

Manpower, Money and Municipalities – A Bayesian Analysis of the Determinants of Local Public Investments in North Rhine-Westphalia

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September 29, 2026

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Abstract

We estimate determinants of local public investments of NUTS-3 regions and smaller municipalities in the most populous German federal state using a Bayesian hierarchical panel analysis, accounting for the nested structure of municipalities in their district. Tax revenue capacity and short-termed liquidity loans exert strong effects on investment, out-ruling institutional factors, such as administrative staffing and district-membership, showing no significant impact. Investment behavior does not differ between district-free cities and municipalities within districts. These findings highlight the dominance of fiscal constraints over administrative capacity in shaping local investment decisions, underscoring the limited autonomy of municipalities despite institutional differences.

Keywords: Local public investment, Fiscal capacity, German federalism, Bayesian hierarchical analysis

JEL Classification: R53, R51, H77, H72, C11

Highlights

- Tax revenue boosts investment in North Rhine-Westphalia's municipalities.
- Liquidity loans reduce local public investment.
- Bayesian estimation shows financial, not institutional, constraints from personnel.
- District effects do not deviate from federal-level tax and personnel impacts.
- High state dependence limits municipal financial autonomy in Germany.

1 Introduction

Public investment at the local level is essential for the provision of public services and goods in federal systems such as Germany, where municipalities traditionally account for roughly two-thirds of public investment (Brand et al. 2024: 128; Bremer, Di Carlo and Wansleben 2023: 1009–1011). Municipalities, as constitutional parts of the federal states (*Länder*), enjoy a certain degree of autonomy under guaranteed self-governance, which includes the right to set their own business tax rates and levy minor taxes and charges (*GG* 1949: Art.28 (2); Scheller and Walker 2017: 353). Within the constraints of limited fiscal space, municipalities face challenges in balancing revenue sources, which are highly dependent on federal and state funds, against current expenditures and investment expenditures (Scheller and Walker 2017: 355). The level of public investment, as a component of disposable expenditure, reveals the functioning of municipal self-administration (Beznoska and Kauder 2020: 20). While structural programs and a system of fiscal equalization aim at ensuring equal living conditions in Germany under the constitutional framework (*GG* 1949: Art. 72 (2)), the state of North Rhine-Westphalia (NRW), with 18 million inhabitants, illustrates the disparity of municipalities’ financial capacities and persistently high municipal heterogeneity in investment levels (Fig. 1.1).

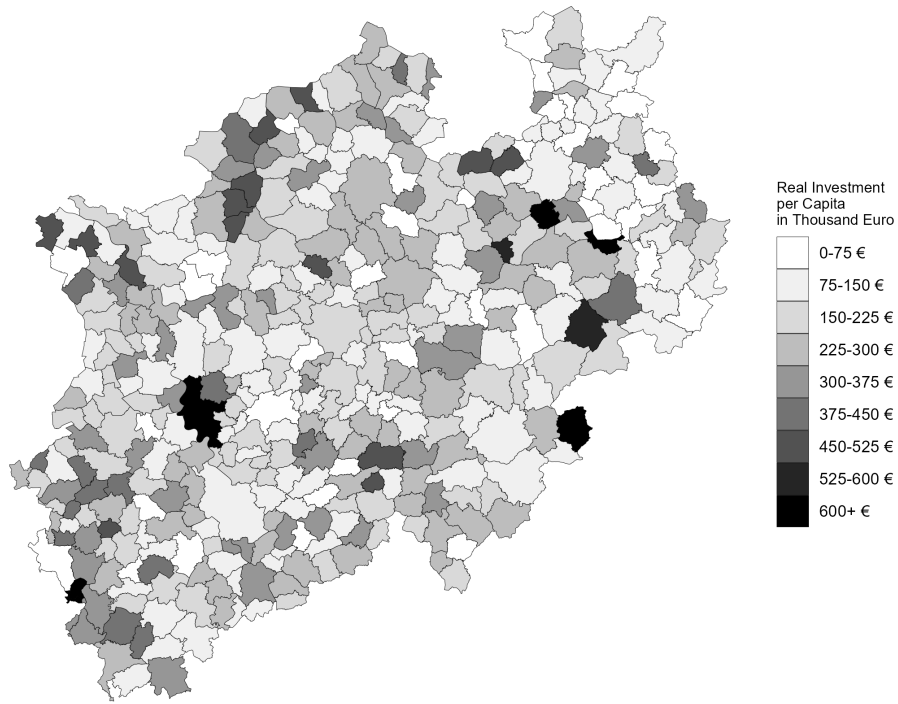
Debates and empirical research about the deteriorating local infrastructure prevail (Gornig, Michelsen and van Deuverden 2015: 251; Raffer and Rietzler 2026: 2), as Germany exhibits comparably low public investment levels, which have not yet caught up with the modest investment recovery in recent years (Gornig, Michelsen and van Deuverden 2015: 251). Studies identify primarily monetary factors, such as tax revenue, liquidity loans and competing mandatory expenditures can be attributed to diverging local public investment levels (Beznoska and Kauder 2020; Bremer, Di Carlo and Wansleben 2023). Further, though less studied, institutional factors, such as the number of administrative staffing in construction departments, affects the ability of local governments to plan and carry out investments and apply for grants (Beznoska and Kauder 2020: 23; Bremer, Di Carlo and Wansleben 2023: 1023–1024; Gornig and Michelsen 2017: 211; Scheller, Rietzler and Raffer 2021: 24).

Employing a Bayesian hierarchical model municipal investment dynamics are studied across North Rhine-Westphalia’s 22 autonomous, district-free cities (*kreisfreie Städte*) and 31 districts (NUTS-3 regions), encompassing a total of 374 small and

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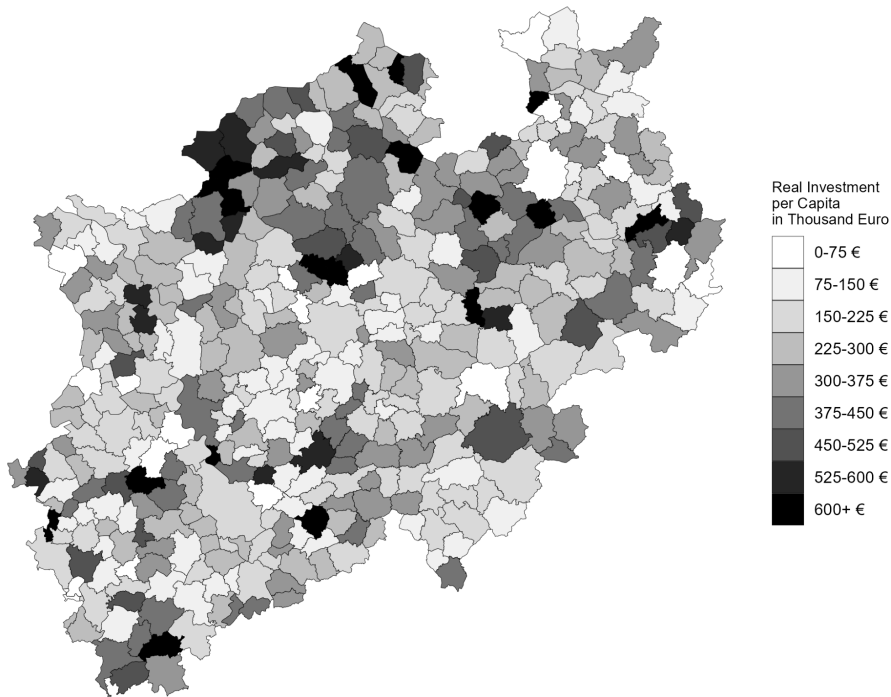
medium-size municipalities (*kreisangehörige Gemeinden*). This modeling can account for institutional differences and spatial dependencies by testing whether district membership of municipalities affects investment activity through changes in tax revenue and staffing levels. Further, the analysis investigates whether financial drivers and administrative capacity explain variations in local public investment activity.

1 Introduction



Source: Own illustration based on IT.NRW 2025a,b; Geoportal.NRW 2026 data (no missing values); price-adjusted to 2020 levels with the deflator of construction expenditure (Destatis 2025)

(a) Public Investment per Capita in 2010



Source: Own illustration based on IT.NRW 2025a,b; Geoportal.NRW 2026 data (no missing values); price-adjusted to 2020 levels with the deflator of construction expenditure (Destatis 2025)

(b) Public Investment per Capita in 2019

Figure 1.1: Regional Distribution of Public Investment per Capita in NRW in the Years 2010/2019

2 Empirical Analysis

Local public capital investment is measured for better municipal comparison as expenditures for construction projects, movable and immovable assets (IT.NRW 2025a). Municipal panel data are available as balanced data set for the core budget between 2009 to 2023 due to accrual accounting from the state’s statistical office (gpaNRW 2025; IT.NRW 2025a,b,c,d,e,f,g,h,i) and includes all 396 municipalities in North Rhine-Westphalia. The first year, 2009, is omitted because the previous year’s investments are used as an independent variable. Data from 2020 onward are further excluded, as the impacts of the COVID-19 pandemic may exert distorting effects on municipal budgets, allocations, and investment behavior (Bogumil and Holtkamp 2023: 289–292; Raffer and Scheller 2022: 14). All variables are price-adjusted and considered in absolute values rather than per capita. Instead of dividing investments by the number of inhabitants, which would assume a linear proportional relationship, population size is included explicitly in the model to directly depict causal pathways. This approach avoids the distortions associated with using population as a highly correlated scaling factor (Firebaugh and Gibbs 1985: 720–21).

The regression model is estimated as a dynamic panel model by including last year’s investment as lagged dependent variable, as it is likely that previous investment influences the actual level (Bremer, Di Carlo and Wansleben 2023: 1021). We employ a Bayesian hierarchical panel analysis to capture further heterogeneity among district-specific parameters. District-free cities are grouped together and compared to districts due to their similar institutional status. Within a district, it can be assumed, that there is a similar level of investment behavior between these municipalities due to the delegation of certain tasks to the district administration. In an extended model setup a special focus is set on different behavior between districts on changes of tax income and personnel capacity, capturing different uses of personnel or financial resources. Robust estimates can be achieved through *partial pooling* modeling, where individual group effects are shrunk to the group mean (Hill and Gelman 2007: 258). The Bayesian setup can potentially overcome inconsistent estimations arising because of the lagged dependent variable in a dynamic model (Nickell 1981; Hill and Gelman 2007: 245–246, 258). For better efficiency and accuracy of estimation, all non-negative variables except the binary variables are log-transformed and subsequently z-standardized for a better model convergence in the estimation process.

2 Empirical Analysis

We use a normal distribution as robust prior for the likelihood of the dependent variable (Equation 2.1), as the log-transformed variable is approximately symmetrically distributed and provides a meaningful range for the outcome. The prior for the standard deviation (σ) of local investment is exponentially distributed (Equation 2.2), which concentrates the probability mass near zero and ensures a positive outcome range (McElreath 2020: 118, 407).

$$Inv_{it} \sim N(\mu_{it}, \sigma^2) \quad t = 1, \dots, T; \quad i = 1, \dots, N \quad (2.1)$$

$$\sigma \sim \exp(1) \quad (2.2)$$

The average public capital investment (μ_{it}) for the municipalities i is:

$$\mu_{it} = \beta_0 + \beta_1 Pers_{it} + \beta_2 Tax_{it} + \beta_3 Soc_{it} + \beta_4 LL_{it} + \sum_{k=5}^9 \beta_k X_{itk} + \gamma_{t[i]} + u_{g[i]} \quad (2.3)$$

The global coefficients stand for the number of personnel in construction departments in Full Time Equivalents (FTE) (β_1), for the tax revenue capacity (β_2), for the social services expenses (β_3), for the amount of the liquidity loans (β_4), and the other β_k with $k \in \{5, 6, 7, 8, 9\}$ stand for the control variables (lagged investment, investment transfers from the federal state, a dummy for the participation in the federal state's consolidation program¹ and the demographic variables through the population size and the net population change). The tax revenue capacity is defined by the net business tax plus the municipal share of the income and the value-added tax, measuring to a certain degree the municipalities' financial autonomy (Statistisches Bundesamt 2024: 11). The intercepts vary over the districts g ($u_{g[i]}$) and over the years t ($\gamma_{t[i]}$) as hierarchical variables.

Weakly informative priors are used for the global regression coefficients (β) and the global intercept (β_0), as well as the group-varying intercepts for districts ($u_{g[i]}$) and years ($\gamma_{t[i]}$) (Equations 2.4, 2.5, 2.6 and 2.7). The choice of a normal prior is justified by firstly the normality of the likelihood prior and secondly the standardization of the data, meaning most effects are expected to be small to moderate. The moderate skepticism towards large effects is appropriate under weak prior knowledge about effect sizes (Gabry and Goodrich 2020; Gelman et al. 2025: 55). Due to variable

¹*Pact to strengthen cities' finances (Stärkungspakt Stadtfinanzen)*

2 Empirical Analysis

standardization, the prior for the intercept (β_0) is centered near zero, as it represents the expected value of the dependent variable when all independent variables are at their mean (Equation 2.4; McElreath 2020: 126). The mean of group-specific priors ($u_{g[i]}$ and $\gamma_{t[i]}$) are equally set to zero, meaning no deviation on average from the global mean (β_0) at the district and year levels (Hill and Gelman 2007: 290). These priors adaptively learn from the data distribution, depending on the strength of the standard deviations (for districts (σ_g) and years (σ_t)), which are set as weakly regularizing, exponential priors (Equation 2.8; McElreath 2020: 216, 403, 407).

$$\beta_0 \sim \mathcal{N}(0, 1) \quad \text{global intercept} \quad (2.4)$$

$$\beta_k \sim \mathcal{N}(0, 1), \quad \text{for all } k = 1, \dots, 9 \quad \text{global slopes} \quad (2.5)$$

$$\gamma_{t[i]} \sim \mathcal{N}(0, \sigma_t^2), \quad t = 1, \dots, T; \quad \text{year-specific intercept} \quad (2.6)$$

$$u_{g[i]} \sim \mathcal{N}(0, \sigma_g^2), \quad g = 1, \dots, G; \quad \text{district-specific intercept} \quad (2.7)$$

$$\sigma_g, \sigma_t \sim \exp(1), \quad \text{for the districts } g \text{ and year } t \quad (2.8)$$

In an extended model setup, both time-specific intercepts, district-specific intercepts and slopes for tax revenue capacity and personnel levels are used to capture institutional heterogeneity across districts and district-free cities:

$$\begin{aligned} \mu_{it} = & (\beta_0 + \gamma_{t[i]} + u_{0g[i]}) + (\beta_1 + u_{1g[i]}) \cdot \text{Pers}_{it} + (\beta_2 + u_{2g[i]}) \cdot \text{Tax}_{it} \\ & + \beta_3 \cdot \text{Soc}_{it} + \beta_4 \cdot \text{LL}_{it} + \sum_{k=5}^9 \beta_k \cdot X_{kit} \end{aligned} \quad (2.9)$$

The likelihood for the data and the priors for the global effects and intercept (β) are defined as symmetric distributions over a normal distribution with exponential distributed standard deviations (Equation 2.1, 2.2, 2.4 and 2.5). The district- and year-specific effects ($u_{jg[i]}; j \in \{0, 1, 2\}$ and $\gamma_{t[i]}$) are specified for the intercept and the parameters for the number of personnel and the tax revenue capacity over conservative symmetric priors as normal distributions (Equation 2.10 and 2.11; McElreath 2020: 403). These effects vary as deviations from the global effect (β_k) or from the global intercept (β_0), being centered around the mean:

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$$\gamma_{t[i]} \sim \mathcal{N}(0, \sigma_t^2) \quad \text{year-specific intercept} \quad (2.10)$$

$$\begin{bmatrix} u_{0g[i]} \\ u_{1g[i]} \\ u_{2g[i]} \end{bmatrix} \sim \mathcal{N} \left(\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \Sigma \right), \quad \text{district-specific intercepts/slopes} \quad (2.11)$$

The variances for the group-specific slopes and intercepts (σ_t und σ_{uj}) are defined as exponential distributions, regularizing how strong the effect of the groups are pooled to each other (Equation 2.12 and 2.13; McElreath 2020: 407). The covariances and variances between the group-specific parameter are defined in the covariance matrix (Σ) over the estimation of the correlation parameters as Lewandowski-Kurowicka-Joe-distributions (LKJ) with a weakly informative scaling parameter of one (Equation 2.14; Gelman et al. 2025: 584; Hill and Gelman 2007: 305, 311–314).

$$\sigma_t \sim \exp(1) \quad \text{Variance of the year effects} \quad (2.12)$$

$$\sigma_{uj} \sim \exp(1), \quad j \in \{0, 1, 2\} \quad \text{Variance of the districts' effects} \quad (2.13)$$

$$\Sigma \sim \text{LKJ}(1) \quad \text{Variance matrix of random intercepts/slopes} \quad (2.14)$$

Simulations of the posterior distributions are done with the Hamilton Monte Carlo Algorithm with a No-U-Turn Sampler (NUTS), which is especially useful for complex hierarchical models (Gelman et al. 2025: 392). The models are estimated with four Markov chains over 4000 iterations and additionally 1000 iterations as initialization phase (Bürkner 2017: 10).²

²The estimation is processed through the statistical software program R 4.4.3 (R Core Team 2024) employing the package *brms* (Bürkner 2017) for Bayesian estimation, which builds on the Stan programming language (Stan Development Team 2024). For the NUTS, the standard target acceptance rate of 95 % is used and adapted to 99 % for the model with group-specific slopes to reduce divergent transitions and thus improve model convergence. For the same reason, district-specific effects are estimated through non-centered parametrization, implemented over a Cholesky-decomposition of the covariance matrix.

3 Results

Local public investment heterogeneity is mainly influenced by financial drivers in the Bayesian hierarchical estimation (Fig. 3.1; 3.2). Fiscal variables reveal a measurable effect size and direction on local investment (Table 3.1). Municipal tax revenue capacity positively affects investment, while the liquidity loan volume negatively affects investment, albeit on a smaller scale (Fig. 3.1). In real terms, a 10% increase in average tax revenue capacity is associated with a 1.586% increase in public capital investment, which is equivalent to an increase of the average 9.6 million euros of local investment by an additional 152,300 euros. In comparison, a 10% increase in liquidity loans causes a reduction in investment expenditure by only 4,908 euros (Table 3.1). The relationships of local public investment with fiscal variables are in line with existing literature (Beznoska and Kauder 2020: 16–18; Bremer, Di Carlo and Wansleben 2023: 1022–1024; Hesse 2024: 333–334). However, the mean effects of social expenditures and personnel capacity in construction departments are economically negligible, and the distribution spans zero, suggesting no clear effect direction (Fig. 3.1).

Table 3.1: Results for Public Investment with Group-Specific Intercepts and Slopes

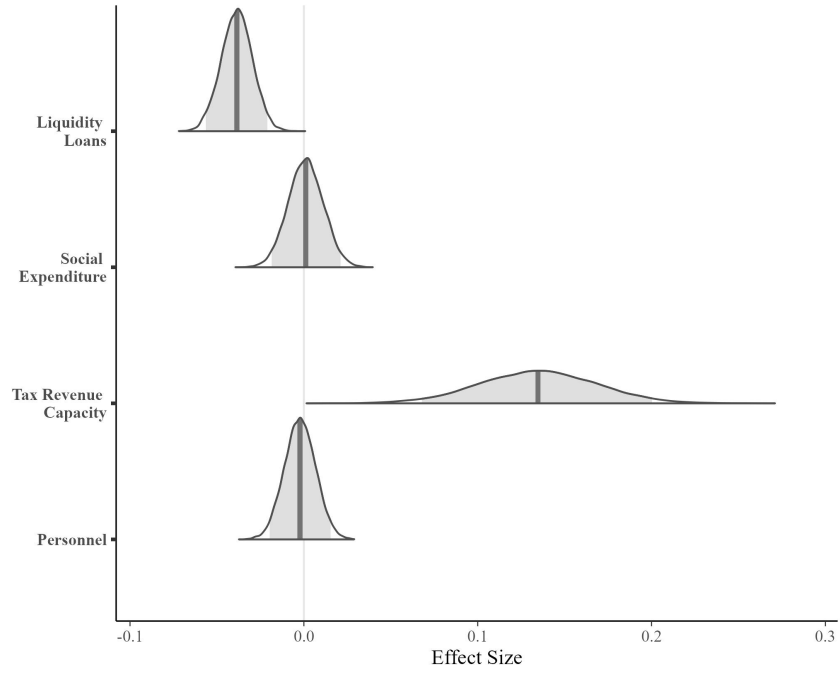
	Model 1: Group Intercepts				Model 2: Group Slopes			
	Mean	SD	2.5%	97.5%	Mean	SD	2.5%	97.5%
Local Investment								
Investment (lag1)	0.5907	0.0114	0.5682	0.6133	0.5856	0.0117	0.5626	0.6086
Personnel	-0.0007	0.0027	-0.0060	0.0047	-0.0005	0.0033	-0.0068	0.0062
Social Expend.	0.0004	0.0038	-0.0069	0.0079	0.0006	0.0038	-0.0068	0.0079
Tax Revenue cap.	0.1586	0.0398	0.0799	0.2357	0.1585	0.0407	0.0792	0.2385
Liquidity Loans	-0.0051	0.0012	-0.0075	-0.0028	-0.0050	0.0012	-0.0074	-0.0026

Note: Price adjusted to 2020 prices; non-binary values in logarithm. 3960 observations.

All Models include time- and district-specific intercepts over 32 groups (the district-free cities and the 31 districts), while the model 2 also includes district-specific tax revenues and personnel levels. The tax revenue capacity affects positively the investment and the liquidity loans reduce investment levels. The inclusion of group-specific slopes does not change the parameters or reveal district-specific deviations from the global effects of taxes or personnel level on investment.

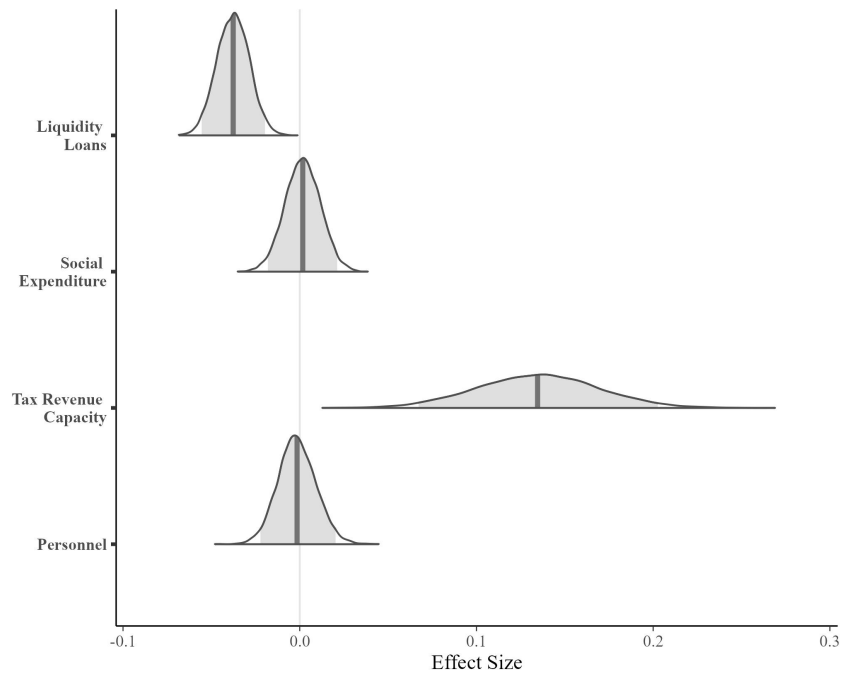
Sources: Own Calculations; (IT.NRW 2025a,b,c,d,e,f,g,h,i); Destatis 2025.

3 Results



Note: Density Distribution of effects with 95%-CI and mean (inner line)

Figure 3.1: Posterior Distributions of Standardized Effects of Main Predictors

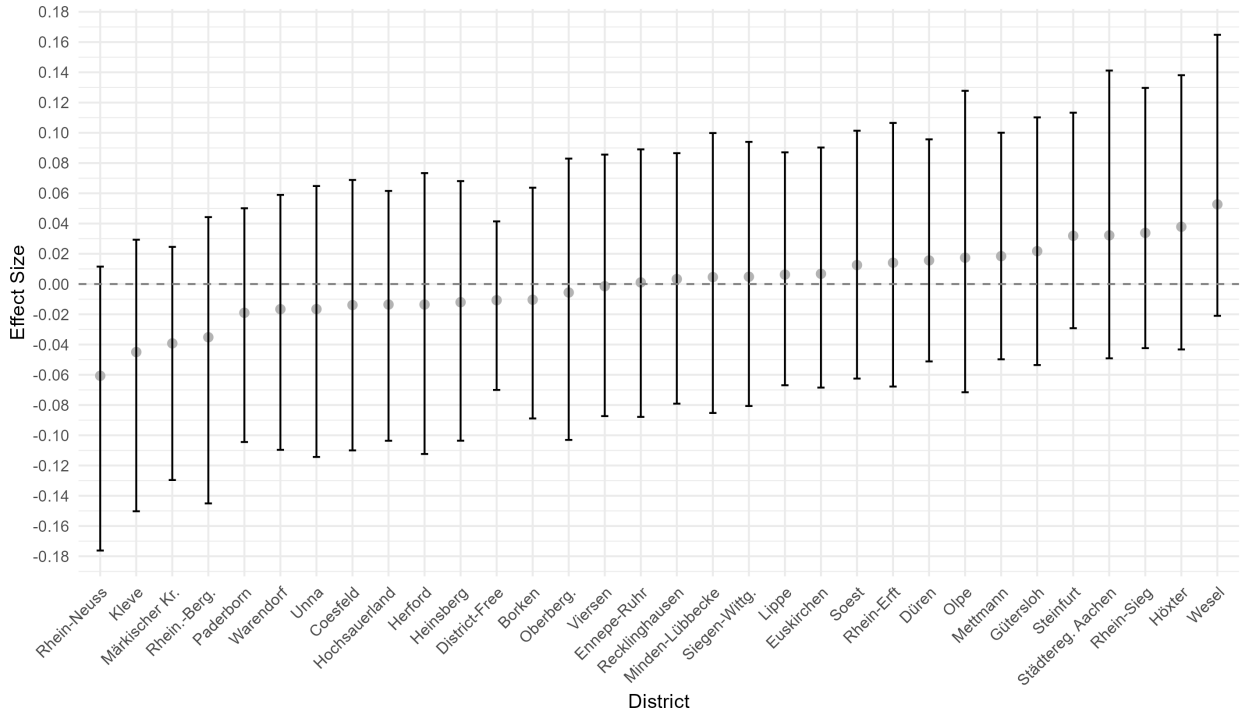


Note: Density Distribution of effects with 95%-CI and mean (inner line)

Figure 3.2: Posterior Distributions of Standardized Effects of Main Predictors with Hierarchical Slopes

3 Results

When including district-specific slopes in the model, effect sizes and directions of the variables stay stable (Fig. 3.1 and 3.2). Only minor and inconsistent deviations from the federal-wide estimated tax and personnel effects are observed for the districts and the group of district-free cities (Tab. 3.1). The 95% credible intervals include zero for all district-specific slopes, with mean deviations of the districts scattered both above and below zero ranging from -0.06% to +0.05% (Fig. 3.3). Consequently, the positive relationship prevails between tax revenue capacity and public capital investments for all districts and district-free cities. This indicates a high degree of homogeneity in the investment behavior of municipalities, despite differences in their tax revenue capacity. The effect of personnel in our estimation remains non-directional and the small district-specific deviations reinforce this finding (Tab. 3.1).



Note: 95%-CI with mean effect (inner circle)

Figure 3.3: Posterior Distributions of District-Specific Deviation from the Mean Tax Effect

4 Conclusion

This paper examines which drivers influence investment expenditure heterogeneity and the extent to which fiscal decentralization in North Rhine-Westphalia enables municipalities to respond autonomously to local investment needs. Our findings highlight the primary role of disposable resources, particularly tax revenue capacity and short-term liquidity loans, in driving investment. The positive effect of tax revenue capacity underscores the importance of own-source funding for municipal investment. However, the volume of liquidity loans signals chronic financial distress, shifting from short-term stabilization to funding permanent spending (Scheller and Walker 2017: 335–338).

The results confirm high financial dependence on the state level, limiting municipalities' autonomy to manage finances and adapt investment strategies. Notably, administrative capacity through personnel in construction departments shows no clear effect, suggesting that financial constraints undermine the ability to plan investments. This state-level fiscal dominance undermines the federal principle of local self-governance, potentially exacerbating regional disparities in investment levels. The lack of detectable institutional effects across districts and district-free cities in the Bayesian hierarchical estimation suggests that autonomy is constrained by financial factors rather than institutional differences. This points to the need for non-earmarked revenue streams to meet local investment needs and ensure regional equality.

Data Sources

- Destatis (2025): *VGR Des Bundes - Deflatoren: Deutschland, Jahre, Verwendung Des Bruttoinlandsprodukts - (Code: 81000-0033)*. <https://www-genesis.destatis.de/datenbank/online/table/81000-0033/table-toolbar>. (Visited on 02/27/2025).
- Geoportal.NRW (2026): *Digitale Verwaltungsgrenzen - Niedrige Stützpunktdichte - Paketierung: Gesamt NRW*. <https://www.opengeodata.nrw.de/produkte/geobasis/vkg/dvg/dvg2/>. (Visited on 08/10/2026).
- gpaNRW (Apr. 2025): *Task Force - Stärkungspakt Stadtfinanzen*. <https://gpanrw.de/beratung/starkungspakt-stadtfinanzen/task-force-staerkungspakt-stadtfinanzen>. (Visited on 04/02/2025).
- IT.NRW (Apr. 2025a): *Auszahlungen nach Auszahlungskonten - Land, Gemeinden, Gemeindeverbände - Jahr (Code 71717-13i)*. <https://www.landesdatenbank.nrw.de/ldbnrw/online?operation=werteabruf&levelindex=2&levelid=1743691783476&etname=71717-13i&Werteabruf=Werteabruf#abreadcrumb>. Text. (Visited on 04/03/2025).
- (Feb. 2025b): *Bevölkerungsstand und -bewegung (ab 1962) - Gemeinden - Jahr (12491-01d)*. <https://www.landesdatenbank.nrw.de/ldbnrw/online?operation=table&code=12491-01d&bypass=true&levelindex=1&levelid=1740405041425#abreadcrumb>. Text. (Visited on 02/24/2025).
 - (Apr. 2025c): *Einzahlungen nach Einzahlungskonten - Land, Gemeinden, Gemeindeverbände - Jahr (Code 71717-03i)*. <https://www.landesdatenbank.nrw.de/ldbnrw/online?operation=werteabruf&levelindex=2&levelid=1743691310606&etname=71717-03i&Werteabruf=Werteabruf#abreadcrumb>. Text. (Visited on 04/03/2025).
 - (Feb. 2025d): *Fortschreibung des Bevölkerungsstands - Gemeinden - Stichtag (12411-01i)*. <https://www.landesdatenbank.nrw.de/ldbnrw/online?operation=table&code=12411-01i&bypass=true&levelindex=1&levelid=1740253331845#abreadcrumb>. Landesdatenbank Nordrhein-Westfalen. (Visited on 02/22/2025).
 - (Feb. 2025e): *Kassenkredite, Wertpapiersschulden und Kredite der Gemeinden und Gemeindeverbände (2015 bis 2018) - Gemeinden/GV - Stichtag (71327K-05i)*. <https://www.landesdatenbank.nrw.de/ldbnrw/on->

- line?operation=table&code=71327K-05i&bypass=true&levelindex=1&levelid=1740413971692#abreadcrumb. Text. (Visited on 02/24/2025).
- IT.NRW (Feb. 2025f): *Kassenkredite, Wertpapiersschulden und Kredite der Gemeinden und Gemeindeverbände (ab 2019) - Gemeinden/GV - Stichtag (71327K-01i)*. <https://www.landesdatenbank.nrw.de/ldbnrw/online?operation=table&code=71327K-01i&bypass=true&levelindex=1&levelid=1740413971692#abreadcrumb>. Text. (Visited on 02/24/2025).
- (Feb. 2025g): *Kassenkredite, Wertpapiersschulden und Kredite der Gemeinden und Gemeindeverbände (bis 2014) - Gemeinden/GV - Stichtag (71327K-09i)*. <https://www.landesdatenbank.nrw.de/ldbnrw/online?operation=table&code=71327K-09i&bypass=true&levelindex=1&levelid=1740413971692#abreadcrumb>. Text. (Visited on 02/24/2025).
 - (Feb. 2025h): *Realsteuervergleich der Gemeinden in Nordrhein-Westfalen - Gemeinden - Jahr (ab 2016 in EUR) (71231-01i - Nettogewerbsteuer)*. <https://www.landesdatenbank.nrw.de/ldbnrw/online?operation=werteabruf&levelindex=2&levelid=1740410037101&etname=71231-01i&Werteabruf=Werteabruf#abreadcrumb>. Text. (Visited on 02/24/2025).
 - (Feb. 2025i): *Realsteuervergleich der Gemeinden in Nordrhein-Westfalen - Gemeinden - Jahr (bis 2015 in Tsd. EUR) (71231-03d - Nettogewerbsteuern)*. <https://www.landesdatenbank.nrw.de/ldbnrw/online?operation=table&code=71231-03d&bypass=true&levelindex=1&levelid=1740409664838#abreadcrumb>. Text. (Visited on 02/24/2025).

References

- Beznoska, M. and Kauder, B. (2020): “Schieflagen der kommunalen Finanzen - Ursachen und Lösungsansätze.” In: *IW-Policy Paper* 15/2020.
- Bogumil, J. and Holtkamp, L. (2023): *Kommunalpolitik und Kommunalverwaltung: eine praxisorientierte Einführung*. Revised edition. Bonn: Bundeszentrale für politische Bildung. ISBN: 978-3-7425-0844-7.
- Brand, S., Salzgeber, J., Hesse, M., Starke, T. and Bender, C. (Dec. 2024): “Achstes Kapitel Steuern, Zuweisungen oder Fördermittel – wie stärkt man die kommunale Investitionsfähigkeit?” In: *Jahrbuch für öffentliche Finanzen (2024) - 2*. Ed. by M. Junkernheinrich, S. Koriath, T. Lenk, A. Ranscht-Ostwald, H. Scheller and M. Woisin. Vol. 262. Schriften zur öffentlichen Verwaltung und öffentlichen Wirtschaft. Berliner Wissenschafts-Verlag, 124–144. ISBN: 978-3-8305-5635-0. DOI: 10.35998/9783830556350. (Visited on 08/23/2025).
- Bremer, B., Di Carlo, D. and Wansleben, L. (Apr. 2023): “The Constrained Politics of Local Public Investment under Cooperative Federalism.” In: *Socio-Economic Review* 21.2, 1007–1034. DOI: 10.1093/ser/mwac026. (Visited on 06/29/2026).
- Bürkner, P.-C. (Aug. 2017): “Brms: An R Package for Bayesian Multilevel Models Using Stan.” In: *Journal of Statistical Software* 80, 1–28. DOI: 10.18637/jss.v080.i01. (Visited on 07/29/2025).
- Firebaugh, G. and Gibbs, J. P. (1985): “User’s Guide to Ratio Variables.” In: *American Sociological Review* 50.5, 713–722. DOI: 10.2307/2095384. JSTOR: 2095384. (Visited on 10/03/2025).
- Gabry, J. and Goodrich, B. (July 2020): *Prior Distributions for Rstanarm Models*. <https://mc-stan.org/rstanarm/articles/priors.html>. (Visited on 07/06/2025).
- Gelman, A., Carlin, J. B., Stern, H. S., Dunson, D. B., Vehtari, A. and Rubin, D. B. (2025): *Bayesian Data Analysis*. 3rd ed.
- Gornig, M. and Michelsen, C. (2017): “Kommunale Investitionsschwäche: Engpässe bei Planungs- und Baukapazitäten bremsen Städte und Gemeinden aus.” In: *DIW Wochenbericht* 84.11, 211–219.
- Gornig, M., Michelsen, C. and van Deuverden, K. (2015): “Local Public Infrastructure Showing Signs of Wear and Tear.” In: *DIW Economic Bulletin* 5.42/43, 561–567.
- GG (1949): *Grundgesetz Für Die Bundesrepublik Deutschland*. (Visited on 09/06/2025).
- Hesse, M. (Jan. 2024): “Ausmaß der kommunalen Investitionsbedarfe und Ursachen der unzureichenden Infrastrukturfinanzierung / Municipal Investment Needs and

References

- Causes of Inadequate Infrastructure Financing.” In: *dms – der moderne staat – Zeitschrift für Public Policy, Recht und Management* 16.2. (Visited on 01/30/2025).
- Hill, J. and Gelman, A. (2007): *Data Analysis Using Regression Multilevel/Hierarchical Models*. Analytical Methods for Social Research. Cambridge University Press. ISBN: 978-0-511-26878-6.
- McElreath, R. (2020): *Statistical Rethinking - A Bayesian Course with Examples in R and Stan*. 2nd edition. New York: Chapman and Hall/CRC. ISBN: 978-0-429-02960-8.
- Nickell, S. (1981): “Biases in Dynamic Models with Fixed Effects.” In: *Econometrica* 49.6, 1417–1426. DOI: 10.2307/1911408. (Visited on 07/21/2025).
- R Core Team (2024): *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing. Vienna, Austria. (Visited on 02/28/2025).
- Raffer, C. and Rietzler, K. (June 2026): “People, Party or Money? Determinants of Local Government Infrastructure Investment.” In: *IMK Working Paper* 230. (Visited on 06/30/2026).
- Raffer, C. and Scheller, H. (May 2022): *KfW-Kommunalpanel 2022*. Tech. rep. Frankfurt: KfW Bankengruppe.
- Scheller, H., Rietzler, K. and Raffer, C. (Dec. 2021): *Baustelle zukunftsfähige Infrastruktur – Ansätze zum Abbau nichtmonetärer Investitionshemmnisse bei öffentlichen Infrastrukturvorhaben*. Tech. rep. Friedrich-Ebert-Stiftung.
- Scheller, H. and Walker, B. (2017): “Municipal Infrastructure Policies in the Federal Republic—In Between Growing Disparities and Losing Political Autonomy?” In: *European Policy Analysis* 3.2, 343–371. DOI: 10.1002/epa2.1027. (Visited on 06/26/2026).
- Stan Development Team (Dec. 2024): *Stan Reference Manual - Version v2.36.0*. <https://mc-stan.org>. (Visited on 06/10/2025).
- Statistisches Bundesamt (2024): *Qualitätsbericht - Realsteuervergleich 2023*. Tech. rep.