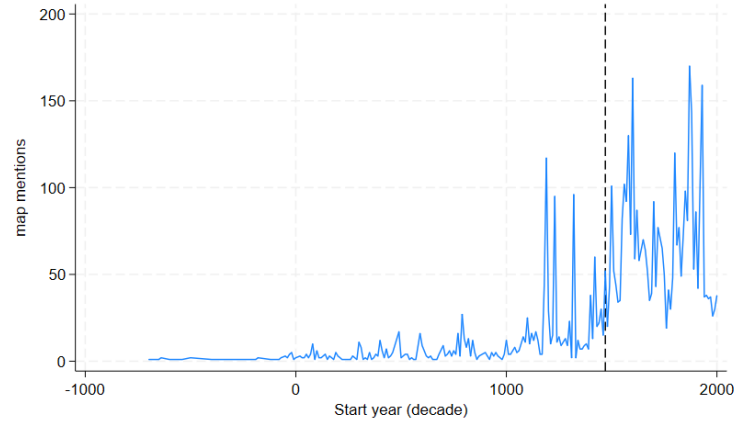
TABLE 8. Previous investment effects on future investment: full controls

	New projects (lay)			New projects (pooled)		
	(1) new proj.	(2) new proj.	(3) new proj.	(4) new proj.	(5) new proj.	(6) new proj.
lagged pooled projects	0.0000459 (0.92)	0.0000459 (1.42)	0.0000478 (0.28)	0.0000459 (0.92)	0.0000459 (1.42)	0.0000478 (0.28)
1370-1419	0.00125 (0.92)	0.00125 (0.92)	0.00336 (0.93)	0.00125 (0.92)	0.00125 (0.92)	0.00336 (0.93)
1470-1519	0.00532 (1.00)	0.00532 (1.00)	0.00385 (0.90)	0.00532 (1.00)	0.00532 (1.00)	0.00385 (0.90)
1520-1569	0.00447 (1.48)	0.00447 (1.47)	-0.00618 (-1.18)	0.00447 (1.48)	0.00447 (1.47)	-0.00618 (-1.18)
1570-1599	0.0264*** (15.98)	0.0264*** (11.70)	0.00551 (0.92)	0.0264*** (15.98)	0.0264*** (11.70)	0.00551 (0.92)
1370-1419 \times lagged pooled projects	-0.000266 (-1.62)	-0.000266 (-1.69)	-0.000489* (-1.91)	-0.000266 (-1.62)	-0.000266 (-1.69)	-0.000489* (-1.91)
1470-1519 \times lagged pooled projects	-0.00000622 (-0.05)	-0.00000622 (-0.06)	-0.0000827 (-0.37)	-0.00000622 (-0.05)	-0.00000622 (-0.06)	-0.0000827 (-0.37)
1520-1569 \times lagged pooled projects	0.0000259 (0.08)	0.0000259 (0.08)	0.000122 (0.71)	0.0000259 (0.08)	0.0000259 (0.08)	0.000122 (0.71)
1570-1599 \times lagged pooled projects	-0.000770*** (-10.31)	-0.000770*** (-9.04)	-0.000522** (-2.45)	-0.000770*** (-10.31)	-0.000770*** (-9.04)	-0.000522** (-2.45)
lay population			0.0000793* (1.76)			0.0000793* (1.76)
prelate population			0.000164 (1.06)			0.000164 (1.06)
has prev proj=1			0.996*** (759.92)			0.996*** (759.92)
has prev proj=1 \times years since prev proj			-0.0000116 (-0.35)			-0.0000116 (-0.35)
has prev proj=1 \times years since prev proj ²			0.000000132 (0.80)			0.000000132 (0.80)
Constant	0.000584 (1.51)	0.000584 (1.30)	-0.0131* (-1.86)	0.000584 (1.51)	0.000584 (1.30)	-0.0131* (-1.86)
location ID FE	—	✓	✓	—	✓	✓
_cons	✓	—	—	✓	—	—
N	32412	32412	32412	32412	32412	32412
Adjusted R2	0.00225	-0.000154	0.318	0.00225	-0.000154	0.318

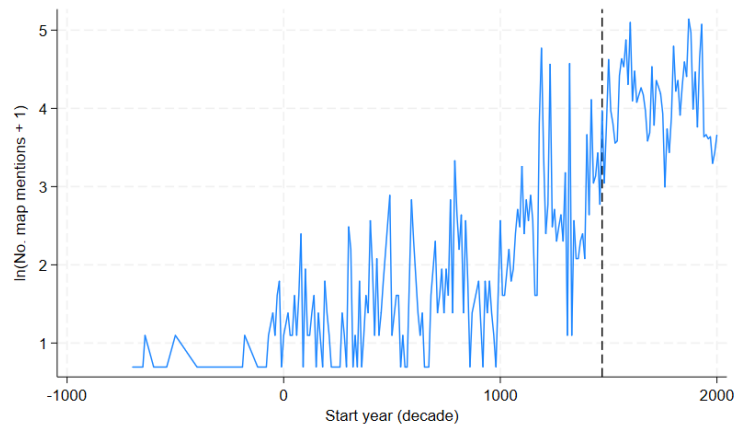
t statistics in parentheses

* $p < .10$, ** $p < .05$, *** $p < .01$

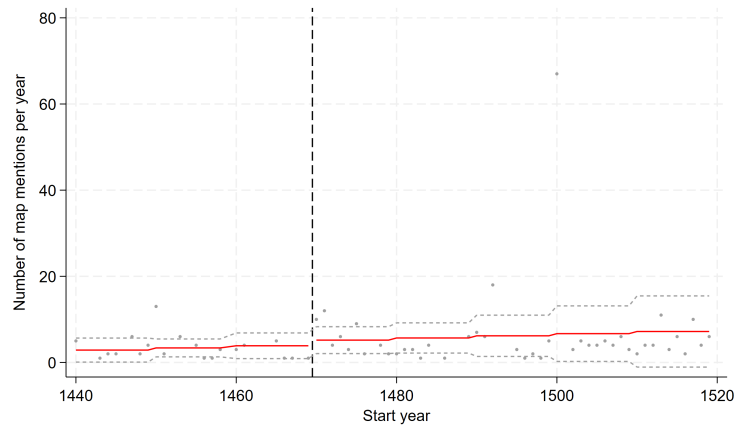
TABLE 9. Previous investment effects on future investment: pooled



(A) Linear scale



(B) Logarithmic scale



(c) Linear fit (outliers omitted from graph)

FIGURE 9. Map Mentions

The first two figures present the summary statistics for all data available in the digitized Nolli Map. In particular, the graphs display the total number of events (unconditional on type) mentioned whose start is in a given 10-year bin. The bottom figure is the result of a placebo RDD design with a linear specification.

	(1)	(2)	(3)	(4)	(5)
	mentions	mentions	mentions	ln(mentions + 1)	mentions (non-inheritable)
Start year (decade)	0.0501 (0.0630)				
papal bull	0.806 (1.844)	2.560 (1.642)	1.430 (3.581)	0.386 (0.263)	3.175 (2.111)
Start year		0.00783 (0.0404)	-625.6 (1033.7)	-0.000608 (0.00496)	-12.23 (523.7)
Start year ²			0.423 (0.700)		0.00774 (0.355)
Start year ³			-0.0000953 (0.000158)		-0.00000163 (0.0000800)
Constant	-69.31 (91.31)	-8.041 (58.75)	308428.3 (508380.8)	2.197 (7.209)	6440.6 (257768.2)
Time	1440-1519	1440-1519	1440-1519	1440-1519	1440-1519
N	63	63	63	63	62
R ²	0.0308	0.0252	0.0351	0.0695	0.0359
Adj. R ²	-0.00148	-0.00731	-0.0315	0.0385	-0.0317

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

TABLE 10. Placebo RDD to test for overall data discontinuity in 1470

The variable “mentions” counts the number of map mentions of any kind of project or event having a given start-year while “mentions (non-inheritable)” excludes instances of inheritable investment in order to highlight continuity in the “ambient environment.” All standard errors are heteroskedasticity-robust.

APPENDIX A. DIFFERENCE IN DIFFERENCE IN A WEIGHTED LEAST SQUARES REGRESSION FRAMEWORK

Consider the standard difference in difference framework,

$$Y_{it} = \beta_0 + \beta_1 Treated_i + \beta_2 Post_t + \beta_3 Treated_i \times Post_t + \varepsilon_{it},$$

adapted to fit within a WLS framework, such that for observation k in group (i, t) , we have:

$$Y_{itk} = \beta_0 + \beta_1 Treated_{itk} + \beta_2 Post_{itk} + \beta_3 Treated_{itk} \times Post_{itk} + \varepsilon_{itk},$$

Then in matrix form, we have $\mathbf{Y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}$, with $\mathbf{X} = [1, T, P, T \times P]$, from which it follows that the WLS estimator satisfies

$$\mathbf{X}'\mathbf{W}(\mathbf{Y} - \mathbf{X}\hat{\boldsymbol{\beta}}) = 0, \quad (5)$$

where \mathbf{W} is a diagonal weight matrix with ω_k on the diagonal entries. The normal equations, then, are as follows.

$$\text{For } \beta_0 : \sum_k \omega_k \times 1 \times (Y_k - \hat{\beta}_0 - \hat{\beta}_1 T_k - \hat{\beta}_2 P_k - \hat{\beta}_3 T_k P_k) = 0 \quad (6)$$

$$\text{For } \beta_1 : \sum_k \omega_k \times T_k \times (Y_k - \hat{\beta}_0 - \hat{\beta}_1 T_k - \hat{\beta}_2 P_k - \hat{\beta}_3 T_k P_k) = 0 \quad (7)$$

$$\text{For } \beta_2 : \sum_k \omega_k \times P_k \times (Y_k - \hat{\beta}_0 - \hat{\beta}_1 T_k - \hat{\beta}_2 P_k - \hat{\beta}_3 T_k P_k) = 0 \quad (8)$$

$$\text{For } \beta_3 : \sum_k \omega_k \times T_k P_k \times (Y_k - \hat{\beta}_0 - \hat{\beta}_1 T_k - \hat{\beta}_2 P_k - \hat{\beta}_3 T_k P_k) = 0 \quad (9)$$

Since $T_k P_k \neq 0 \iff T_k = P_k = 1$, equation 9 simplifies to $\sum_{k \in (1,1)} \omega_k (Y_k - \hat{\beta}_0 - \hat{\beta}_1 - \hat{\beta}_2 - \hat{\beta}_3) = 0$, or, equivalently, $\hat{\beta}_0 + \hat{\beta}_1 + \hat{\beta}_2 + \hat{\beta}_3 = \frac{\sum_{k \in (1,1)} \omega_k Y_k}{\sum_{k \in (1,1)} \omega_k} = \bar{Y}_{1,1}^W$.

From equation 6, it follows that

$$\sum_k \omega_k Y_k = \hat{\beta}_0 (\sum_k \omega_k) + \hat{\beta}_1 (\sum_k \omega_k T_k) + \hat{\beta}_2 (\sum_k \omega_k P_k) + \hat{\beta}_3 \sum_k \omega_k T_k P_k \quad (10)$$

$$= \hat{\beta}_0 (W_{00} + W_{01} + W_{10} + W_{11}) + \hat{\beta}_1 (W_{10} + W_{11}) + \hat{\beta}_2 (W_{01} + W_{11}) + \hat{\beta}_3 W_{11} \quad (11)$$

where $W_{it} = \sum_{k \in (i,t)} \omega_k$. Analogously, from equations 7 and 8 respectively, we obtain:

$$W_{10} \bar{Y}_{10}^W + W_{1,1} \bar{Y}_{11}^W = (\hat{\beta}_0 + \hat{\beta}_1) (W_{10} + W_{11}) + \hat{\beta}_2 W_{11} + \hat{\beta}_3 W_{11} \quad (12)$$

$$W_{01} \bar{Y}_{01}^W + W_{1,1} \bar{Y}_{11}^W = (\hat{\beta}_0 + \hat{\beta}_2) (W_{01} + W_{11}) + \hat{\beta}_1 W_{11} + \hat{\beta}_3 W_{11} \quad (13)$$

Solving the resulting linear system⁵⁷, we obtain

$$\begin{aligned}
\hat{\beta}_0 &= \bar{Y}_{00}^W \\
\hat{\beta}_1 &= \bar{Y}_{10}^W - \bar{Y}_{00}^W \\
\hat{\beta}_2 &= \bar{Y}_{01}^W - \bar{Y}_{00}^W \\
\hat{\beta}_3 &= \bar{Y}_{11}^W - \bar{Y}_{10}^W - \bar{Y}_{01}^W + \bar{Y}_{00}^W \\
&= (\bar{Y}_{11}^W - \bar{Y}_{10}^W) - (\bar{Y}_{01}^W - \bar{Y}_{00}^W) \quad \square
\end{aligned}$$

Similarly, the variance is given by:

$$\text{var}(\hat{\beta}_3) = \sigma^2 \times \left(\frac{1}{\sum_{k \in (1,1)} \omega_k} + \frac{1}{\sum_{k \in (1,0)} \omega_k} + \frac{1}{\sum_{k \in (0,1)} \omega_k} + \frac{1}{\sum_{k \in (0,0)} \omega_k} \right)$$

and σ^2 , as weights account for frequency, is the common error variance, so that the formula accounts for effective sample sizes, such that $\text{var}(\varepsilon_{itk}) = \sigma^2$.

⁵⁷Alternatively, to recover $\hat{\beta}_3$, we multiply equation 5 by the vector $(0, 0, 0, 1)$ to obtain

$$\hat{\beta}_3 = (0, 0, 0, 1)' \hat{\beta} = (0, 0, 0, 1)' (\mathbf{X}' \mathbf{W} \mathbf{X})^{-1} \mathbf{X}' \mathbf{W} \mathbf{Y} = \frac{\text{cov}_W(Y, T \times P)}{\text{var}_w(T \times P)}$$

where $\text{cov}_W, \text{var}_W$ are the W -weighted covariance and variances, respectively. This simplifies the solution considerably.