FUNCTIONALIST POLITICAL DECENTRALIZATION IN A POSTFUNCTIONALIST WORLD: POLITICS AND CONSEQUENCES

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ABSTRACT

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Multi-level governance (MLG) is increasingly prevalent among governments. While the literature has moved on from simple Functionalist explanations to the postfunctionalist argument, it remains unclear how the two interact. Specifically, it is less clear on what would happen to MLG when Functionalist considerations get in the way of postfunctionalist considerations. With three papers, this dissertation looks at how functionalist considerations in regional governance could assume, or sometimes, replace postfunctionalist considerations in regional governance in the case of municipal reform in Norway, protest management in China, as well as developmental inequality within metropolitan areas.

To my father, Edmond, and my late mother, Emily.

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LIST OF ABBREVIATIONS

1C2S	One Country, Two Systems
ACME	Average Conditional Mediation Effect
ADE	Average Direct Effect
CEPA	Closer Economic Partnership Agreement
CNN	Convolutional Neural Network
CV	Coefficient of Variation
DID	Difference-in-Difference
DRL	Descriptive Representation of the Local
DV	Dependent Variable
ERL	Hong Kong- Guangzhou Express Rail Link
GDP	Gross Domestic Product
GPU	Graphics Processing Unit
HZMB	Hong Kong- Zhuhai- Macau Bridge
IPE	Internal Political Efficacy
MCMC	Markov Chain Monte Carlo
MLG	Multi-level Governance

OECD	Organization for Economic Co-operation and Development
RMSE	Root Mean Squared Error
ROI	Region of Interest
SAR	Special Autonomous Region
SWIR	Shortwave Infrared
UEI	Unionist Economic Integration

Can Economic Integration reduce social unrest? Evidence from China, Hong Kong and Macau

To control restive regions, authoritarian states may use force or side payments. However, it has been noted in the literature that launching military suppression is costly for the national center, so the center would prefer using side payments whenever possible (Hale 2008). These could come in many forms, such as interregional fiscal transfers (Beramendi 2012, 37–38; Hale 2008), concession of economic powers (Bolton and Roland 1997; Cunningham 2011) and the like. One great tool is Unionist Economic Integration (UEI) programs. Unlike international economic integration that is usually referenced in the political economy literature (Alesina and Spolaore 1997, 2003; Alesina, Spolaore, and Wacziarg 2000; Suesse 2018; Coufalova 2019), UEIs focus on merging domestic economic markets in a union. As a domestic market expands to cover the restive region, they now share a "mutual economic advantage" with the sovereign state. Because these regions are also benefiting from the union, their case for more autonomy or outright secession is less justified (Rokkan and Urwin 1983, 94; Miller 2000)

However, the current literature on UEIs runs into at least two issues. First, discussion on UEIs tends to focus on the democratic context. Discussions in both Political Science and Economics tend to focus on utility maximization at the level of voters across regions (Alesina

and Spolaore 2003, 1997; Alesina, Spolaore, and Wacziarg 2000; Bolton and Roland 1997; Abbink and Brandts 2016). Focus then shifts to the comparisons of utility between the majority and the minority (Alesina, Spolaore, and Wacziarg 2000; Beramendi 2012). However, this strategy does not help explain union maintenance in authoritarian contexts, where the role of a leviathan authoritarian government at the national center is crucial (Hale 2005). Second, the comparative literature fails to explain why UEIs work in some region but not others in the same polity. In our empirical example, the current comparative literature does allude to differences between Hong Kong and Macau on colonial experiences and the composition of the bureaucracy (Mendes 2013; Gunn 1996; Fong 2015), but it does not explain how these factors interact with UEIs. Although conceptually the UEI seems to be a powerful means to co-opt the regional populace, it does not follow that it has the same effectiveness across all regions. In the case of China, it is notable that Hong Kong is more restive than Macau: Hong Kong has gone through three major episodes of social movements: the 2003 July First March, the 2014 Umbrella revolution and the recent 2019 Anti-extradition bill movement. Macau had almost no protests. This paper thus aims to address this puzzle: *In the authoritarian state, why could UEIs reduce social unrest in some regions but not others?*

I argue the key to solving the puzzle lies in the concept of economic dependence of the regional populace to the national center. Drawing from the commercial peace literature (Barbieri 1996; Gartzke and Westerwinter 2016), I argue that it is a region's dependence on the national economy that determines the effectiveness of UEIs. This has to do with the mechanism through which UEI reduce social unrest - it adds to the expected cost of contention. Economic

Dependence changes the baseline cost of contention - a less dependent region would have a lower baseline cost, so whatever that has been added by UEIs might remain insignificant such that the regional population do not care about the increased cost of contention. For the region that is dependent on the national economy, then that baseline could be much higher, so the regional population might shy from protesting given the higher expected cost of contention.

In this paper I exploit the introduction of the Closer Economic Cooperation Agreement (CEPA) in Hong Kong and Macau. I show that given the equivalent UEI package at roughly the same moment, the differing levels of economic dependence on the Chinese economy in Hong Kong and Macau explains the different trajectories of social unrest in the two regions. I then extend this argument to other Chinese provinces. The same effect direction is present yet the estimation uncertainty is much higher.

Economic Integration and Social Unrest

What makes or breaks the effect of economic integration on unrest suppression? The secessionism literature argues that domestic market integration helps substitute the secession-inducing effects from international economic integration. In this literature, secessionism is a result of economic globalization: Increasing trade flows following by international economic integration makes the income of the regional populace much less dependent on good relations with the national center. It no longer needs to trade as much with the national center, so it may risk worsening relations, or even breaking off from the union to further tap on the benefits

of international economic integration (Alesina and Spolaore 2003, 1997; Alesina, Spolaore, and Wacziarg 2000).

For the authoritarian state, one way to prevent secession would be to integrate the regional economies with that of the center such that trade within the union outweighs international trade. Again, because there is now more income from having good relations with the national center, one could argue that such concessions could eliminate the secessionist threat arising from international economic integration.

This is the logic behind what I call Unionist Economic Integration (UEI) institutions. UEIs refer to economic institutions for the construction of a common economic entity within the same political union. As per the definition of institution, these are rules or procedures for promoting economic integration with the center (Jepperson 1991; North 1990, 3). Because of territorial expansion and recession, histories of domination and colonialism, political decentralization and centralization, the regional market may be isolated from or developed on the sidelines of the national economy. Through UEIs, the state attempts to harmonize economic practices and facilitate flows of labor, capital, goods, and market between the peripheral region and the national center. UEIs speak to Bolton & Roland (1997)'s idea of the removal of intra-union trade barriers. For Bolton & Roland (1997), this would imply that tax preference differences across regions would disappear, such that voters across regions would be happy to stay within the political union. Appeasement through UEI is also found in the works of theorist David Miller, who argued that the region would now share a "mutual economic advantage" with the national center so they have a weaker case for secession (Miller 2000). Stein Rokkan also

wrote that, the earlier construction of a common labor market, the more likely the domination of that common labor market over others in peripheral regions (Rokkan and Urwin 1983, 96).

Like other institutions, UEIs can be institutionalized to various degrees, ranging from weak institutionalization with no formal rules written or provisions written into law; to strong institutionalization with provisions clearly written into law, specialized agencies created to conduct economic integration, so on and so forth.

Throughout history there has been a limited number of examples of UEIs[1]. For example, the US-Hawaii Reciprocity Treaty enabled the integration of Hawaii's sugar market with that of the US. The elimination of sugar tariffs created a special interest class that supported annexation (La Croix 2019, 14). Outside of the context of Western industrialized democracies, the highly integrated oil and gas market in the Russian Federation enabled Boris Yeltsin to award loyal regions with cheap oil and gas prices, and punish disloyal regions by raising them (Hale 2005, 59). Following the annexation of the Portuguese possessions by India, the Indian government has also used economic assistance programs to reconciliate wage and price differences (Rubinoff 1995 ,p.44).

However, some regions are appeased by UEIs but not others. Even more puzzling is that in the case of China, both Hong Kong and Macau are relatively well-off compared to other peripheral regions like Tibet and Xinjiang. They are also equally exposed to the increasingly globalized economy, after inheriting capitalistic economic systems from the United Kingdom

and Portugal respectively. To explain peculiar cases like these, we will have to focus on the region's overall level of dependence on the national economy.

How Economic Dependence shape the effectiveness of UEIs

The causal mechanism through which UEIs could suppress dissent is to increase the expected cost of contention. In other words, citizens would bear a higher economic cost if they decide to confront the national center given these economic linkages.

This idea can be traced to the commercial peace literature. The main claim of this literature is that under some conditions, trade can reduce international conflict (Barbieri 1996; Gartzke and Westerwinter 2016). One common prediction from this literature is the asymmetry of the trade relationship between two countries. When one trade partner is much more dependent on the other, the likelihood of militarized conflict increases. Increasing trade between two partners are said to be conflict-reducing because it increases the potential harm incurred onto oneself, as well as limiting the potential harm incurred onto the other party.

Of course, we cannot expect trade dependence to be exactly the same as UEIs. Nor should we equate regional dissent to militarized conflict or secessionism. This is precisely why UEIs may have different effect directions on regional dissent. First, quite often "dependence" refers to the regional periphery being dependent on the national center (Rokkan and Urwin 1983; Miller 2000), which is unlike the trade dependence case that could go both ways. Second, UEIs are usually imposed. Third, the qualitative difference of our problem portrays a very

different picture for a region that is highly dependent on the national economy: Given the dominant position of the national center, they could threaten the withdrawal of UEIs from disloyal regions (Cunningham 2011). In our context of UEI in a non-democracy, there exists a leviathan capable of making asymmetrical economic relations. The leviathan can assign carrots and sticks strategically such that the dependent region would rather stay loyal, and the independent region is indifferent between staying loyal or not (Hale 2005). Taking these concerns together, we cannot simply take the theoretical expectations from the international relations literature as granted.

In this sense, the way that economic dependence determines the effectiveness of UEIs in dissent suppression is as follows: UEIs increase economic dependence uniformly. However, the initial level of economic dependence sets different baselines of the expected cost of contention. Only if the baseline is high enough and when UEIs add to that baseline (i.e. in the case of a highly dependent region) would UEI be effective in dampening unrest. For lowly dependent regions the increased cost of contention can be hedged by domestic economic activities and international trade. The increased cost is only large enough to deter people from protesting in highly dependent regions, where international trade or other domestic economic activities are not sufficient to cover the increased cost of contention. In other words, the key term for the causal effect is *indifference*. In lowly dependent regions, the increase in the expected cost of contention introduced in UEIs are negligible such that people are indifferent to UEIs, and thus they do not dampen unrest. In highly dependent regions, that increase is substantial given the already high initial level of economic dependence, so UEIs work.

The effectiveness of UEIs is path dependent (Pierson 2000b, 2000a). Highly dependent regions will become less resistant to more dependence. In the highly dependent case, UEIs create a positive feedback loop for cooperation with the national center (Pierson 2000a), so over time, citizens living in highly dependent peripherals will be more likely to accept further integration and less likely to mobilize for protest. These citizens are likely to look over any negative impact UEIs might have on the domestic economy. However, less dependent regions may grow more resistant to more dependence. Because the regional citizens are indifferent to UEIs, there is no positive feedback loop to sustain the UEIs. However, negative impacts UEIs might have on the domestic economy could be amplified (e.g. trade diversion, increased competition from national businesses, etc.). Pushing unwanted UEIs in less dependent regions might lead to more public backlash, even though economic dependence is increasing over time. In this case, UEIs now come off as a harmful institution to the regional economy with little benefits to the regional citizens. Citizens may declare unwanted trade agreements as an attempt to restrict trade activity in the region, or delcare unwanted visa agreements as failure to control immigration. To overcome the path dependence in less dependent regions, the national center has to provide a variety of highly institutionalized UEIs all at once at the risk of even more backlash.

Why (not) UEIs?

For the national center, UEIs are useful tools to avoid using coercion on unrest or fighting anti-secessionist wars (Hale 2005; Cunningham 2011). Authoritarian governments do not want to use the coercive apparatus when it is not necessary because doing so might signal

regime instability. Coercion can also be difficult as the regime could not identify which peripheral citizen is a loyalist and which one is an activist. Untargeted prosecution do not only hint on regime instability, it would also lead to further public backlash such that more citizens could sympathize with the resistance (Xu 2020). Ceteris paribus, if by creating economic institutions like UEIs can buy off the hearts and minds of peripheral citizens, then the authoritarian state would always prefer UEIs over armed suppression. However, the authoritarian state may switch to other strategies if UEIs are no longer useful to them. For example, UEIs can be ineffective in some regions, and as such the authoritarian state may switch to more coercive tactics to subjugate the region. Alternatively, advances in surveillance capabilities could allow the authoritarian state to conduct targeted prosecution with little visibility, making targeted prosecution a preferred strategy over UEIs (Diamond 2019; Xu 2020).

The regional opposition to UEIs may seem paradoxical at first: Opponents to UEIs want to cut economic ties with the center, because they do want to be threatened by the national center of cutting economic ties. This seems self-defeating at first glance. I argue that the underlying motivation is similar to the prediction from the Obsolescing Bargaining Model (OBM), where a party avoids signing an agreement that is hard to change in the future (Eden, Lenway, and Schuler 2005). The regional citizens want to avoid UEIs given that the institutionalization of the UEIs may make it difficult to modify other political institutions goverining the relations between the national center and the periphery. Once UEIs are

institutionalized, the national center can always threaten to remove economic ties in future constitutional bargaining.

Alternatively, opposition to UEIs can be elite-driven as well. Ethnic entrepreneurs can always claim to represent their own kin more by outbidding against other elites (Chandra 2005; Zuber 2011). Ethnic entrepreneurs can declare UEIs as "selling off" the economic interests of one's kin vis-a-vis that of the national center to gain support in elections. Compared to the OBM explanation, this argument does not assume that the regional citizen always want to renegotiate with the national center for better constitutional arrangements.

In short, UEIs reduce social unrest by increasing economic dependence. However, its effectiveness hinges on the initial level of a region's economic dependence on the national center. People's acceptance to UEIs is path dependent. The center wants to use UEI as a low-risk appeasement strategy to reduce social unrest, but the regional citizens may oppose it since they 1) do not want to involve themselves in obsolescing bargaining; or 2) some regional groups have been mobilized to oppose the national center due to ethnic outbidding.

If all this is true, then we may hypothesize that:

H1. The more institutionalized UEIs are in a region, the less social unrest is in that region.

H2. Conditional on higher levels of dependence on the national economy, the more institutionalized UEIs are in a region, the less social unrest is in that region.

Empirical Analysis

The Case of Hong Kong and Macau

Hong Kong and Macau are officially "Special Autonomous Regions" (SARs) within the People's Republic of China. Before joining China, Hong Kong and Macau were under British and Portuguese colonial rule respectively. Hong Kong and Macau were transferred to Chinese rule in 1997 and 1999 respectively. The two SARs have been ruled by the "One Country, Two Systems" (1C2S), a system agreed between the British and the Chinese in the 1984 Sino-British Joint Declaration. The 1C2S mandates that the capitalist order in the former colonies shall continue, while mainland China will practice socialism, although together they will constitute one single country. The Basic Laws of the Hong Kong SAR and Macau SAR further expanded on this concept, in which the principles of "Hong Kong/ Macau people ruling Hong Kong/Macau", "High Degree of Autonomy", and that the 1C2S shall remain unchanged for 50 years were written into the Basic Law. If one reads the two basic laws legalistically, one would find out that the two regions are granted high levels of autonomy including but not limited to, independent taxation authority, the authority to make an independent monetary policy, and independent budgeting authority. The only two areas where authority is reserved for China are foreign policy and national defense. Hong Kong and Macau may attend some international events under the alias "Hong Kong, China" and "Macau, China" respectively. The People's Liberation Army (PLA) maintains an active garrison in Hong Kong and Macau.

The imperative of Economic Integration as a co-optation tool first came up after the 2003 First of

July protest. Prior to the adoption of any economic integration, the fundamental tenet of the "One Country, Two Systems" principle is to "keep Hong Kong and Macau from Mainland China at a certain distance" (So 2004; Ma 2015; Fong 2015; Cheung 2007). This is best summarized by the famous quote from the then Chinese premier Zhou Enlai on Hong Kong, as China will "formulate long-term plans and make maximum use of the place" (*Chanqi Dasuan, Chongfen Liyong*) (Fong 2015, 107). Mainland China is also well aware of this tenet since the establishment of the PRC, as Hong Kong and Macauc citizens were treated as "outsiders" and have to apply for a visa to enter China until the retrocession (Cheung, 2007, p.89). There were rarely any mass protests in the two regions immediately after the handover.

In 2003, an underestimated protest involving some 500,000 Hong Kong citizens erupted. Mass protests erupted against the drafting of a National Security Law that would have allowed the state to prosecute political opponents. The Central Liaison Office (CLO) failed to predict the scale of the protest and was busy looking for remedies (So 2004, 21–22). Meanwhile, the economies of the two SARs were plagued by the SARS outbreak. Beijing then decided to slow down its pace of united front work. Instead of launching political initiatives, economic integration initiatives were proposed so that the economy of the SARs will be more dependent on the mainland (Peter Chiu 2006; Lo 2008, 11–12; 51-52; Rezvani 2012, 99–100; Ma 2015; Yuen 2014) According to Yuen (2014), he quoted Ke Dai, a United Front worker, saying that CEPA is a process introduced to speed up the return of Hong Kong people's hearts and minds (*Renxi Huigui*) .

The first of such initiatives is a free trade agreement called the Closer Economic Partnership Agreement (CEPA). The first iterations were signed in 2003 and 2004 with Macau and Hong Kong respectively. 10 Supplements were added thereafter to further liberalize the trade of goods and services between China and the two territories. As CEPA deepens, trade tilts towards China intensively. In Hong Kong, domestic exports have been gradually leveling out, reaching an all-time low at 0.57% in 2015, a figure even lower than the 1980s level in the Chinese reform era. Aggregated Re-Exports to China dominated the scene as they consist of half of all exports of Hong Kong by 2009. In Macau, regardless of the share of exports to China, actual export volume toppled in 2008-2009 amid the financial crisis and has not recovered to pre-crisis levels. Imports from China to the two SARs have been increasing at an even faster pace after CEPA, as Chinese imports consisted of some 49.03% of the total imports of Hong Kong. Macau may have diversified its imports, but Chinese imports still reached an all-time high at 3 billion MOP. In this way, CEPA has been more successful in tilting trade of the two SARs with China than improving bilateral trade.

Other forms of UEI include the Individual Visit Scheme (IVS), a visa liberalization scheme for Chinese citizens living in selected cities (Ma 2015; Yuen 2014); the various stock market integration programs between Chinese financial markets and the Hong Kong Exchange (HKEx). Last but not least, in 2017, the Chinese government started to talk about the concept of a "Greater Bay Area". Modeled after the San Francisco Bay Area and the Tokyo Bay Area, the Chinese government wants to deepen the integration of the two SARs and nearby Chinese cities in the Pearl River Delta.

Previously the literature has mostly focused on historical and institutional differences between Hong

Kong and Macau despite the homogeneity in the constitution (Gunn 1996; Mendes 2013; Fong 2015).

While they could explain why contention can be observed in Hong Kong but not Macau, they do not provide a mechanism through which UEIs reduce or fail to reduce social unrest in the periphery. In the next empirical section I will show that the mechanism is the change in the expected cost of contention conditional on the degree of economic dependence.

Impact of Trade Liberalization on Social Unrest in Hong Kong and Macau, 1994-2018.

In the first empirical study, I focus on the CEPA in Hong Kong and Macau. I chose to study CEPA for three reasons: First, the case of CEPA constitutes a quasi-experimental setup: the equivalent agreement has been applied to both Hong Kong and Macau at roughly the same time, thus the CEPA constitutes a treatment. If we treat Hong Kong, a highly globalized, independent economy as the control group, then the highly dependent Macau economy would be the treated group. This quasiexperimental setup allows the identification of causal effects directly. Second, it has the longest history across all UEI variants in Hong Kong and Macau. If social unrest takes time to develop, then we could identify the effect of UEI given its longer history compared to newer variants like the stock connects or infrastructure projects that have only been launched in less than 10 years. Last but not least, Hong Kong and Macau constitutes a great case of paired comparison too. This is a unique situation where within Authoritarian

China, there exist two regions with clearly-inked autonomy arrangements. Studying these two regions allow us to control for numerous background variables: they have a similar culture; and they are both capitalistic societies; and their constitutional structures are also highly similar. Having only economic dependence vary between these two regions thus allow the identification of causal effects from economic dependence.

The varying levels of economic dependence lies in the economic structure of the two regions. Macau's economy is structured around the gaming industry while Hong Kong's economy is structured around the financial industry. Hong Kong's economy is also much larger than Macau's, with Hong Kong's GDP at $ 362 billion and Macau's GDP only at $54 billion (World Bank 2018). Hong Kong's financial sector is highly globalized and integrated with the international markets, yet the Macau economy is mostly geared towards the service and gaming industry for Chinese and Hong Kong citizens.

Compared to Taiwan, on which China claims as part of its periphery, Hong Kong and Macau are more suitable as the UEIs in the two cases are imposed. Citizens in these two regions had no way to stop the agreement from being enacted. This allows us to avoid the issue where the citizens start off antagonized with the Chinese officials and their trade agreement in hope to renegotiate for better terms of the agreement in the future.

Data and Methods

In this study I analyze an original dataset on the dissent over the 1C2S and intensity of protests in Hong Kong and Macau between 1994 and 2018.

Dependent Variable

I measure social unrest in two ways. The first way is to look at the yearly aggregated mean of approval of the 1C2S system for the two regions. In Hong Kong and Macau, the Public Opinion Research Institute (PORI) conducts a yearly study of residents' confidence in the 1C2S autonomy arrangement that spans back to 1993 (1999 for Macau). I code the yearly percentage of citizens feeling not confident with the 1C2S as the level of dissent towards the 1C2S. When multiple surveys were conducted in the same year, I take the average value for that year. The range of the study period with the largest number of observations is between 1994 and 2018.

Second, I regress the yearly count of protest events identified in Hong Kong and Macau. Protest events are identified from the GDELT 2.0 Events Database. The GDELT 2.0 Events Database is a real-time event monitoring system that captures breaking events and reaction every 15 minutes in the world (The GDELT Project 2015). I obtained the yearly count of protest events from citizens directed at the Chinese government in the two regions. This data has a study period between 1997 and 2019.

Independent Variables

The covariate of interest, economic dependence, can be calculated by trade data (Barbieri 1996). At the moment I utilize the trade intensity index (Dale 1997; Flörkemeier 2000). This index measures regional trade bias vis-a-vis global trade. It has no upper bound. A higher index refers to the increased bias of country i to j when trading (one could imagine in a

set of possible trading partners, i is much more likely to trade with j with other countries $-j$). Following Dale (1997), the index for country i's bias to country j is defined as:

$$l_{ij} = \frac{x_{ij}}{X_i} / \frac{M_j}{T}$$

where x_{ij} is the total exports of country i to country j; X_i is the total exports of country i; M_j is the total imports of country j; and T is the world total imports. In words, this is a ratio of two separate ratios: on the left-hand-side: a ratio of exports from i to j to i's total exports, and the right-hand-side: a ratio of imports of j to the world total imports. The ratio thus gives a rough sense of how much bias country i has with respect to j when choosing all possible export destinations in the world, controlling for the amount of imports of the destination country j [2]. I rely on data from the National Bureau of Statistics of China, the Hong Kong statistical yearbook, the Macau Statistical yearbook and the World Bank to calculate this index. Only trade in goods is used as trade in services data is not available for Macau.

I operationalize UEI institutionalization as the trade intensity ratio of China with respect to Hong

Kong and Macau. This can help us pick up the preferential treatment of China to Hong Kong and Macau in the form of additional flow of goods. Because UEIs are created to increase economic ties from the national center to the periphery, we can measure the degree of the institutionalization of UEIs by looking at how much dependence China is creating vis-a-vis Hong Kong and Macau.

Similarly, I operationalize dependence as the trade intensity ratio of Hong Kong and Macau with respect to China. Reversing i and j in the trade intensity ratio means that we are now looking at the regional bias emerging from Hong Kong and Macau when choosing over trade partners. I stipulate that when the region is highly dependent on trading with China, this quantity will be extremely high.

When calculating the trade intensity ratios, only data on trade in goods is used. The data on trade in services is unavailable for Macau so I used only the data for trade in goods.

Last but not least, I included several control variables. First, I included the total trade volume since it is the openness to trade that motivated citizens to express secessionist tendencies (Alesina and Spolaore 2003; Alesina, Spolaore, and Wacziarg 2000). Second, I included the yearly FDI volume between China and Hong Kong/Macau since CEPA could also lead to an increase in FDI activity between the center and the periphery.

Third, I accounted for the joint movement of China and Hong Kong/Macau's stock markets. At time point t, this quantity is computed as the absolute difference of the net change of stock indices between region k's stock market composite index and China's stock market composite Index from $t-1$ to t. The motivation behind this quantity is to measure the joint movement between region k's stock market prices and China's stock market prices. If the difference is low, then we can argue that the two markets are well integrated. For Hong Kong, I used the yearly close prices for the Hang Sang Composite Index (HSI). For China, I used the yearly end date prices for the Shanghai Composite Index (SCI). No such composite index exists

for Macau, so I calculated one with 4 main Macau-based companies listed on the Hong Kong Stock Exchange. This Macau composite Index consists of prices of yearly end date prices for 4 companies: Galaxy, SJM, Wynn Macau and Sands China. The index is constructed by weighting the yearly end date prices of each of these companies by their relative capitalization each

year.

Finally, I included several event dummies to indicate the initialization and completion of special infrastructure projects aiming to promote economic integration with China. While these cannot be identified as UEIs since they are not institutions, these are economic integration projects that could potentially serve as confounders in the analysis. These include the event dummies for the debate and completion for the HZMB, the Hong Kong-Shenzhen ERL. I have also controlled for the announcement of Co-development projects on the Hengqing Island by the Macau government. Each of these events are entered into the regression model as a pulse intervention. This means that they are entered as dummy variable with a value of "1" on the year that the event took place, with all other years set to "0".

Table 1 reports the descriptive statistics in this study. Descriptive statistics by region is available in the appendix.

Estimation Technique

I fitted a multi-level linear regression model to predict the degree of discontent with the 1C2S. The protest count data cannot be predicted using the linear model since count data do not follow the normal distribution, so I fitted a multi-level zero-inflated negative binomial (ZINB) model instead. I included a random intercept for both the year and country levels. The 1C2S model is fitted using the lme4 package in R. The model for protest counts failed to achieve convergence under frequentist estimation, so I estimated the model using the Bayesian approach via the brms package in R. I have allowed the covariance matrix of the error to follow the AR(1) process, such that non-independence across times can be captured by the error term.

A detailed discussion of the Bayesian models and regression coefficients is available in the appendix.

Results

Table 1: Descriptive Statistics of the Hong Kong/Macau Analysis

	Mean	Median	Std. Dev.	Min	Max
Dissent in 1C2S %	0.247	0.231	0.146	0.045	0.584
N Protest	59.545	3.500	194.599	1	903
UEI	8.040	6.354	4.540	3.291	19.627
Dependence	194.544	23.747	207.367	9.090	529.906
Total Trade (Billion USD)	368,768.800	354,201.400	381,991.500	2,249.088	1,139,859.000
FDI Volume (Billion HKD)	198.531	97.900	225.039	0.659	711.200
Stock Market Joint Movement	1,231.173	525.921	1,282.206	18.495	4,512.079

Figure 1 shows the result from the observed value prediction of dissent towards 1C2S, conditioning on the level of dependence to the minimum and maximum observed levels in the data. From figure 1 we can see that at minimal levels of UEI institutionalization, the difference in the predicted percentage of people unsatisfied with 1C2S is subtle between the cases of low and high economic dependence. As UEI institutionalization increases, the predicted effect direction differs. We see that for regions with low level of dependence, the percentage of dissent towards 1C2S increases as UEI increases, while that relationship is negative for regions with high levels of dependence. At middle levels of UEI institutionalization, highly dependent regions have reached nearly 0% of dissent towards 1C2S expressed, while for independent regions that figure is slowly climbing towards 50%.

Table 2: Estimating the level of dissent towards 1C2S

	Dependent variable:		
	Dissent Towards 1C2S		
	(1)	(2)	(3)
Dependence	−0.026** (0.008)	−0.003 (0.018)	0.005 (0.037)
UEI	0.236 (0.326)	2.115*** (0.538)	2.572 (1.474)
Trade Volume	0.00002*** (0.00000)	0.00005*** (0.00001)	0.0001*** (0.00002)
FDI Volume			−0.020 (0.017)
Stock Market Integration			0.0001 (0.001)
HZMB			2.222 (4.394)
Hong Kong-Shenzhen ERL			3.014 (6.239)
Hengqin Joint Development			−3.306 (4.304)
Dependence * UEI		−0.007*** (0.002)	−0.009* (0.004)
Intercept	21.302*** (5.158)	1.012 (19.616)	−3.543 (25.546)
Random Effects			
Year	6.35	4.569	3.835
Region	0	25.888	30.104
Observations	46	46	34
Log Likelihood	−163.822	−163.573	−123.111
Akaike Inf. Crit.	341.644	343.145	272.221
Bayesian Inf. Crit.	354.445	357.774	292.064

Note:

*p<0.05; **p<0.01; ***p<0.001

Reported are estimates obtained from a multi-level linear regression model.

Standard errors are in Parenthesis.

Figure 2 shows the result of the predicted effects from the model on the number of protests observed in a year. The minimum, mean and maximum levels of dependence have been used to produce three predictions for regions with low, medium and high dependence respectively. While the estimates are prone to error due to a small sample size, we could still see the same effect shown in figure 1 - given high levels of dependence, basically the region would never protest; Given low levels of dependence, the reduction effects of UEI is still present, yet it only works at much higher levels of UEI institutionalization (>50).

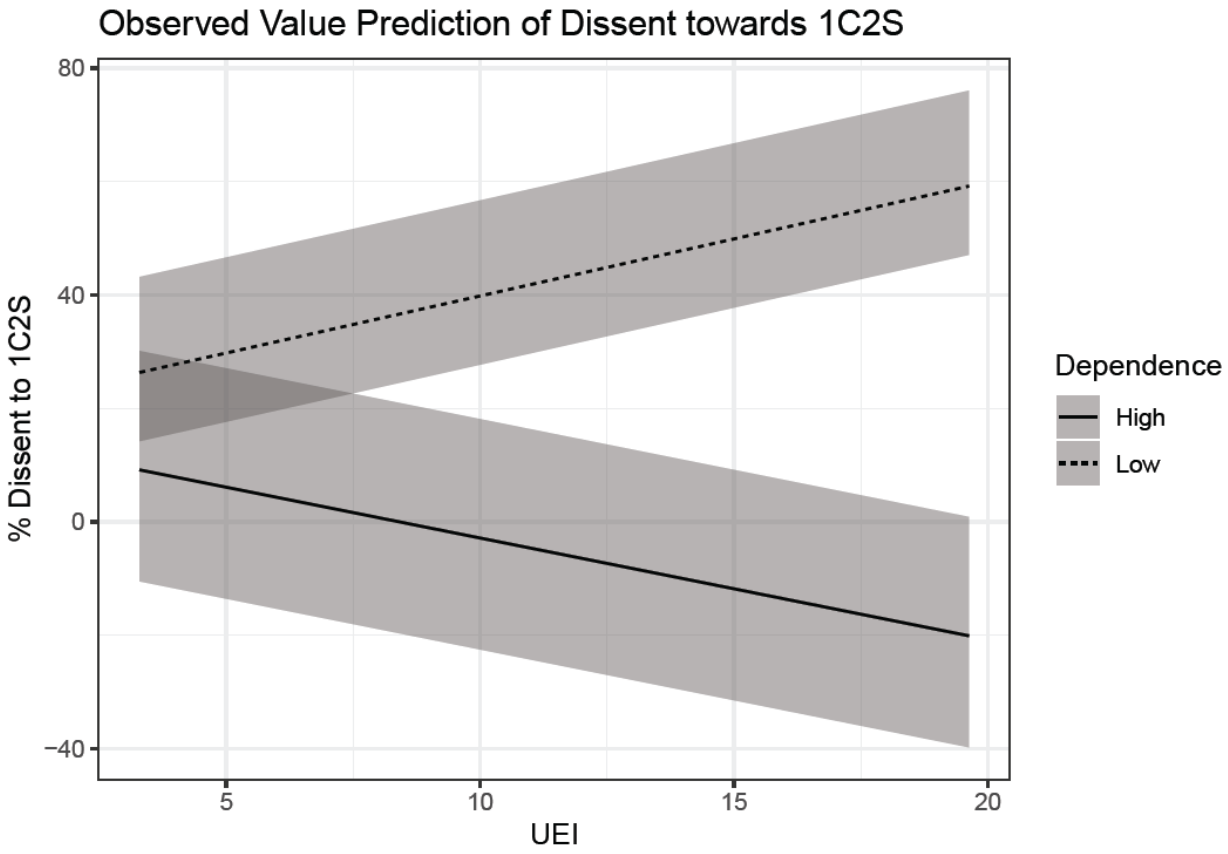

Figure 1: Predicting dissent towards 1C2S

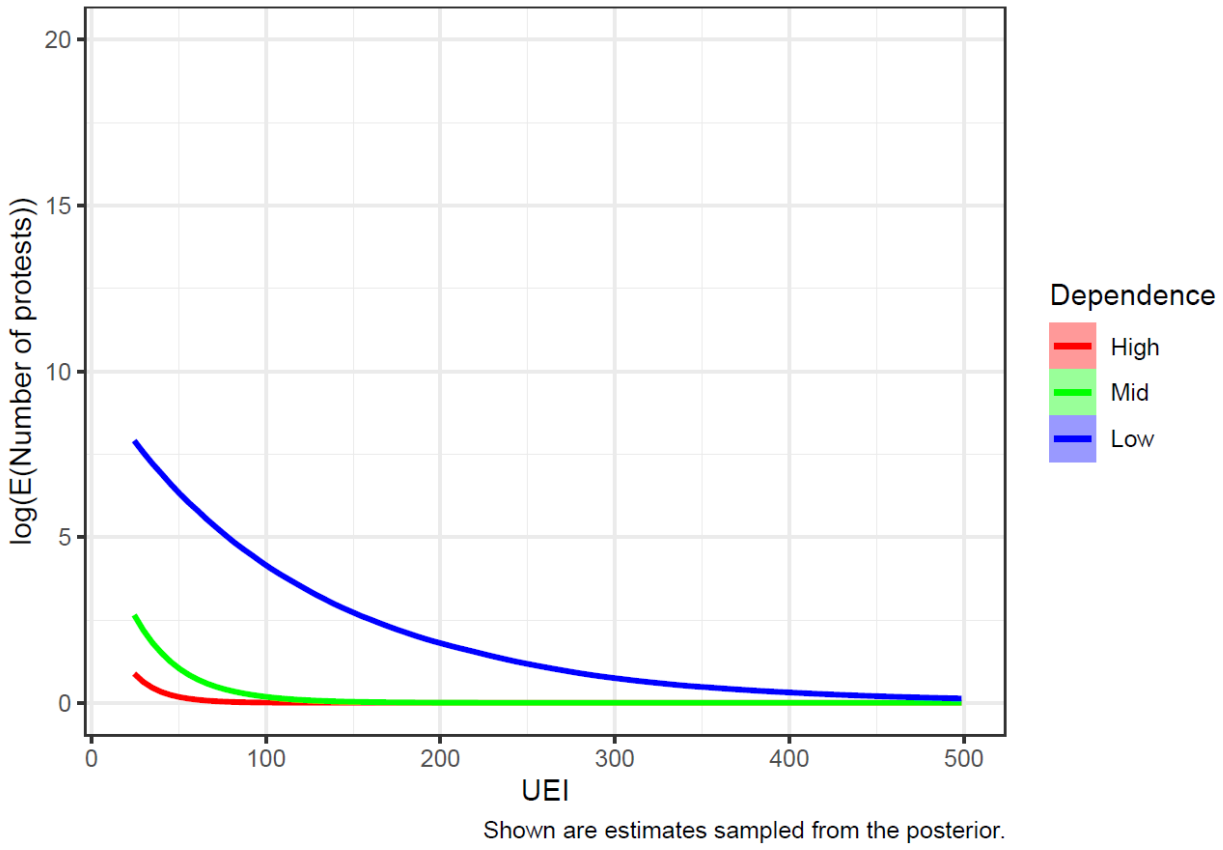

Figure 2: Predicting the mean number of protests per year in Hong Kong and Macau

From Figure 1 and Figure 2, we have found support for both H1 and H2.

One could argue that the results is an artifact of the difference in prosperity of the two regions. However, the relative deprivation argument would suggest that it is Macau that should see more unrest. In the appendix, I showed the models with the log of GDP per capita added in the estimation. Results show that the effect direction observed still holds, albeit the interaction variable between Dependence and UEI lost significance. However, given that GDP correlates strongly with the trade data I am using, those results should be taken with a grain of salt. GDP

should matter in the same way as the total trade volume as a measure of economic alternatives should they revolt against the national center. The distribution of this coefficient is almost identical in the Bayesian model.

Alternatively, one could argue that it is the difference in income inequality between the two regions that explain the different levels of social unrest. This could be true, as some protests might be related to rising income inequality. In the appendix I re-estimated the models with the gini coefficient added in. The data for gini coefficient is not available at a yearly interval, so I extrapolated the gaps in between observations. I found that in the 1C2S dissent model, the interaction variable lost significance, but with a p-value of around .126, which is very close to the $p<.10$ significance threshold. The distribution of this coefficient is almost identical in the Bayesian model, so the interaction effect for the protest count model holds.

How UEIs increase the expected cost of contention in Hong Kong and Macau

Now that we know UEIs does suppress dissent conditional on the level of economic dependence, but how do they work? In this case study section I will examine if the empirical patterns discovered above apply in Hong Kong and Macau.

Hong Kong: UEIs failed to increase the cost of contention

As discussed above, the CEPA was launched at a time of economic turmoil (So 2004; Ma 2015; Fong

2015; Cheung 2007). The Hong Kong government was quick to sign the agreement to the trade liberalization scheme, and that lays the foundation for further integration. The first sign that CEPA led to increased dissent towards China is the question of inter-border trade. CEPA enables the free movement of goods, which led to sudden rise in demand of Hong Kong goods in the Mainland. Together with the Individual Visit Scheme (IVS), Chinese citizens may now purchase goods in Hong Kong and bring them back to China. This leads to a rise of parallel trading in the Northern border of Hong Kong which deprived of Hong Kongers goods in the early 2010s.

Popular sentiment against China peaked around 2012, when the parallel trading problem was combined with the question of Birth tourism of Chinese mothers in Hong Kong. The IVS allowed Chinese mothers to travel and give birth in Hong Kong (Tsang 2012; "Duli Meiti" 獨立媒體 [Hong Kong Independent Media] 2012; ON.CC 2013; Ma 2015). Groups advocating for local rights began to rise, such as the North District Parallel Imports Concern Group, Hong Kong Indigenous, Hong Kong Local Power and the Claudia Mo-led Hong Kong Local (Yuen and Chung 2018). Some of these groups first began advocating on the protection of the Hong Kong market, yet eventually they took the matter to the streets, launching protests against parallel trading and immigration. During the 2016 legislative election there was heavy outbidding from localist parties against the traditional pan-democrats. For example, Civic Passion ran a mostly negative campaign attacking the Democratic Party for launching talks with Beijing officials in 2010. They claimed the talks have constrained the opposition's options in the future, just as the

OBM predicted. They eventually captured one seat in the New Territories West Constituency. Youngspiration, another localist party, captured 2 seats in the legislature.

In response to mass mobilization of the umbrella movement, the Chinese government enacted stock market integration between Shenzhen, Shanghai and Hong Kong in 2016. However, Hong Kong investors were not as keen as Chinese investors in utilizing the stock connect. Most of the capital flows tend to come from Chinese investors buying in Hong Kong (ON.CC 2015). It has also been speculated that Beijing might have two ulterior motives on stock market integration: 1) First, it was to encourage Hong Kongers to adopt the 2015 Constitutional Reform. If Hong Kongers rejected the 2015 reform, then Beijing would command Chinese companies to cease investing in Hong Kong (Lian 2014; Lam and Wong 2015); 2) it was to extend Beijing's reach of Hong Kong's financial markets through Chinese companies, of which many belonged to the State-owned Assets Supervision and Administration Committee (SASAC) (Donald 2014, 89). For instance, the SASAC as a whole wielded 74.08% stake of China Mobile, the most prominent red-chip firm listed in Hong Kong at the time. The SASAC reports to the State Council (pp.236-237). This speaks to the predictions from the OBM, in which China did use the stock-connects to push through the 2015 reform. In response, the localist opposition launched various protests, reminding the locals that China might break the promise of offering universal suffrage in 2017 (BBC 2015).

Recently, the Hong Kong government has been pushing for integration within the "Greater Bay Area" with Guangdong. It created a new office for the Greater Bay Area Development. The Hong Kong goverment allocated land for the construction of a Hongkong-

Shenzhen Innovation & Technology Park (HSITP), and created a board of directors for the project. The project received public backlash due to the massive delays and cost overrun. Even pro-China lawmakers like Michael Tien and Leung Che-Cheung have raised concerns about the project cost and potential moral hazards down the road (ON.CC 2020).

In Hong Kong, UEIs failed to increase the expected cost of contention in various occassions. The CEPA, combined with the IVS, only served to provide opportunities for some segments of the business community but did not benefit all Hong Kongers much. The under-utilization of the stock connects followed the same trajectory as Hong Kong investors were indifferent to the new project. New institutions on the Greater Bay Area project invited criticism from even pro-China legislators. If anything, UEIs seem to have added to public backlash, as parallel trading disrupted the supply of goods in Hong Kong and gave rise to the localist opposition in Hong Kong.

Macau: UEIs increase the cost of contention to an already high baseline

The situation is drastically different in Macau. Historians pointed out that the Macau people were frustrated with the colonial Portuguese administration. Crime was rampant and they saw transition to Chinese rule as an opportunity to improve law and order (Gunn 1996; Mendes 2013).

Macau's heavy economic dependence on China comes from its structural reliance on tourism and the gaming industry. Macau's gaming industry is inward-looking, mostly geared towards serving Chinese tourists (Liu et al. 2015; Lo 2014). In 2015, Gaming Tax Income

constitutes up to 83.5% of Macau's total tax income (Liu et al. 2015, 500). Because of this structural reliance, there are not many alternatives to economic cooperation with China.

Perhaps the addition to the expected cost of contention is most obvious in the joint development of the Hengqin Island between Zhuhai and Macau. In the 2000s, the Macau administration had been in contact with the Zhuhai administration for possible joint rule on Hengqin Island, an island to the West of Macau that is within Zhuhai's city limits. Eventually, the Chinese government allowed the Macau administration to co-develop a small section to the East of the island with the Zhuhai government. Due to Macau's limited land mass and industrial diversity, the Macau government decided to focus on non-gaming development on Hengqin Island (Fan et al. 2013, 1301; Liu et al. 2015, 509; Lo 2014, 82– 83; Zheng 2010). Macau went ahead and constructed a new University of Macau campus on Hengqin island in 2013 (Jiang 2013). Pro-China forces applauded the Hengqin Island project as an example of Sino-Macau cooperation, arguing that cooperating with China helps Macau's development. In this particularly case, it helped Macau extend its borders (Jiang 2013; Yu 2013). The cost of opposition is immediately felt when journalists asked about the implementation of 1C2S on Hengqin Island.

Specifically, a journalist asked the University of Macau about what happens when students organize June 4th memorial meetings. The university gave no direct response, yet stressing that Macau laws apply on campus (Jiang 2013). If massive protests were to occur on Hengqin or Macau, the Chinese government has all the rights to revoke the administrative rights of Macau on the island.

Compared to Hong Kong, Macau's baseline cost of contention is much higher. Its economy is structurally reliant on China's, so it lacks alternatives to economic integration with China. If protests occur, then China's economic retaliation would hurt Macau much more since Macau would not be able to divert its economic activity with another country. UEIs add to this already high baseline cost, as suggested in the Hengqin case. If Macau revolts against China, then it would lose all its extra holdings on Hengqin Island. Considering that the Hengqin development area is nearly of the same size as Macau, that would imply a huge economic cost.

Fiscal Decentralization, Economic Dependence and Protests in China, 2000-2019

Table 3: Descriptive Statistics of the Chinese Provincial Analysis

	Mean	Median	Std. Dev.	Min	Max
N Protests per year	10.019	0	28.484	0	318
Subsidies (100 million CNY)	182.119	106.559	431.753	0.200	9,630
Shared Income (100 million CNY)	2,850.832	1,685.985	3,598.380	18.506	28,647.890
Trade Volume (100 million CNY)	48,504.460	8,768.165	111,800.400	30.500	873,772.700

While the results from the Hong Kong-Macau paired comparison shows the moderating effect of economic dependence on the effectiveness of UEIs, it is unclear to what extent this finding travels. Hong Kong and Macau are still peculiar regions not only in China but in the world - not many regions shared the same situation as two regions.

To examine the validity of my findings, I test my claim in all Chinese provinces in 2000-2019. I exploit the Chinese Fiscal Decentralization system, which gives us a rough measure of how much UEI and how much economic dependence is in each of the provinces. Fiscal Decentralization in China means that almost all taxable income at the provincial level are shared, with a few exemptions (Montinola, Qian, and Weingast 1995). I measure the level of UEIs as special fiscal transfers from the central government to the provinces. These special transfers include various subsidies such as gas price subsidies or food price subsidies. Then, I measure the level of dependence as the total of shared tax income. The motivation is from the hypothetical scenario in which the province breaks away from China: If they break away, then they lose the shared income tax with the national government. The potential amount the province could lose could be a good indication of how dependent a province is on the Chinese state.

The dependent variable is the protest count data acquired from the GDELT 2.0 Events Database. Because the GDELT Data is geocoded, it is possible to reverse geocode the data and identify in which province has a protest taken place. I then calculate the yearly aggregate of protests for each province. Figure 3 plots the distribution of all protest events captured by GDELT 2.0 across China in the study
period.

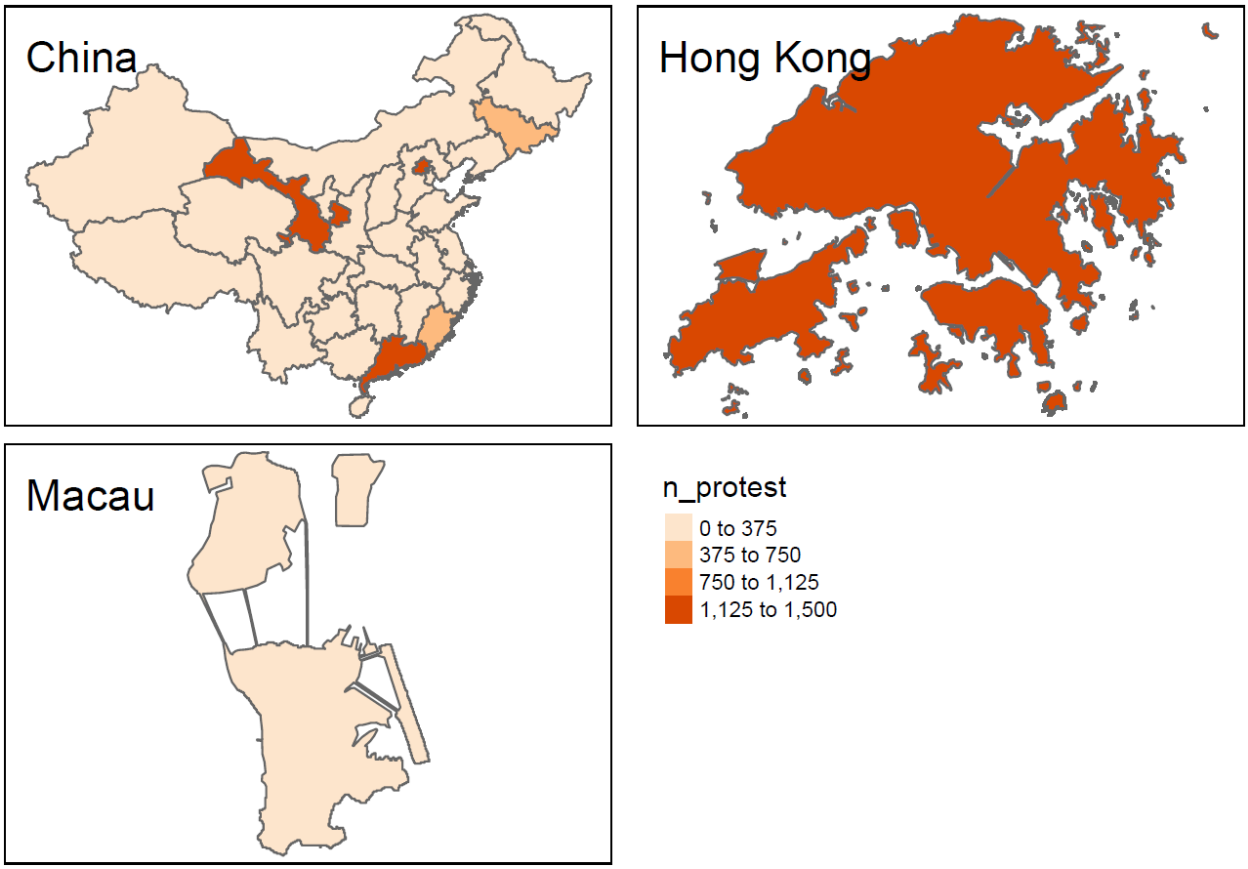

Figure 3: Aggregated Number of Protests between 2000-2018 across China, Hong Kong and Macau

Due to data limitations, I can only control for the total trade volume disaggregated at the provincial level. The Chinese statistical authority does not break down trade in services by region, so I continue using trade in goods data only.

Same as the Hong Kong-Macau study, I fitted a multi-level ZINB model with year and country intercepts. Hong Kong and Macau are excluded from this study, since this is a validation task. One could think of this extension as using Chinese provincial data to test the

out-of-sample validity of my findings. If the same pattern holds, then my theory should be able to travel beyond Hong Kong and Macau.

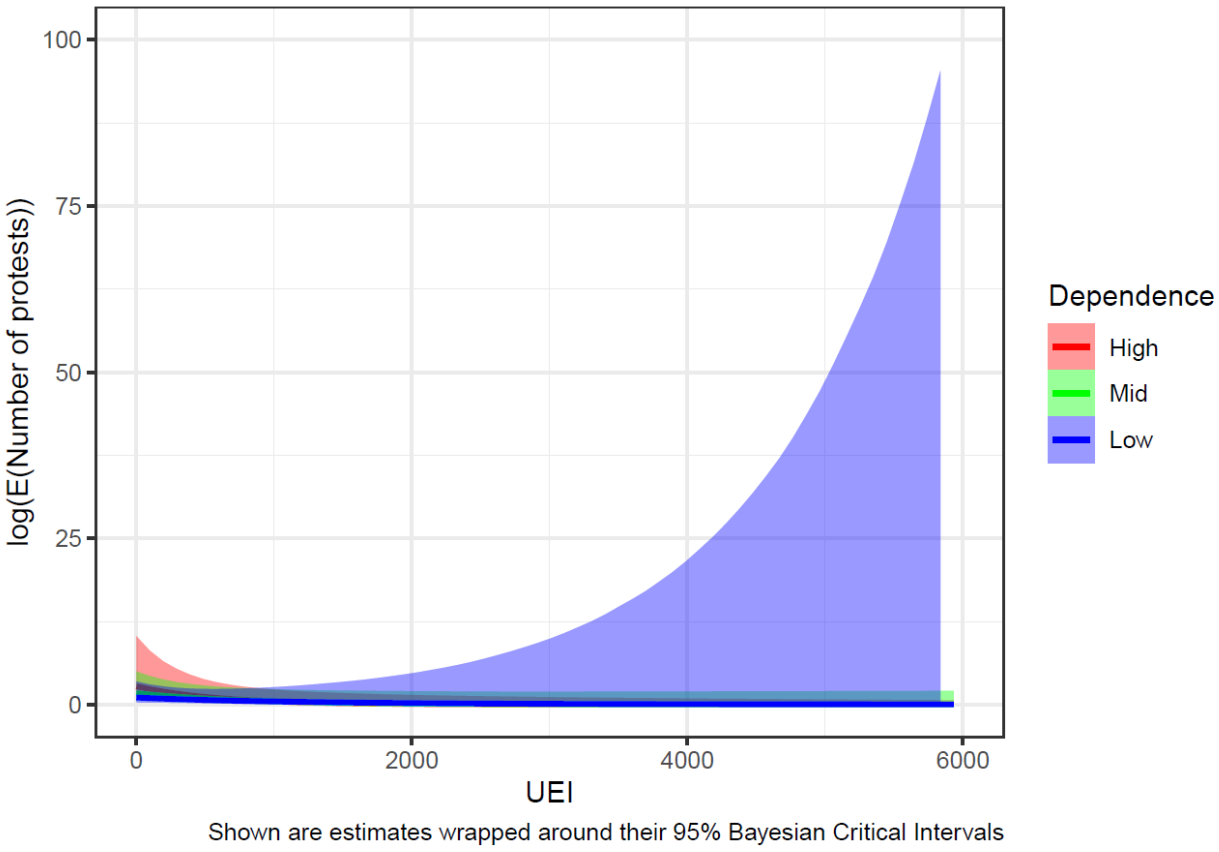

Figure 4: Predicting the mean number of protests in Chinese provinces

Figure 4 shows the predicted mean counts of protest as a function of economic dependence to the center. It shows the predicted mean number of protests for the three groups: those with maximal amount of shared income, mean amount and minimal amount of shared income. Similar to the Hong Kong-Macau study, a large part of the posterior distribution of the

coefficient for the interaction between UEI and economic dependence remains in the negative, however its 95% Bayesian Critical Interval crosses 0 (-.57, .22). Therefore, one should take the results from the plot with a grain of salt. While the group means are not that different as they cluster around 0 protests a year, the range of possibilities varies by group. One can observe that at low levels of UEI institutionalization, the high dependence group is the group more likely to protest. However, as UEI increases, the group order switches place - now the low dependence group is most likely to protest as my theory suggests.

In this study, UEI has a somewhat consistent negative effect. Recall that this coefficient denotes the conditional effect of UEI on the mean number of protest when there is absolutely no economic dependence. The 95% Bayesian Critical Interval for UEI is at (-1.31, .03), with a mean point estimate at -.57. This suggests that for every additional 100 million yuan added to the demeaned subsidies amount, the mean number of protest in that particular province should reduce by around .43 per year. Therefore, when a region is economically independent from the center, it takes approximately 232.558 million yuan of subsidies to reduce the mean number of protest by 1. A plot of the predicted effects is available in the appendix.

Albeit less accurate, this validation exercise suggests that my theory might travel to the rest of China as well. The estimated coefficients in the China model follow the same trajectory of that estimated in the Hong Kong/Macau model.

Discussion

In this paper, I tried to explain why UEIs could reduce social unrest in some regions but not in others. I argue the key is to look at how dependent the regional economy is on the national economy. If the region becomes highly dependent on the national economy, then the regional population would be much less likely to express dissent in the autonomy agreement between the national center and the region in question. In the Hong Kong-Macau study, I found this to be true for both regional dissent on the 1C2S and the number of protests. In the extension to China, the same pattern holds, albeit the uncertainty of the estimation is much higher.

The paper has made three main contributions to the literature. First I showed that economic integration can be used for authoritarian control. It is a tool devised to impose extra costs on contention much like the use of social co-optation strategies like social welfare (Xu 2020). If economic integration with the rest of the world creates centrifugal forces from the center (Alesina, Spolaore, and Wacziarg 2000; Alesina and Spolaore 1997, 2003 ; Coufalova 2019), then the authoritarian state could also produce centripetal forces towards the center with UEIs. If the authoritarian state could pay off a degree of UEI that produces more centripetal forces than the centrifugal forces from international economic integration, then they would be able to appease restive regions.

Second and most importantly, the paper has provided an initial explanation as to why economic integration could appease regional unrest and why it could not. I showed that economic dependence is the key driving force for the effectivenss of UEIs in peripheral regions.

The crux of the problem in implementing UEIs is that the regions have different baselines in terms of their economic relationship with the authoritarian center. If UEIs serve to increase the expected cost of contention, then the next question is how large is that expected cost to begin with. If the starting point is low, then the authoritarian state needs to institutionalize UEI a lot more to induce the region to pay attention to the economic costs of contention. The starting point of this expected cost is going to be higher for regions like Macau, whose economy is geared towards Chinese tourism and the gaming industry (Liu et al. 2015; Lo 2014; Yee 2001). Compared to regions like Hong Kong, whose economy is more outward looking and independent from the national economy, their initial expected cost is going to be much lower. With empirical evidence, I showed that the central government needs to pay roughly 232 million yuan of subsidies a year to a region with absolutely no prior economic dependence if the authoritarian state wishes to reduce the mean number of protest by at least one. This cost can run extremely high if the authoritarian state wishes to suppress dissent entirely in regions like Hong Kong, in which over the course of 2019 saw nearly 900 protest events during the anti-extradition bill movement. In many ways, this alludes to the commercial peace theory in International Relations, which suggests that trade asymmetry is a common reason for interstate conflict (Barbieri 1996; Gartzke and Westerwinter 2016). We also see that given low dependence, localists in Hong Kong opposed to new UEIs as they avoid entering into an obsolescing bargain like they did in 2015, and they outbidded other moderate oppositions in the 2016 legislative elections.

Third, I showed that it takes time for UEI to have an effect. In the Hong Kong/Macau model we see that the effects of UEI institutionalization is more obvious for UEIs that have been implemented for a longer time (e.g. FDI and Trade Steering as part of CEPA). For more recent UEIs, such as Stock Market Integration the effect is more subtle. Since UEIs ultimately alter the expected cost of contention, it is likely that the effect of UEIs is compounded. Therefore, the longer the UEI is in place, the stronger its appeasement effect. Note that in the China model we see that UEI alone has a consistent negative effect. Since fiscal decentralization have been in place in China for a much longer time than the CEPA in Hong Kong/ Macau, this could speak to how UEIs would have developed a consistent reductive effect over time.

That being said, this paper is only the first step towards explaining the effectiveness of UEIs in authoritarian contexts. It definitely has its share of weaknesses that can be addressed in future work.

First, we will need more regional data to refit the China model. One of the reason that estimation uncertainty is higher for that model is likely due to the quality of the data available. Authoritarian statistics are likely prone to falsification. This is a particularly endemic problem in China as the bureaucracy awards economic performance via promotion to middle tiers of office (Shih, Adolph, and Liu 2012). Another source of measurement error in the China model is simply due to the lack of disaggregation in the many indicators used. Recall that the dependence measure is operationalized as the total shared income, but we only have a rough estimation of how large the shared income segment is. With more quality data on economic dependence and UEIs, we should be able to see a clearer effect compared to what has been

reported here. More data on income inequality in Chinese provinces could also help us control for the role of inequality in explaining the number of protests too.

Second, we need to unravel the causal story further. In this paper I have shown the causal mechanism of UEIs at the regional level, but at the individual level, UEIs could be used to turn supporters into winners and the opposition into losers in the economic realm. As the classical long views of democratization focus so much on the role of inequality (Acemoglu and Robinson 2006; Boix 2003), one might believe that by gaming the rent (re-)distribution to the extreme , the authoritarian state would be able to hold together the income inequality that impedes the democratization of the state (Magaloni 2006). In this sense, the concept of UEI is no different: it aims to create the winners and the losers from economic integration. More economic engagement with the national center might bring business opportunities that turn those business-owners into regime supporters. For those who have no stake in the Chinese economy like younger people or workers employed by a Hong Kong-based business, UEIs may mean the loss of whatever economic autonomy the region might have. This thus pits the regional population against one another, increasing the severity of the collective action problem at the regional level. Perhaps this is why when mass protests erupted in Hong Kong in 2014 and 2019, they did not spread en masse up North as the regional populations up north failed to mitigate the collective action problem.

Third, the paper so far offered very little insights about what might happen when UEIs do not work. Considering the sheer amount of UEIs required to appease a economically independent region, the authoritarian state might simply want to switch to more repressive

strategies. For example, Xu (2020) shows that the Chinese state has now switched to targeted prosecution powered by mass surveillance from co-opting counties with social welfare. Information throttling and flooding of irrelevant information has also served to distract political discussion online in China (Roberts 2018). The 2020 National Security Law imposed on Hong Kong is a strong indication that the Chinese state has grown frustrated with the ineffectiveness of social co-optation strategies like the UEIs. As a result, Beijing decided to adopt a full-blown iron fist approach. Future research should assess where the breaking point is, i.e. at what point would the authoritarian state switch from UEIs to other repressive strategies to manage social unrest in the periphery.

Conclusion

The authoritarian state could use UEIs to manage social unrest in the periphery, yet its effectiveness hinges upon the degree of economic dependence of those regions. UEIs adds to the expected cost of contention, and thus one must also incorporate the baseline expected cost at the regional level. UEIs could become a bad idea when the region has no prior economic relationship to the authoritarian center, so the peripheral population is indifferent to the added costs of contention. Effectiveness of UEI is path dependent: More dependent regions are open to accepting more UEIs, whereas less dependent regions may oppose to UEIs as they do not want to enter into an obsolescing bargain, or that UEIs induce ethnic outbidding within the region. In the comparison of Hong Kong and Macau, China gave the same degree of UEIs to both regions. Macau was less restive after exposure to UEIs because they had a very high initial level

of economic dependence to China, thus UEIs increased the expected cost of contention in Macau substantially. In Hong Kong, the low initial levels of economic dependence undermined the effectiveness of UEIs since the increase in the expected cost of contention created by UEIs was offset by international trade.

It remains interesting to see how well the findings travel beyond the Greater China region. I have showed empirical evidence that my findings not only apply in Hong Kong and Macau, but possibly to all provinces of China. Moreover, this paper introduces a broad story of economic dependence that could apply broadly to free trade agreements within and between countries. The paper could very well speak to the ongoing research agenda on the leverage of Free Trade Agreements (FTAs) in International Relations. In the case of China's increasing global influence, one could think of how the Belt & Road Initiative (BRI) builds economic dependence in the destination country, and thus making it more difficult for the citizens there to express discontent with China's increasing influence in the world (Rabena 2018; Ferdinand 2016). China's participation in the newly signed Regional Comprehensive Economic Partnership (RCEP) agreement may further constrain opposition against China in the international arena following the argument of economic dependence.

Notes

1. UEIs are rare in modern history because they are usually the first steps taken in the process of state-building (Flora, Kuhnle, and Urwin 1999, 58). In other instances, states annexed a territory without signing a specialized institution like the UEI. States either deem that the market was already integrated such that UEIs are not needed, or that there could be

opposition from vested interests from the national center. For example, German business interests defeated economic concessions for Alsace-Lorraine following annexation in 1871 (Silverman 1971).

2. Plots of the trade data in time series format are available in the appendix.
3. This chapter previously appeared as an article in the Journal of East Asian Studies. The original citation is as follows: Chan, H. Y. K. (2021) "Can Economic Integration Reduce Social Unrest? Evidence From China, Hong Kong, And Macau," *Journal of East Asian Studies*. Cambridge University Press, 21(3), pp. 403–426.

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Can municipal amalgamation lead to a higher voter turnout? The case of Norway

Introduction: Size and Democracy

The debate on size and democracy is a classical one in Political Science. From Aristotle to Rousseau, theorists argued that democracy works best in smaller jurisdictions. In smaller towns, it is said that people know their town and its inhabitants the best: "citizenship would be close to friendship, close even to a kind of extended family,... where the eternal human quest for community and solidarity can be wholly satisfied within the visible and comprehensible limits of the polis"(Dahl, 1967: 955; Dahl and Tufte, 1973). However, if jurisdictions are too small, then the influence that citizens can exert over policies that shape their lives would be rather limited (Dahl and Tufte, 1973: 42).

In the case of municipalities, this problem is particularly severe. To address this, local governments want to achieve economies of scale through amalgamation, or internalize externalities, yet democratic theory warns the unintended consequences of decreased participation among citizens (Dahl and Tufte, 1973; Swianiewicz, 2010, 2018). This warning is supported by a long line of empirical evidence showing that municipal amalgamation reduces local voter turnout (Bhatti and Hansen, 2019; Hansen, 2015; Lapointe et al., 2018; Lassen and Serritzlew, 2011; Steiner and Kaiser, 2017). However, others also argue that municipal amalgamation could increase voter turnout (Bhatti and Hansen, 2019; Koch and Rochat, 2017). The literature suggest that turnout increases as highly motivated voters want to re-elect their old local representatives into the new local council.

This paper argues that non-legitimized municipal amalgamation could increase voter turnout in the short-run, but the effect is conditional on the local context and the voter's intention of voting. When municipal amalgamations are carried out against a voter's wishes, then they can be mobilized to vote as a reaction to the lack of legitimacy of the reform. There are at least two candidate mechanisms through which the protest voting occurs. First, voters may want to re-elect old local representatives into the new council in order to safeguard their local interests. Voters with a strong local identity are particularly likely to vote under this mechanism (Bhatti and Hansen, 2019; Koch and Rochat, 2017). Alternatively, people can use this vote to hold local officials that forced through the reform accountable. In this way, the vote in the local election is essentially to punish these officials that went against their wishes and reward the old representatives. So, under these two mechanisms, can the effect of amalgamation on local voter turnout be actually positive?

Because there are both plausible theories for a positive *and* negative effect for amalgamation reforms in a local election, the aggregate-level effects of amalgamations could be difficult to identify. This paper contributes to the ongoing literature on amalgamation reforms by adding that the effect direction of municipal amalgamation is highly contingent upon the local context of the reform, and the underlying motivations of the individual voter.

To show this, I capitalize on the unique situation where the 2015 and 2019 Norwegian local elections coincided with the local government reforms from 2014 to 2020. The Norwegian reform changed very little beyond municipal borders and municipal size, thus eliminating the need to control for changes in local electoral institutions, local authority change, people's socio-economic background as well as people's social networks. This thus allows the targeted investigation of the effect of municipal amalgamation at the municipal and individual level. With a customized dataset on district-level turnout rates in the 2015 and 2019 Norwegian Local Elections, I attempt to replicate the existing positive or negative effects reported in the literature using the Difference-in-Difference (DID) design and successfully identified a negative effect of municipal amalgamation in the 2019 turnout levels. To probe deeper into the individual-level reasons for voting, I turn next to data from the Norwegian Citizens' Panel Wave 16 to compare the propensity of voting of individuals given different motivations to vote. Through two mediation analyses, I find that those who are subject to a non-legitimized reform and want to punish local politicians responsible for the decision are more likely to go

vote.

In the first section, I review the existing literature on the effects of municipal amalgamation on local voter turnout; The second section presents my theory on the importance of local context and voter motivations on the effects of municipal amalgamation; The third section reports on the municipal-level analysis; The fourth reports on the individual-level analysis; The fifth discusses and concludes.

The Puzzle of Municipal Amalgamation and Local Voter Turnout

In the literature, it is well documented that under municipal amalgamation, municipalities have seen lower voter turnout in local elections (Bhatti and Hansen, 2019; Cancela and Geys, 2016; Koch and Rochat, 2017; Kraaykamp et al., 2001; Lapointe et al., 2018; Van Houwelingen, 2017). Two meta-analyses identified a negative effect on voter turnout in the majority of the cases. Cancela & Geys (2016) reported that such negative effects were found in 69% of the local elections after amalgamation increased the average municipal population size. Houwelingen (2017) found 60 negative relationships but only 10 positive relationships after municipal amalgamation. However, a small literature did find that after municipal amalgamation voter turnout could increase (Bhatti and Hansen, 2019; Strebel and Schakel, 2021). How can we make sense of these conflicting findings? Are there some conditions through which municipal amalgamation can increase or local voter turnout, despite a negative effect at the aggregate-level?

In municipal amalgamation reforms, only two things are changed: municipal borders and subsequently municipal size. Many well-documented factors that could depress voter turnout are not changed in this type of reform. For example, it does not affect the timing of the election, so we eliminate the effect of concurrent national and local elections (Hajnal and Lewis, 2003). Nor does it increase the cost of non-voting like compulsory voting laws do (Blais, 2006). Municipal amalgamation also does not change electoral rules.

Municipal amalgamation does not change people's informal social networks (ISN) such that people are more or less pressured to vote. Even if the municipal borders have changed, people share the same set of neighbors, so it is quite unlikely that people's discussion networks for politics would change such that people are less likely to vote (Abrams et al., 2011).

Nor does municipal amalgamation change the authority of local governments. Therefore, we could also eliminate the causal effect of political authority enjoyed by local officials (Gendzwill, 2019; Wood, 2002).

What municipal amalgamation could change is municipal size. With changing size comes with a change in the number of eligible voters, as well as the set of potential candidates running in an election (Saarimaa and Tukiainen, 2016). Scholars noted that these changes will eventually lead to decreased utility in voting in municipal elections after mergers.

Why municipal amalgamation could reduce local voter turnout

A key causal mechanism discussed in the literature is that municipal amalgamation decreases local voter turnout by increasing the jurisdictional population (Cancela and Geys, 2016; Lapointe et al., 2018; Van Houwelingen, 2017). Jurisdictional population matters because it changes the probability of which a single vote could alter the election outcome (Lapointe et al., 2018; Lyytikaeinen and Tukiainen, 2019). This probability (called p) is central to the Riker-Ordershook model in the classical voter turnout literature. In the classical literature, people go vote because they believe their vote has the probability of changing the outcome of the election. Such probability is usually infinitesimally small in national elections (Riker and Ordeshook, 1968). p is sensitive to population size because the smaller the population size, the more likely p would increase. The influence of each vote increases as the jurisdiction gets smaller. In Municipal Amalgamation, jurisdictions usually become larger not smaller, and thus the expected causal effect is negative (Gendzwill, 2019: 15). However, this suggests that the effect identified is that of jurisdictional population change, not municipal amalgamation. Studies that controlled for population change have still found a negative effect of municipal amalgamation (Koch and Rochat, 2017).

The mechanism regarding population brings us to the second point, which stipulates that larger, amalgamated municipalities implies will have to cater to more preferences. As Montesquieu foresaw, the common good in larger communities would have to be sacrificed to thousand considerations and subordinated to various exceptions, thus it is harder to satisfy every citizen in this community (Dahl and Tufte, 1973: 7). This laid the foundation for the popular argument regarding political efficacy. For example, Lassen & Serritzlew (2011) argued that as the municipality gets larger, citizens would find the municipal government more alien and

distant from them. This makes them feel as if their participation might not be worth their time, and thus municipality amalgamation would reduce what the authors called the Internal Political Efficacy (IPE) of citizens living in amalgamated municipalities. The authors showed that after the Danish local government reforms in 2007, IPE was indeed decreased in amalgamated municipalities, yet they did not assess its impact on local voter turnout. Subsequent studies have continued to replicate this negative effect on satisfaction (Hansen, 2015) and trust (Hansen, 2013), yet none has been able to link it to local voter turnout directly.

The dilution of taste might only occur when the amalgamation occurs between two municipalities of drastically different sizes. The average taste of citizens living in a smaller municipality changes if it is being absorbed into a much larger municipality, but again, this means that the effect on voter turnout is a function of new municipal size, not of municipal amalgamation per se. The other possibility is that municipal amalgamation is more likely to occur when people live close to each other, but then the effect of municipal amalgamation would be a function of geographical proximity of voters to the new center of the municipality, not of the shift of municipal borders per se (Saarimaa and Tukiainen, 2014: 109–110).

Could municipal amalgamation increase local voter turnout?

Alternatively, there is an argument for the case where municipal amalgamation could increase local voter turnout. There is an argument that municipal amalgamation triggers those who are highly attached to the old municipality, such that they will be mobilized to vote to ensure the old representatives could make it to the local council of the new municipality (Bhatti and Hansen, 2019; Lyytikaeinen and Tukiainen, 2019; Saarimaa and Tukiainen, 2016; Strebel and Schakel, 2021). In particular, the new municipality may have reduced representation per capita and reduced representation of the old municipal structure if a smaller municipality gets merged to a larger municipality (Bhatti and Hansen, 2019; Koch and Rochat, 2017). As Strebel and Schakel (2021) shows, Norwegian voters unhappy with the reform might want to vote for the opposition parties instead. Saarimaa and Tukiainen (2016) shows, in the case of Finland, votes become more concentrated around the less represented parts of a constituency following a reform. This suggests that voters who perceived a threat to their local representation after a merger would be motivated to go vote.

When municipal amalgamations become such a salient issue that people are prompted to vote for the

opposition, one may argue that the first local election after amalgamations could become an important one compared to previous local elections. The "second-order election" literature suggests that mobilization in highly salient subnational elections may result in a higher voter turnout (Bechtel, 2012; Gendzwill, 2019; Schakel and Jeffery, 2013). Higher turnout can be observed in subnational governments with more regional authority than those that do not (Schakel and Jeffery, 2013). Just like the case of regional authority, an election immediately following municipal amalgamation might attract a lot of attention from the media. Media exposure increases the salience of the election. High salience, according to the "second-order election" thesis, would result in more mobilization efforts for voting that leads to higher turnout. One could then argue that turnout is higher in amalgamated municipalities since they are the ones affected by the reform, so the positive effect from this argument would be stronger in amalgamated municipalities.

Individual Explanations to amalgamation effects on turnout

In the divided literature on the amalgamation effects on turnout, scholars are generally interested in the *average effect* of municipal amalgamation on turnout. However, as discussed above, with multiple plausible reasons at work, it is quite difficult to separate and show the effect direction of municipal amalgamation. If all of the above mechanisms are at work, it is possible for these effects to cancel out. If they do not cancel out, then chances are the literature will continue to document both positive and negative effects. It is essential that we move the analytic scope down to the individual level and examine how individuals react to the implementation of the amalgamation reform.

One way to begin is to consider the local context of the amalgamation reforms, which has been so far overlooked in the literature. To understand why people turn out to vote following amalgamation reforms, we should first situate these individuals in the local context of each municipality. The local context of an amalgamation reform is highly contingent upon how the amalgamation decision was made. For example, a reform can be adopted 1) without consultations, 2) with consultations/consultative referendums but government went against the result, 3) or with consultations/ consultative referendums and the government followed the results. Perhaps the most non-legitimized amalgamation would be situation (1), followed by (2). If the local context is (3), then it is less of a non-legitimized amalgamation in process terms.

Candidate mechanisms

It does not follow that all upset voters would turn out to vote. As Downs (1957) suggests, voters can be rationally ignorant if they believe it is too costly to react to these local contexts. To overcome this cost consideration, the individual must have a very strong incentive that they attach to the vote. I will now discuss two candidate mechanisms which encourages voters to turn out to vote following a municipal amalgamation reform.

Voting to affirm local identity

In a non-legitimized amalgamation, the most eager ones to vote would be those who are highly attached to their old municipal structure. For people who are highly attached to a given local community, then they care very strongly about the local political outcomes (Dahl and Tufte, 1973: 42; Koch and Rochat, 2017; Swianiewicz, 2010). If people do not share a mutual conception of what the local community entails, that attachment could be weaker, thus there is less value to participate in the local affairs of that community.

The relationship between local attachment and voting is best understood under the framework of the postfunctionalist theory. A key proposition of this theory is that government can be two things to people – an instrument for the provision of public goods, and an expression of community (Hooghe and Marks, 2016). It is the latter notion that could provide a line of sight on an alternative mechanism: it is possible that municipal amalgamation challenges entrenched understandings of local identity. In this tradition, strong identity helps explain political participation at the subnational level. For example, subnational elections need not to be "second-order elections" if people have strong subnational identities. They will use subnational elections as an opportunity to express their attachment to the region (Paterson et al., 2001; Saarimaa and Tukiainen, 2016; Schakel and Jeffery, 2013: 5; Wyn Jones and Scully, 2006). Strong regional attachment could also enforce the regional elites' preference to strengthen regional competencies (Tatham and Bauer, 2020). These elites might be able to further mobilize the people to vote and legitimize their claim to regional competence, thus resulting in a positive feedback loop for higher voter turnout and support for decentralization.

Sometimes, municipal attachment has a very strong intrinsic value to its inhabitants. For example, an experiment asking people to offer a price tag on the names of their municipality found that a substantial

portion of inhabitants offered a high price to keep their old municipal name in face of amalgamation. This effect is the strongest when they have a strong attachment to the municipality (Soguel and Silberstein, 2015). Another piece looking at municipal amalgamations in Quebec found that just the municipal name per se is a source of contention in the course of amalgamation reforms (Adam, 2008). In this sense, changing municipal borders might present an existential challenge to that municipal attachment, particularly when the municipality is a smaller one subject to be "annexed" by a larger unit. For larger municipalities, increasing municipal sprawl might undermine the distinctiveness of their municipality too. As suggested by the literature, the expected response is that they will turn out to vote in hope to re-elect local representatives from the old municipality to the new municipal council. This behavior is well-documented in the amalgamation reforms in Denmark, Finland and Switzerland (Bhatti and Hansen, 2019; Koch and Rochat, 2017; Saarimaa and Tukiainen, 2016; Saint-Blancat and Friedberg, 2005). For these voters, safeguarding the representation of their old municipality is the reason why they turn out to vote (Hansen and Kjaer, 2020; Strebel and Schakel, 2021).

Following these arguments, municipality amalgamation threatens people's local identity. For those who are highly attached to their old municipality, they will be induced to turn out to vote to protect the representation of their old municipality in the new. This follows the logic of descriptive representation of the local (DRL). A key underlying assumption of DRL is that representatives from the local area will be a better representative than someone from outside (Aars and Ringkjøb, 2005; Childs and Cowley, 2011: 8; Evans et al., 2017; Jonhson and Rosenblatt, 2007: 168–9; Mansbridge, 1999). As Mansbridge (1999) put it:

Long-term residents in a town often argue for electing to office someone born in the town on the implicit grounds that lifetime experience increases the representative's common experiences with and attachment to the interests of the constituents... (Mansbridge, 1999: 629)

Indeed, recent literature has shown that people tend to favor "localness" of a politician. The main mechanism underneath is that voters use descriptive labels such as the birthplace and length of residence of a politician to infer whether they would act in the interests of the local community in question (Jonhson and Rosenblatt, 2007; Rosie Campbell, 2019). Once the amalgamations are over, people who are still highly attached to the

old locale might want to strive for the DRL of the old municipality since they believe those old representatives are the only ones that can best represent them. In other words:

H1. Under a non-legitimized amalgamation, the stronger the voter is attached to their pre-amalgamation municipality, the more likely they will vote following amalgamation.

Voting to hold local officials accountable

In addition, we would also expect those who follow an economic voting mindset to be critical of the non-legitimized nature of the reforms. Following the notion of "procedural democracy", citizens are expected to "have an adequate opportunity, and an equal opportunity, for expressing their preferences as to the final outcome" (Gordon, 2001: 25; Krouse, n.d.: 458–9). But if the elite suppresses information, or ignores those preferences expressed by the citizens, then this decision-making process is not a procedural democracy. If voters share this same view of democracy, then they expect themselves to be consulted, and such opinion must be reflected in the policy outcome.

When consulting the public about municipal amalgamation, the local elites might impose their preferences on the voters. For example, the elites might prefer amalgamation for better access to national or federal funding, pooling existing municipal resources, or providing services in a more efficient manner. The locals may prefer the status quo to protect their unique local identity, allocation of funds for specific local projects (e.g. maintaining schools with the local dialect/ language), and et cetera. In other cases, the elites may prefer no amalgamation whereas the citizens prefer amalgamation. Because the local elites do have better access to the political system, or even final say over the matter, they could go against the wishes of the masses. When this occurs, i.e. a reform is forced through, the local citizens might want to punish such politicians for failing the ideal of procedural democracy. Those who would want to punish local politicians by voting in the local election might go vote to punish local politicians who went against referendum results or did not launch any consultations in the first place.

This mechanism regarding local accountability is only valid as long as the attribution of responsibility is clear (Powell and Whitten, 1993). If the electorate can accurately pinpoint a particular level of government responsible for the reforms, then they can accurately punish them in the appropriate level of elections. In our

case of municipal amalgamations, if the reforms are solely carried out by the municipal council, then voting in the municipal elections to punish the incumbent makes sense. However, if the reform is a decision from a multi-level governance apparatus that various levels of government could be responsible for the outcome, then the attribution of responsibility can be clouded (León, 2012; León and Orriols, 2016; Pardos-Prado and Sagarzazu, 2019).

If the local government is wholly responsible for the amalgamation outcomes, then we should expect that:

H2. Under a non-legitimized amalgamation, the more the voter wants to reward or punish local politicians, the more likely they will vote following amalgamation.

In short, municipal amalgamation is unlikely to have a uniform effect across the entire electorate living in merged municipalities as there are mechanisms that both increase and decrease the incentive to vote. I argue that an increase in turnout is possible in a very specific local context, in the case where the municipal officials fail to follow the desires of citizens living in the old municipal structures. The increase also takes place for a specific subset of citizens, namely 1) those with a strong attachment to their local community; and/or 2) those who want to hold local elites accountable in an election. When all these conditions are met, then municipal amalgamation could encourage such voters to go out and vote.

These positive effects are mostly reactionary, and thus they are unlikely to continue following the second or third election. For those who have strong attachment to the old municipality, new party lists could claim to represent the old municipalities and thus address the concerns of these protest voters (Saarimaa and Tukiainen, 2016). With the old localities represented, the incentive to turn out to vote for these attached voters may wear out over time. For those who want to punish the local elites responsible for reform, there will be no one to punish if the old elites are out of the office. The change in the distribution of candidate party lists over time will also wear out the incentives to vote for these people.

Local Government reform in Norway, 2014-2020

In Norway, municipalities (kommuner) constitute the lowest tier of government. They are responsible for providing primary education up to tenth grade, outpatient health services, and unemployment benefits. They

are also responsible for zoning, local economic development, and the maintenance of municipal roads (Flo, 2003; Tranvik and Fimreite, 2007). Up to 98% of the primary and lower secondary schools (Up to 10th grade) are overseen by these municipalities. They are a substantial employer in these localities too. A 2011 report suggests that around 23.2% of the local populations are municipal employees (Bonesrønning, 2013).

The debate on municipal amalgamation first began with the 1992 Municipality Act. It aims to increase local autonomy by joining government structures at the municipal level. It is seen as a failure as municipalities were unwilling to merge (Tranvik and Fimreite, 2007). The difficulty is attributed to the use of block grants at the municipal level, so municipalities had very little incentive to lose autonomy due to the risk of funding loss. Reforms remained sluggish throughout the 1990s and the 2000s due to the difficulty of implementation (Swianiewicz, 2010).

In 2014, the Norwegian parliament initiated a new local government reform. On 1/1/2020, the number of municipalities was reduced from 428 to 356, and the number of counties (the middle-tier government) was halved from 19 to 11. According to the government, the new municipal structure aims to improve service delivery, coordinate community development, improve municipal finances and strengthen local democracy (The Government of Norway, 2019). The Norwegian News Agency (NTB) estimated nearly 1.7 million Norwegians would be affected by the reform (newsinenglish.no, 2020). After the reform, the median population of municipalities increased from around 3445 to 4715 (OECD, 2018).

The 356 new municipalities are created through voluntary mergers, subject to approval by the various municipal councils. At times these councils used local referendum to consult the local population, but a majority of these referendums resulted in a no-majority and thus it was up to the councils to decide the fate of the old municipality (Folkestad et al., 2021). This suggests that the responsibility of amalgamation outcomes lie solely at the hands of local politicians. Quite often the municipal electorate opted for no reform, then the municipal council decided to go ahead with the reforms anyway, resulting in non-legitimized amalgamations.

There are three reasons why Norway is well suited for this study. First, the Norwegian amalgamations were mostly voluntary. Unlike in other cases like Denmark, most amalgamations were the result of a complicated process of negotiations and Oslo's use of concessions (such as financial incentives, expert advice, and process

facilitation) (Klausen, 2017; Klausen et al., 2019). Most of these agreements of intention for mergers were non-binding, meaning that municipalities could back out anytime they want in the process. Because municipal councils were allowed to follow or go against the referendum results, we then have variations where some reforms are non-legitimized (i.e. council went against the referendum results) and some are legitimized (i.e. council followed the referendum results). Unlike the Danish case, the Norwegian case helps us understand the effect of the legitimacy of the reform.

Second, the Norwegian reform changed very little competencies of the municipalities. Unlike in other cases like Denmark where amalgamation was developed alongside further decentralization, the Norwegian case helps us isolate confounders from the change of local autonomy.

Third, the Norwegian reform spans two local elections: 2015 and 2019. The 2015 election used pre-amalgamation municipalities as constituencies yet the 2019 election used post-amalgamation municipalities even before the reform was complete. This creates a unique situation where the two elections can be perfectly separated into a pre-treatment (2015) and post-treatment (2019) election, which allows the identification of causal effects both at the municipal level and the individual level.

Does municipal amalgamation reduce voter turnout in local elections? A municipal-level analysis

Data

I first conduct a municipal-level analysis to identify the aggregate-level effect of municipal amalgamation in Norway. The purpose of this exercise is to show that the negative effect found in the literature also travels to Norway too, but individual-level positive effects can co-exist with such negative effects in the aggregate.

I put together a simple dataset of voter turnout rates in local elections. The unit of analysis is a municipality in their pre-reform boundaries. I follow the literature in using pre-amalgamation districts to determine changes to turnout level after mergers for the amalgamated municipalities (Lapointe et al., 2018; Saarimaa and Tukiainen, 2016). This is possible by deriving the turnout rates using district-level electoral results

published by the Norwegian government (Valg Direktoratet, 2022). The dependent variable is the voter turnout rates for 2015 and 2019. Voter turnout is defined as the ratio of votes casted to the number of eligible voters in a municipality.

Between 1992 and 2019, there are 7 municipalities that went through mergers before the 2014-2019 reform. In order to isolate the effect of the 2019 reform alone, I removed those 7 municipalities from the dataset. There is one municipality (Narvik) where the government did not report the population for 2015 and was dropped. 8 new municipalities did not provide district-level election data showing the turnout for the merged municipalities and thus have also been dropped.

The treatment variable is a dummy variable indicating whether the municipality is merged or not. The merger decision data is available from the Norwegian Mapping Authority (Kartverket). Because the merger has not yet taken place in 2020, this treatment essentially measures the announcement of a merger decision. Since the 2019 election uses post-amalgamation municipalities as constituencies, we can argue that the 2019 election thus assigns the announcement of the merger decision to citizens as they learn about their electoral districts.

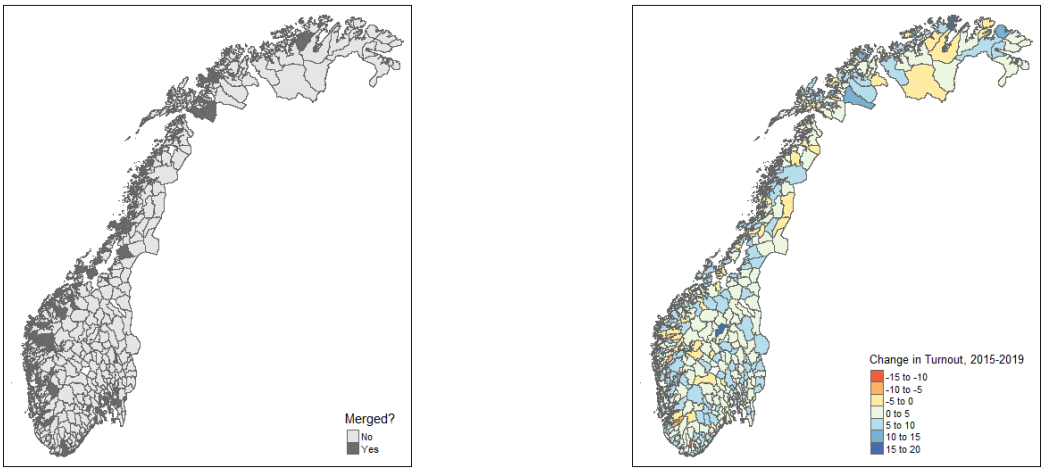

Figure 5: Amalgamated Municipalities and their change in voter turnout from 2015 to 2019.
Notes: The left panel shows the amalgamated municipalities highlighted in dark gray. The right panel shows the change in turnout from 2015 to 2019. Yellow/ Red fill denote a decrease in turnout in 2019, and Blue/ Dark Blue fill denote an increase in turnout. Municipalities that are split between multiple municipalities, and municipalities merged prior to 2015 were omitted from these maps.

Table 4: Descriptive Statistics of Municipal Characteristics

	Unamalgamated	Amalgamated
N	285	60
Turnout (2015)	62.811	62.308
Turnout (2019)	66.813	64.835
Population (2015)	11,256.130	39,114.180
pc. Population completed at most basic education (2015)	25.075	0.062
pc. Population completed at most upper secondary education (2015)	36.399	9.466
pc. Population completed at most higher education (2015)	18.706	5.032
pc. Labor votes received (2015)	31.769	28.201
pc. Center votes received (2015)	19.201	18.807
pc. Urban Population (2015)	52.204	14.980
pc. Population over 65 (2015)	19.113	4.550

Notes: Shown are the mean values of each of the variable, grouped by their amalgamation status.

All data are collected from Statistics Norway (SSB), in particular from the Municipality-State Reporting system (KOSTRA).

Figure 5 plots the municipalities that are amalgamated and the change in voter turnout. Tables 4 shows the municipal characteristics of the amalgamated and un-amalgamated municipalities.

Identification Strategy

I use the Difference-in-difference (DID) estimator to identify the causal effect of amalgamation (Bhatti and Hansen, 2019; Lassen and Serritzlew, 2011; Swianiewicz, 2018). The DID design is particularly suitable for the study of amalgamation reforms because some municipalities were amalgamated but some were not. The DID can be estimated as a typical linear regression model with the following form:

$$y_{i,t} = t + \delta_i \ + \delta_i * t \ + \gamma_i$$

Where $y_{i,t}$ is the turnout level of municipality i in year t. δ_i is a binary indicator indicating whether municipality i has been merged or not, t is a binary indicator that takes on a value of 1 if the election is after the merger (2019), and 0 if it is before (2015). The interaction $\delta_i * t$ is the DID estimand, and γ_i is the fixed effect for municipality i. Any time-invariant controls or controls that can be modified by the treatment should not be included in the DID estimation since they will be controlled for by γ_i.

For the DID design to work, the parallel trends assumption must hold. In this case, the parallel trends assumption appears to hold. Appendix C2 shows that pre-treatment trends for both the merged and unmerged municipalities were mostly parallel.

Results

Table 5 shows the results of the effects of municipal amalgamation on voter turnout in the 2019 Local Election in Norway. We see that the DID estimator is negative and significant, at β = -2.857***. The results suggest that amalgamated municipalities on average have a 1.476% lower voter turnout compared to the unamalamgated municipalities. This finding shows that the aggregate-level negative effect of municipal merger on local voter turnout travels well to the case of Norway too.

Tne result is robust to alternative explanations. First, it is an effect uniform to all kinds of amalgamations, be it a "strong treatment" or "sister municipalities" such as the case of a smaller municipality joining a larger one (Koch and Rochat, 2017; Lapointe et al., 2018; Saarimaa and Tukiainen, 2016), or the other way around.

Table 5: Aggregate-level Effects of Amalgamation on Local Voter Turnout in Norway, 2019

Term	Beta	SE	T-Statistic	P Value
Intercept	56.506	1.651	34.235	0***
Amalgamated	1.480	2.342	0.632	0.528
2019	4.003	0.195	20.505	0***
Amalgamated*2019	-1.476	0.468	-3.154	0.002**

Notes: Shown are the beta estimates and their standard errors of a 2-way Fixed Effects model with municipal-level fixed effects estimating the DID. The municipal-level fixed effects coefficients were not shown for the sake of simplicity.

Koch & Rochat (2017) argue that the information cost to learn about new candidates is higher in these municipalities. In Appendix C4, I show that being a sister municipality has no statistically significant effect on the change in voter turnout.

I have also checked against the possibility of any placebo effects. In Appendix C5, I fitted two models - a dynamic DID model to test the effect of DID in years before 2019, and a standard placebo test regressing the turnout levels in each year to see amalgamation is correlated with other years of turnout. The analysis shows that the amalgamations (occurred between 2015-2019) are uncorrelated with turnout levels of prior years.

With the uniform negative effect replicated in the case of Norway as well, could we find traces of positive effects? Particularly, as we dive deeper in the individual-level calculus for voting?

How Does municipal amalgamation reduce voter turnout in local elections? An individual-level analysis

Data

To directly test H1 and H2, I conduct an individual-level analysis using data from the Norwegian Citizen Panel (NCP). The aim is to test two candidate mechanisms: That the effect of non-legitimized reform is mediated by 1) the voter's strong local attachment to their old municipality; and/or 2) the voter's interest in holding local officials accountable. The NCP is an online-based panel survey conducted twice a year. Since the 2019 election took place in September 2019, I used the NCP wave 16 data which is conducted immediately following the election from October to November 2019.

Dependent Variable

The dependent variable is the respondent's self report of whether they voted in the local elections in September 2019. I code this variable from a question asking about respondents which party or list they might vote for in the upcoming local election. Two options indicate non-voting: "I will not vote" and "I am not eligible". I code the "I will not vote" responses as 0 and "I am not eligible" responses as NA. For all the other party vote choices I code them as 1. Under this strategy, 11530 (89.8%) of the respondents said that they voted in the 2019 election.

Independent Variables

Treatment Variables

To test H1 and H2, I use the same set of treatment variable. The main independent variable of interest is a dichotomous variable that called "Non-legitimized Amalgamations". This occurs when the voter reports that they are living in a municipality that is going to be merged *and* that they are opposed to the municipal reforms.

Mediators

Second, I include two independent variable of interests to test H1 and H2 respectively. To test H1, I include a variable that asks the respondent's attachment to their old municipality. The question asks people to gauge their attachment to the municipality they are currently living in. Because no municipalities will be officially merged until 2020, it seems reasonable to infer that the data indicate people's attachment to their old municipality. After recoding, this variable takes on a 1-5 scale, where 1 indicates no attachment and 5 indicates very strong attachment.

For H2, I include a variable asking people to rate their importance to reward or punish local politicians when voting. After recoding, this variable takes on a 1-5 scale, where 1 indicates no importance to rewarding/punishing local elites and 5 indicates that this consideration is very important to the voter.

Figure 6 plots the distribution of these two independent variables in the sample.

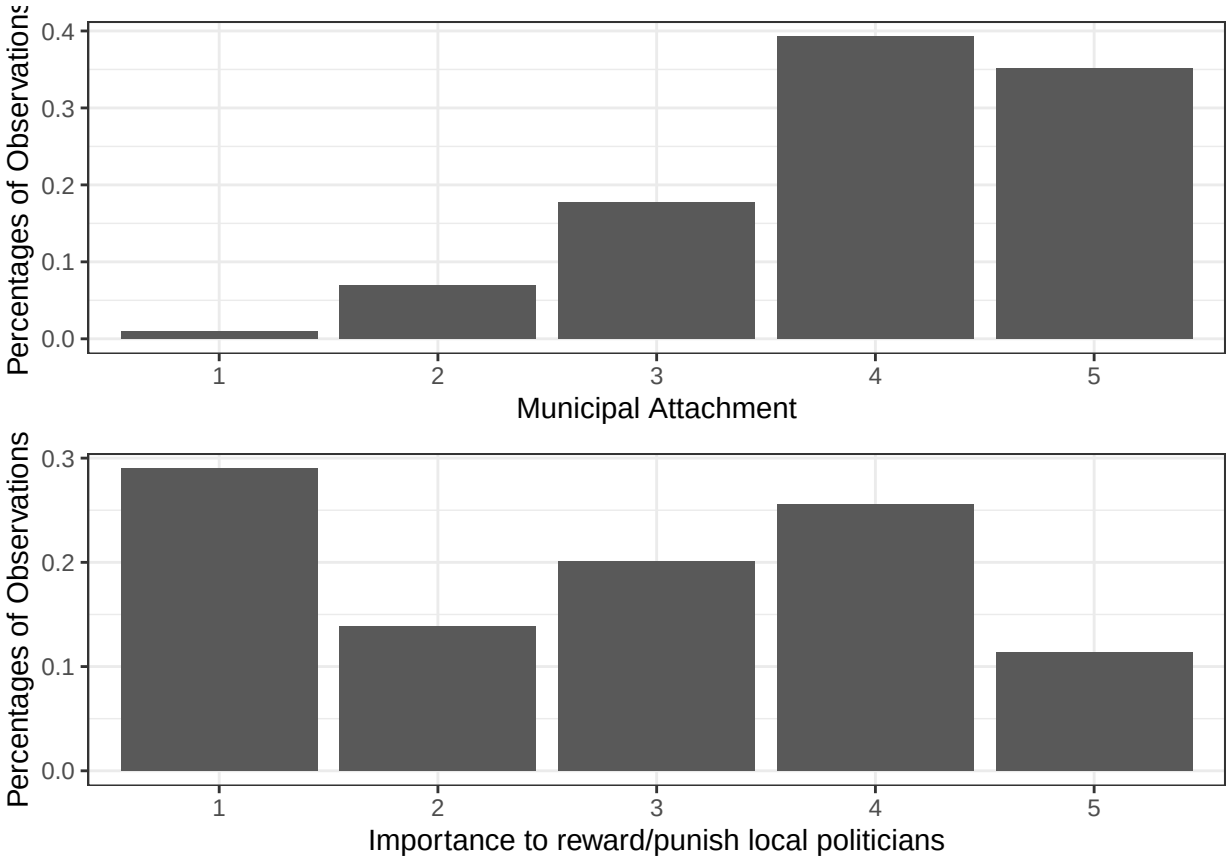

Figure 6: Distribution of the Independent Variables

Notes: Upper panel shows the distribution of the municipal attachment variable, where 1= Felt very distant to the old municipality, and 5= Felt very close to the old municipality. N= 914. Bottom panel shows the distribution of the respondents claiming that the importance to reward/punish local politcians when they vote in a local election, where 1= Very unimportant and 5= very important. N=914.

Control Variables

I control for four kinds of variables. First, I included a dichotomous variable indicating if the respondent is living in a municipality to be amalgamated. Controlling for the amalgamation assignment is important as it shows that the causal effect occurs independently of the amalgamation assignment per se. If the causal effect is statistically significant but the treatment assignment is not, then it reinforces the argument that we should not expect to see an average effect on the treated, but rather focus on what kind of voters would be more likely to vote given their specific local context.

Second, I control for the popular alternative explanation as per Lassen & Serritzlew (2011), namely that it is the internal political efficacy that might reduce voters' incentive to participate in local elections. I include two variables in this group: their perceived political efficacy, in the form of whether they find the political

system in Norway gives them a say in what the government does; Second, I include a variable controlling for whether people find politics too complicated to follow. For those who have low political efficacy and find politics hard to understand, there will be less incentive to vote (Bhatti and Hansen, 2019; Dahl and Tufte, 1973: 13; Lassen and Serritzlew, 2011).

Second, I control for a group of common reasons to go vote. I control for those who say that they go vote because it is their civic duty, those who want to influence municipal politics by voting, those who want to reward or punish national politicians, and those who want to safeguard municipal interests of their old municipality. These are all legitimate reasons to go vote, and I believe that those who find these reasons important in their voting calculus would be more likely to go vote.

Third, I control for the perceived salience of the amalgamation reforms in the 2019 local elections. The "Second-Order Elections" literature suggest when a particular issue is highly salient, then the turnout in that election is likely to be higher (Bechtel, 2012; Gendzwill, 2019; Schakel and Jeffery, 2013). If this is true, then the respondent would be more likely to go vote if they find amalgamation reforms highly salient in the 2019 election.

Finally, I include demographic controls. I control for the respondent's gender, education level as well as age. I have no expectation about the causal effect of gender and age. I expect the higher the education of a respondent, the more likely they will go vote.

Identification Strategy

This study is a mediation analysis. The goal of mediation analysis is to find out the mediation effect among the treated units, namely the Average Conditional Mediation Effect (ACME). In the potential outcomes framework with treatment t and mediator M_i, the ACME is defined as:

$$\delta_i(t) = Y_i(t, M_i(1)) - Y_i(t, M_i(0))$$

With the mechanism candidates as the mediator and the opposition to reform as the treatment, I recovered

the ACMEs using the `mediation` package in `R`. The ACME point estimates and their standard errors are recovered from 1000 bootstrapped samples of the dataset.

The treatment assignment (individual's opposition to reforms) is unlikely to be random. Therefore, I matched respondents with covariate balancing propensity scores to simulate the controlled experiment design. After matching, I have recovered 457 respondents in both the control and treated groups. The matching results can be found in Appendix D3.

Causal mediation analysis assumes sequential ignorability (SI) (Imai and Keele, 2010; Imai et al., 2010). The SI assumption consists of two parts. The first assumes that the treatment assignment is orthogonal to the expected outcome $Y_i(t, M_i)$ and the mediator $M_i(t)$. This is usually fulfilled by randomizing the treatment assignment (Imai and Keele, 2010: 312). While randomized assignment was not possible with survey data, the propensity score matching exercise does help us to get as close as possible to randomized treatment assignment by finding pairs of respondents with close demographic features. The second part assumes that the expected outcome is also orthogonal to the mediator, and that would require X_i to include all pre-treatment and post-treatment confounders which is difficult to uphold. The SI is usually very strong and researchers tend to visualize how sensitive the results are to the deviation from the SI instead of testing for the assumption directly. Appendix D5 shows the results of this sensitivity analysis on the model testing H2 (local accountability). The resulting plot shows that as the sensitivity parameter $\rho \approx -0.15$, the ACME for the treated group will cross zero and become a null effect. This suggests that the findings are sensitive to the violation of the SI assumption if the errors of the two segments of the structural equation model become negatively correlated, but the results will be robust as long as the errors are positively correlated.

Results

Figure 7 shows the recovered ACMEs from the mediation analysis using two different methods of bootstrapping. The left panel shows the ACME for sense of community, and the right panel shows the ACME for the importance of holding local politicians when voting. The full regression table can be found in Appendix D4.

From figure 7 we see that the ACME for the sense of community is not statistically significant and not in

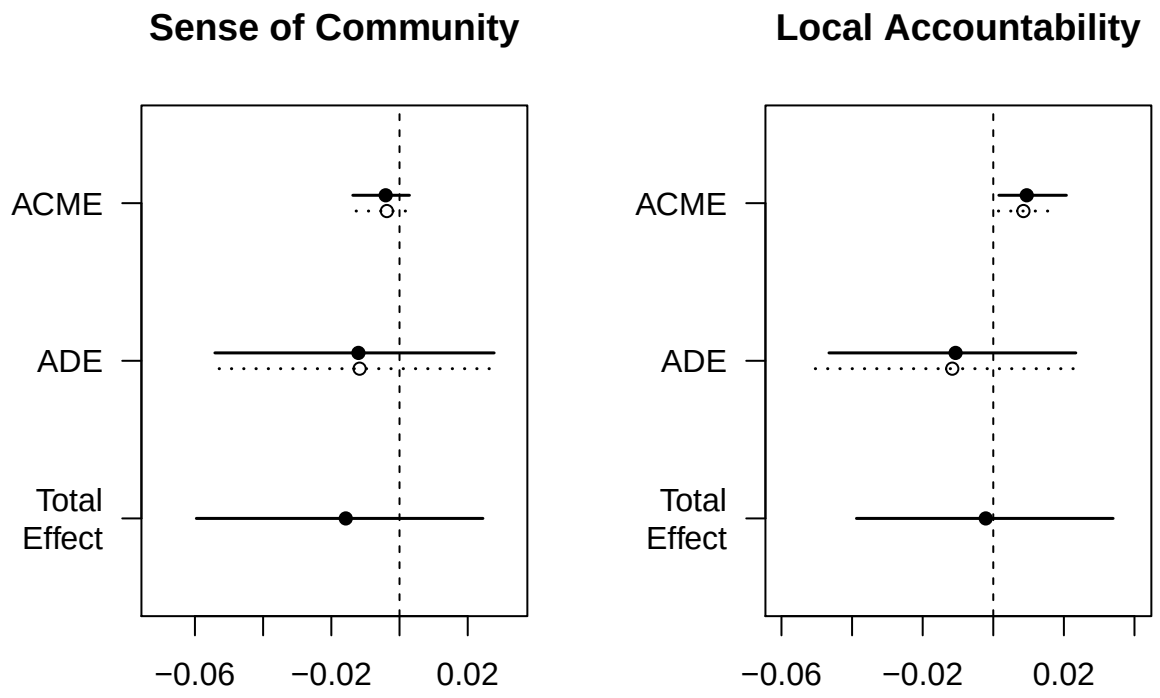

Figure 7: Mediating Effects of Sense of Community and Holding local politicians accountable
Notes: The solid dot indicates the mean point estimate of the effect, the horizontal line indicates the 95% confidence interval recovered using bootstrapping. The hollow dot and the dotted line show the mean point estimate and the 95% bias-corrected and accelerated (BCa) intervals. N=849 for the estimated ordred logistic models.

the expected direction. There is not enough evidence to determine if having a stronger sense of community would mediate the effects of being opposed to the reform to voting. However, the direct effect of municipal attachment on the probability of voting is significant, b= 0.438***. This seems to suggest that voters who have a strong local attachment will vote regardless of the outcomes and nature of the municipal amalgamation reform. Therefore, H1 is not supported.

For H2, there is a statistically significant positive effect for holding local politicians accountable. The ACME across the treated and control respondents is 0.009 (p= 0.01**). Because the dependent variable is dichotomous, the ACME could be interpreted as odds ratio. On a scale of 1-5, if respondents give 1 score higher to the importance of holding local politicians accountable, then the person's odds of voting in the local election increases by a factor of 1.009. Therefore, there is support for H2.

However, note that there is a small negative albeit insignificant effect on the average direct effect (ADE) of being opposed to the reform to voting. If this was true, this would suggest that people who are opposed to the reform would still not turn out to vote if they do not find holding local officials accountable as an important reason for voting. Because the ACME and ADE are in opposing direction as they are given the data, the total effect hovers around 0. Nonetheless, this exercise shows that people are more inclined to vote in the 2019 local election if they are opposed to the reform, and they think that by voting they can hold local politicians accountable.

It is important to note that the amalgamation assignment variable alone is not significant in both the mediating and outcome models when I tested H2 (b= 0.102, n.s.) This suggests that the mediation effect uncovered here is a better explanation that amalgamation outcomes per se.

Some other variables in the model also have a significant effect. Those who assign 1 point higher to the importance of civic duty in voting will be 1.775 times more likely to vote. Similarly, those who give 1 point higher to the importance of influencing municipal politics will be 1.827 times more likely to vote. Those who think that it is their duty to vote would be 1.775 times more likely to vote. Some people use the local election as a way to participate in national politics. Those who assign 1 point higher to the importance of holding national politicians are 1.304 times more likely to vote. Finally, people who have completed some form of higher education are 2.503 times more likely to vote.

Alternative Explanations

How robust are the findings reported here? We can examine the robustness of the findings vis-a-vis three alternative explanations discussed in the literature.

First, let us examine the plausibility of the internal political efficacy (IPE) argument (Hansen, 2013, 2015; Lassen and Serritzlew, 2011). The IPE argument goes, municipal amalgamation reduces one's IPE, thus leading to feelings of distance and alienation from the new municipal government. This in turn reduces political participation and inhabitant satisfaction of municipal services following municipal amalgamation. The IPE literature does not address the issue of voter turnout decrease directly, yet it is plausible that voters

don't want to go to the voting booth if they think that their vote does not matter anymore.

I recovered the ACME of IPE vis-a-vis that of municipal attachment simultaneously in an alternative model. I operationalized IPE as political efficacy, namely whether the person believes that they have a say in Norwegian politics. The results can be found in Appendix D7. The resultant ACME is negative and not significant, but in the final model IPE has a positive and significant relationship with the probability of voting. This suggests that there is indeed a positive relationship between IPE and voting, but it is unclear if the effect is a causal one given that the ACME is not significant and negative.

Second, we need to examine whether it is municipal size that is driving the results. After all amalgamation changes not only municipal borders but also municipal size. Quite often it is the very small municipalities that are being merged such that they could take advantage of the economies of scale in a larger administrative unit (Swianiewicz, 2010, 2018). Since municipal size affects the chance of making a difference by voting (the p term in the Riker-Ordershook model), larger municipalities may see a lower turnout rate.

In Appendix D8, I used size as the mediator in the same analysis. The results show that municipal size has no statistically significant ACME. However, there is a significant negative effect, $\beta = -.21, p = .09+$ on the probability of voting. Consistent with the literature, municipality size seems to have a negative association with people's incentive to vote, but there is no evidence to show that this effect is a causal one.

Last but not least, a reasonable doubt would be that territorial patterns of turnout might be driving the results. After all, in Norway the reforms were highly unpopular whereas in cities are welcoming these reforms to incorporate more surrounding towns and villages into their city limits. In addition, the survey data is theoretically hierarchical, where individuals are nested within counties (regions). To address this, I examine the intraclass correlation coefficient (ICC) of county on the probability of voting. The resulting coefficient is only 0.019. In other words, only 1.9% of the total variance in the dependent variable is explained by county. Given how small the ICC is for county, I can conclude that the regional patterns are not that important for explaining an individual's probability to vote in the model.

Discussion

This paper makes four contributions to the literature. First, this paper gives a case why scholars have not been able to agree on the effect direction of amalgamation reform on turnout. In the Norwegian case, we have recovered a negative effect of municipal amalgamation over turnout in the aggregate. As scholars focus on specific country cases and specific elections, we then have documented cases of both an increase and decrease in the literature. However, as the individual-level results show, this may change contingent on voters' underlying reason to go vote. Therefore, I argue that the literature may wish to move on from seeking an average effect of municipal amalgamation across all treated units to seeking an effect of municipal amalgamation on specific local contexts and for specific kinds of voters.

Second, with the individual-level analysis, this paper presents two candidate mechanisms as to why voter turnout would actually be higher following amalgamation even though the effect in the aggregate is negative. This is a two-part mechanism: First, one must consider the local context. When the reform is being pushed through without support from the local populace, then voters might react to this non-legitimized nature of the reform by voting. Second, the underlying mechanism depends on how the voter perceives the purpose of voting. Since a non-legitimized reform fails the notion of procedural democracy (Bailey and Braybrooke, 2003: 108–9; Krouse, n.d.: 458–9), if citizens attach a high value in holding these local elites accountable, then turnout can indeed be higher as people go to the voting station to express their grievances of the reform. This protest voting mechanism is in line with Strebel & Schakel (2021), which suggest that people subject to non-legitimized reform will be more likely to vote for the opposition. The findings further speak to the importance of the notion of procedural democracy, that the citizens care about the influence of their preferences on a binding decision, which is part of the "enlightened understanding" criterion of Dahl's definition of procedural democracy (Krouse, n.d.: 458–9).

The protest voting mechanism connects quite well with my other finding, that is a higher IPE remains a reason as to why turnout can increase (Hansen, 2013, 2015; Lassen and Serritzlew, 2011). While there is no evidence showing that the effect of IPE is a causal one on voting, the notion of IPE transfers well to the context of political participation. People will still participate in local politics so long as they believe they have

a say in public affairs. Only when people believe they have a say on these matters, would protest voting make sense. This goes back to the classical Riker-Ordershook model, where the perceived capability of one's vote making a difference is the most importance motivation behind why people go vote. While a non-legitimized amalgamation reform could harm some of people's IPE, so long as they believe in the opportunities provided by the entire political system, they would believe that their vote can indeed voice out their frustration with the reform. Eventually, these people with high IPE would be able to make use of the 2019 local election to punish the local politicians, which given Norway's context, are the ones solely responsible for deciding the fate of the old municipalities.

Third, the paper highlights the importance of local context when considering amalgamation reforms. Whereas previous research has mostly neglected the peculiarites of local context, this paper attemps to quantify the local context surrounding the election being studied. In Norway, the key difference in local contexts is how the public is consulted (Folkestad et al., 2021). A lot of public disapproval occurs from the fact that the municipal council sometimes can go against the referendum results, and thus why the protest voting mechanism makes sense.

Another reason that protest voting works is that the responsibility of the reform is very clear in the case of Norway, namely municipal governments. In other reforms where the decision to amalgamations is arrived after deliberation of multiple levels of government, then voters might have a difficult time attributing the responsibility to a particular level of government (Arceneaux and Stein, 2006; Powell and Whitten, 1993). An example of a reform that is hard to attribute responsibility to is the municipal amalgamations in Ontario, Canada. Municipal amalgamation in Ontario requires the approval from the so-called "Triple Majority" - majority approval from the two municipalities affected and the county council (Miljan and Spicer, 2015: 5). This makes the attribution of responsibility much more difficult than the case of Norway.

Fourth, the results sheds light on the how local identities can shape political behavior (Hooghe and Marks, 2016). Local identity has a role to play in understanding how municipal amalgamations change people's voting behavior, but in a rather subtle way. In the paper, municipal attachment per se does not have a statistically significant ACME, but it does have a positive and significant direct effect on voter turnout in

local elections. What this might suggest is there is a strong association between local identity and local voting, but the causality is unclear. From my findings, it is at least clear that the effects of a non-legitimized reform is not mediated by the strength of local identity. It is particularly interesting that voters who are highly attached to their old municipality are not necessarily keen on holding these officials accountable, as the coefficient for municipal attachment on the propensity to hold local officials accountable is closing in to zero and not significant. A possible explanation for this situation is that voters who are highly attached to their municipalities are already set on voting regardless of the amalgamation outcomes, and thus the amalgamations have no bearing on their propensity of voting. This resonates well with recent findings that there is a center-periphery dimension of public trust where the rural population tend to trust the national politicians less and local politicians more (Stein et al., 2021). The implications of this finding is that people with a strong local identity will go to vote but that has very little to do with municipal amalgamations.

Finally, this brings us to the last contribution of this paper to the general literature on voter turnout. It once again reaffirms the turnout literature that people go vote because of the change in the perceived benefit voting would add at the collective level (Franklin, 2004; Green and Shaprio, 1994). Municipal amalgamation poses an existential threat to one's municipality, so when the group-level benefit is under threat, then voters have a higher incentive to turn out to vote. From the support to H2, we can argue that local voters respond to this threat by punishing the local politicians responsible for threatening the old municipal structure.

While this Norwegian story sheds light on the underlying causal effects and mechanism of municipal amalgamation on political participation, how well does the story travel? Note that the Norwegian case is a less-likely case: When the average turnout is as high as 64.8% in 2019, there is very little room for further increase. If such an increase can be identified in a hard case like Norway, then it should also be identified in other more-likely cases outside of Norway. This should apply to most of the OECD countries that have completed amalgamation reforms.

This paper has several limitations that can be addressed in future research. In particular, at the individual-level only a self-reported measure of voting is available. Over-reporting remains a common problem in political science survey which could lead to biased estimates of causal effects. However, notice that any increase in

turnout can be difficult to identify when the sample is more likely to go vote than the population. Still, future research must employ strategy a to validate voter record and adjust for any over-reporting.

Second, in future research we might want to test if the positive effect persists over time. According to the literature, turnout increase lingers over long periods of time (Bhatti and Hansen, 2019; Koch and Rochat, 2017; Kraaykamp et al., 2001), and it remains to be tested if the Norwegian case follows this trajectory or not.

Finally, this paper has not been able to examine the effect of other identities. It could very well be that people with strong local identities will also have strong regional identities, and thus the type of identity may not matter as much. It remains to be tested in future research whether the type of identity could play a role in determining people's propensity to vote.

Conclusion

Exploiting a unique situation in Norway between two local elections in 2015 and 2019, this paper finds that municipal amalgamations can increase voter turnout under the logic of protest voting. I showed that it is difficult and unreasonable to uncover an average effect of municipal amalgamation on turnout, and we should move the analytical scope to the individual level. I identify a possible mechanism that could lead to higher turnout: When the voter is opposed to the amalgamation reform and they want to hold the local politicians accountable for forcing through the reform, then they are more likely to turn out to vote. Immediately following non-legitimized amalgamations like those in Denmark, people are more likely to go vote as a form of protest voting (Bhatti and Hansen, 2019).

This paper contributes to the literature by showing a possibility where municipal amalgamation could increase voter turnout. To understand how this is possible, one must take into account the local context of the referendum. The sudden increase in turn out come mainly from people unsatisfied with the amalgamation reforms, and are looking for a way to react to the existential threat to their locality (Bhatti and Hansen, 2019; Hansen and Kjaer, 2020; Strebel and Schakel, 2021).

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Satellite Index of Development: A novel method to measure subnational development with daytime satellite images

Introduction: Measuring development below the national level

Political Science and Political Economy have a wide variety of measures on economic development and development inequality at the national level. Sometimes, researchers may want to make an argument about economic development below the national level, but there is a chronic lack of subnational-level measures on economic development and intraregional inequality.

There has been some scholarly interest in measuring economic development below the national level. Traditionally, governments would survey the locality to assess their levels of economic development at a fixed interval, but surveying through fieldwork is very expensive. Other efforts have been made to produce proxy measures at limited cost. For example, the PRIO-GRID project has embarked on a task of measuring economic development beyond national boundaries, whereas economists have been using nightlights as a proxy for economic development for a long time. Others have turned to mathematical models that compute the share of national economy by each geographical constituents in a state. Each of these methods have their own merits and faults, but a critical problem remains that they are only available for limited geographical locations, limited scale and limited time period.

To resolve this data availability problem, I propose a machine learning model that takes satellite images as input to generate an estimate of economic development in a region of interest (ROI) and time period specified by the researcher. The fitted model takes a 6-band satellite image data as input and will be able to produce an estimate of the level of development for the entire image. The machine learning model automates the process of manually computing economic development in new ROIs and new scales (e.g. cities and counties), providing researchers with a rapid way of measuring economic development given time and resource constraints.

The model is also able to produce estimates with moderate levels of applied relevance. By applying the model to produce estimates of city-level GDP, I show that the model estimates are robustly correlated with existing data, thus providing researchers with confidence of the internal validity of the measures. I then use these applied estimates to investigate one of the long-standing research questions in the literature of political decentralization: To what extent does regional authority reduce intra-regional inequality within regions. With the data availability problem resolved using my model estimates, I show that self-rule authority may reduce intraregional inequality at higher levels of economic development, corroborating the literature on the reductive effects of regional authority over intra-regional inequality (Lessmann, 2009, 2012).

This paper is divided into 5 sections. The first reviews the literature on the measurement of economic development below the national level, the second introduces the machine learning model, the third reports the model performance, the fourth introduces the applied case of explaining intra-regional inequality as a function of regional authority in metropolitan areas, and the fifth concludes.

Measuring Economic Development Below the National Level

Existing Approaches

Data availability is not a new problem when it comes to studying economic development below the national level. At the national level, international organizations such as the World Bank produces readily available measures to allow researchers compare GDP across countries, but data becomes increasingly scarce once we move down below the national level. To address this problem, scholars have started to utilize geo-located data to produce these measures. Geo-located data provide higher resolution, thus allowing the measurement

of economic development below the national level.

The first attempt to get a local-level measure is the G-ECON project and the Gross Cell Product (GCP) measure. The project divides the entire surface area of the earth into 1-degree longitude by 1-degree latitude grid cells, and estimates the GDP levels for all such cells for every 5 years in the interval of 1990-2005 (Nordhaus et al., 2006). The G-ECON project is a first attempt and thus the measure is rather coarse. The resolution can be roughly translated to around 100 km^2 cells, which is too large for building measures at the county, local or city level. The data is also limited by its rather short interval from 1990-2005 and it is no longer updated after 2005.

The PRIO-GRID dataset is a major improvement over G-ECON because it provides higher resolution grid cells. The project aims to standardize the use of grid cell GIS data by dividing the earth surface into roughly 50*50 km cells (Tollefsen et al., 2012: 367). These equally-sized and reasonably high resolution grids could help measure economic development below the national level. The PRIO-GRID data also comes shipped with 1990 estimates of GDP, primarily based on the GCP estimates from G-ECON. The PRIO-GRID dataset has been used by political scientists to measure local economic development. For example, Pierskalla et al. (2017) treats each grid as an individual unit of observation and fits a regression model explaining economic development at the grid-level. Scholars have also used the dataset to estimate other quantities relevant in Political Science, as well as subnational terrorism (Nemeth et al., 2014) and political violence (Vestby et al., 2022).

The PRIO-GRID data has two limitations that can hinder subnational political economy research: First, it is scale-static at the grid-level. This is by design since the dataset aims to standardize grid cell data, so the data aggregates 50*50km areas and will not go below further. This is limiting when studying certain smaller regions of interest (ROI). For example, the city of Bratislava is difficult to measure using this dataset, because the small capital city has only a metropolitan area of 2,053 km^2. Its downtown area is only 367.584 km^2, at which a 2500 km^2 PRIO-GRID cell fully encapsulates. This makes demarcating the city area and its surrounding regions a daunting task using such data. Second, its refresh cadence is limited to every 5 years, which makes it difficult to study temporal trends in the data.

Alternatively, economists and political scientists have turned to nightlights data. Nightlights data is an established proxy to economic development as it has been argued that only more developed areas are able to afford turning on the lights at night (Chen and Nordhaus, 2011; Michalopoulos and Papaioannou, 2013; Nordhaus and Chen, 2015; Pierskalla et al., 2017). Nightlights measures of development have also been known to be more accurate than official development statistics in the developing world (Nordhaus and Chen, 2015). In Political Science, nightlights data have also been used to measure public goods provision and regional government governing capacity (Daxecker and Prins, 2021; Pierskalla et al., 2017). Nightlights data is readily available from two sources: the US Air Force Defense Meteorological Satellite Program (DMSP), and they come in the form of a time series for 1992-2014. After 2014, there is the Visible and Infrared Imaging Suite (VIIRS) suite that provides yearly snapshots of nightlights data in the world. Attempts have been made among researchers to harmonize the discontinuity in the dataset after 2014 (Li et al., 2020).

While certainly nightlights data is accepted as a reasonable proxy to development across fields, there remains two problems with the use of nightlights data. First, the literature is well aware of the "bottom-coding" problem when using nightlights data. The "bottom-coding" problem refers to the inaccuracy of measuring less developed regions when the nightlight intensity is weak. Once below a certain threshold, the satellite sensor would no longer be able to pick up dim nightlights, and thus coding these less developed areas as completely undeveloped (Chen and Nordhaus, 2011). Second, developed countries are introducing regulations that limit the use of nightlights. The main use of turning the nightlights off is to protect migrating birds at night as birds often crash into buildings that are lit up at night. This practice is slowly taking up among European and American localities. For example, some 12000 communes in France have fully or partially switched off public lighting at night (ANPCEN, 2015). In 2022, Berlin has switched off spotlights illuminating 200 of its historic buildings and monuments (Menzel, 2022). Similar policies are also in place in Austria, Germany, Spain and Italy (Salger, 2022; Südtirol News, 2022; Woodti, 2022). In the United States, 12 states have state-level programs to switch off nightlights, and many more localities have adopted their own (Audubon, n.d.). As "Lights Out" programs like these become more popular in the developed world, nightlights may not be the most appropriate proxy since the highly developed Western economies are turning off their nightlights en masse.

In conclusion, there have been efforts to measure economic development below the national level. However, they all suffer from three pitfalls. First, they do not support a flexible scale. G-ECON and PRIO-GRID provides data at a fixed scale of 1-degree longitude * 1-degree latitude and 0.5-degree longitude * 0.5-degree latitude cells respectively. Second, it can be difficult to get the latest measure since these datasets have fixed temporal interval available. G-ECON is limited to an interval of 1990-2005 for every 5 years. To use the nightlights dataset beyond 2014, the researcher would have to somehow harmonize the DMSP and VIIRS datasets. Last but not least, the nightlights data, while being a vastly superior improvement over gridded data, can potentially suffer from regulatory risk as the developed world aims to turn off nightlights in the future. In the future, the internal validity of nightlights as a proxy to development may decrease as more developed countries follow suit to introduce legislation that limits nightlights. We need an alternative that is able to be 1) scale-agnostic, 2) readily available over reasonable timeframes and 3) free from regulatory risks that the nightlights data is suffering.

Measuring Economic Development using Daytime Satellite Images

To address these limitations in the existing approach, I train a neural network to help construct a numeric index from daytime satellite images. Daytime Satellite images are increasingly easy to come by. They can serve as an efficient and cheap alternative to estimating economic development on the ground where fieldwork or surveying methods are expensive. Modern satellite images also include multiple spectral bands beyond red, green, and blue color channels. These extra channels have been used to compute remote sensing indices to measure vegetation, waterbodies and heat on the surface.

The satellite image approach has several advantages over the existing PRIO-GRID and nightlights measures. First, the model is scale-agnostic. Because the researcher can choose their ROI of their choice, the researcher can acquire predictions at different scales at ease: be it the street-level, commune-level, city-level, or region-level. Second, the model allows the construction of high-resolution time series predictions. These satellite image collections have a monthly refresh cadence, so it is possible to acquire monthly predictions for the same area. Using the machine learning model that I am constructing, it is also possible to extend the study period from 1972-2022, far longer than any of the existing implementations discussed.

There has been an emerging literature about the use of daytime satellite images in measuring economic development. For example, Goldblatt et al. (2018) uses a variety of remote sensing indices captured in satellite images to generate predictions about nightlights luminosity as a proxy for urbanization. They constructed a classifier that takes satellite images as input, extract the remote sensing features and generate a 30m*30m ROI for the probability that an area is built-up (defined as 50% or greater of the area is paved by human-made structures). Ackermann et al. (2020) restricts their model to include only daytime satellite images to detect man-made structures shown by satellite images. Engstrom et al. (2017) uses a mix of daytime satellite images and survey data to estimate the poverty rate of 3,500 km^2 subnational areas in Sri Lanka. Similar to economic development, researchers have used image models to predict related measures such as levels of poverty (Pandey et al., 2018) or electricity usage (Robinson et al., 2017). Most of these models are interested in object detection or land use classification, and thus it is less clear how these model outputs can be transformed to be used as an numeric estimate of economic development to be used in statisical analysis. The model I am proposing thus aims to produce one single numeric measure for each city in each year, thus they can be easily be plugged in typical statistical models for quantitative analysis.

Urbanization and Development

Rather than estimating economic development directly, the information derived from a satellite image measures urbanization. Therefore, this proposed model uses urbanization as a proxy to economic development. Urbanization is defined as "a process which reveals itself through temporal, spatial and sectoral changes in the demographic, social, economic, technology and environment aspects of life in a given society. Urbanization is a progressive concentration of population in urban units" (Davis, 1965). As part of the population migration to urban areas, urbanization also captures the change from a rural lifestyle to an urban one (Chen et al., 2014: 2). As urbanization accelerates, there will be advancement in urban technologies. For example, prior to the industrial revolution, roads are paved for horse carriages for faster movement of urban populations. Industrial Revolutions then brought innovations of railways, motorways that have reduced transportation costs for both people and goods (Jedwab and Vollrath, 2015: 16). For example, given walking speed, traditional cities were limited to about 20 km^2 in size prior to the industrial revolution. The advancement of horse carriages,

railways and roads rapidly expanded the limits of the city. The invention of cheap steel and the elevator has also allowed the construction of high-rises that further increased the concentration of business activities in the city (Bairoch, 1988; Glaser, 2011). Therefore, what the satellite images are showing are actually urban technologies such as highways, roads and buildings that are demarcated from rural areas, bushes, and the like.

Because satellite images are showing urbanization, it does not necessarily equate economic development. However, in the literature regarding urbanization and growth, scholars have found a strong, consistent positive correlation regardless of countries and years (Bairoch, 1988; Chenery and Taylor, 1968; Chen et al., 2014; Henderson, 2003; Jedwab and Vollrath, 2015; Kuznets, 1968). Some scholars challenge this relationship by raising examples of "Urbanization without Growth" in the developing world (Fay and Opal, 2000). But as Jedwab and Vollrath (2015) demonstrate, "urbanization without growth" does not necessary debunk the relationship between urbanization and economic growth. The main argument here is that urbanization increases agglomeration of people, goods and capital. It allows countries to save on the transportation costs of people, goods and ideas. This agglomeration effect is the main effect that drives the increase in productivity. The agglomeration effect is further magnified by the advancement in urban technologies, such as roads, highways and railways that are captured in the satellite images.In other words, the satellite images are indeed plausibly capturing the growth factors as part of urbanization.

What the satellite images are not capturing are the rural-to-urban migratory patterns that is part of the urbanization process. People can be encouraged to relocate to cities with urban bias policies. Examples of urban bias policies include food subsidies for urban residents, designating a new administrative center away from existing cities, increasing public employment in the manufacturing and service sector, agricultural overtaxation, and et cetera. These urban-bias policies would create urban primacy, namely that people are attracted to urban areas with no direct relationship to the city's economic growth (Chen et al., 2014: 1; Jedwab and Vollrath, 2015: 16; Moomaw and Shatter, 1993, 1996). Fortunately, the satellite images do not capture these artificial indicators of urbanization that are not related to development. In this sense, the limitation of satellite images is turned into an advantage by filtering out elements that are not related to development, leaving us only with infrastructure that is known to be correlated with development.

However, it is necessary to point out the limitations of this strategy. First, while the correlation between urbanization and economic development has been strong, it is increasingly weakened by the fact that the developing world is also urbanizing. As they urbanize, their initial levels of economic development would take time to catch up with the developed world, causing the drop in the correlation (Jedwab and Vollrath, 2015: 4–5). This may lead to short-term instability in measuring the level of economic development in the developing world, but the findings from this strategy should travel well up to middle-income countries (with per capita GDP between $3000-8100 in 2010 dollars, such as the Philippines or Turkey, Jedwab and Vollrath (2015), p.5). Second, the justification for daytime satellite images is heavily contingent upon the correlation between built-up infrastructure and growth, and is likely to be weaker in detecting newer forms of economic activity. For example, post-COVID work-from-home policies at the workplace could have reduced the demands for the commute, thus leading to lowered demand for quality highways and roads. Instead, this kind of economic activity would lead to development of the internet infrastructure, such as fiber optics cable underneath the ocean that is not visible in daytime satellite images. What the visible infrastructure shows, is the capacity for the primary and secondary industries, as well as services more directly related to those industries. To the extent that the modern economy depends heavily on the trade of the primary and secondary sector, daytime satellite images should still be able to capture most of the economic activity. However, as the tertiary sector becomes more dominant in the world over time, this strategy may no longer be able to succinctly capture economic activity as it currently does.

All in all, urbanization indicators from remote sensing data is a reasonable proxy to development, provided that we limit our study scope in the developed and middle-income countries. Its accuracy may decrease over time, but it is reasonable strategy for now. In the literature, this is also a practice. For example, Liu et al. (2015) uses the nightlights data as a proxy to urbanization even though scholars have justified its use as a proxy to economic development.

Data and Methods

Data

The satellite images come from the USGS Landsat 8 Top of Atmosphere (TOA) collection, accessed through the Google Earth Application Program Interface (API). With a custom-built script, I find the images in the collection that are enclosed in a region of interest (ROI) that I specified. The ROI in the training data varies from cities to regions. The variety in the size of the ROI helps maximize the diversity of terrain in the model. For each geographical unit, their ROI is defined using data from the OpenStreetMap (OSM) API, which includes crowdsourced information about the boundaries of cities and administrative regions around the world.

I then extract all matched images in the collection recorded between 2014-2021 since these are the years that data are readily available in Landsat 8. Finally, I sorted each image by the cloud cover in ascending order, such that the images that I download are less likely to be obstructed by clouds. If multiple images exist for the same year, the one with the least amount of cloud cover would be downloaded. In each image, only the areas within the ROI will be populated. All pixels outside the ROI but included in the image array will be populated with values of 0s.

For each image, I extract 7 relevant channels: Red, Blue, Green (RGB), Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Elevated Vegetation Index (EVI) and the Normalized Difference Built-up Index (NDBI). These extra remote sensing channels help the model further demarcate light-shaded terrain like sand, desert and snow from built-up areas. The target variable is the NDBI (Goldblatt et al., 2018; Kawamura et al., 1996) of an image, which can be computed as follows:

$$\frac{SWIR - NIR}{SWIR + NIR}$$

Where SWIR is the Shortwave Infrared band and NIR is the Near-Infrared band on an image. The NDBI does not have a fixed range that it can take on, but it can be normalized as part of the feature engineering steps in the model. These remote sensing indices can be computed programmatically, which saves the researcher vast

amount of time and resources to acquire the segmentation masks required for classification models. Figure 8 shows the example of Vienna as source image (left panel) and its NDBI (right panel) when plotted as a grayscale image, with black pixels indicating no built-up and white pixels indicating built-up. Not only does the NDBI closely track the presence of buildings and roads in the ROI, it also tracks the presence of farmlands. This makes the NDBI an accurate alternative over nightlights data as it captures primary, secondary and teritary economic infrastructure at the same time.

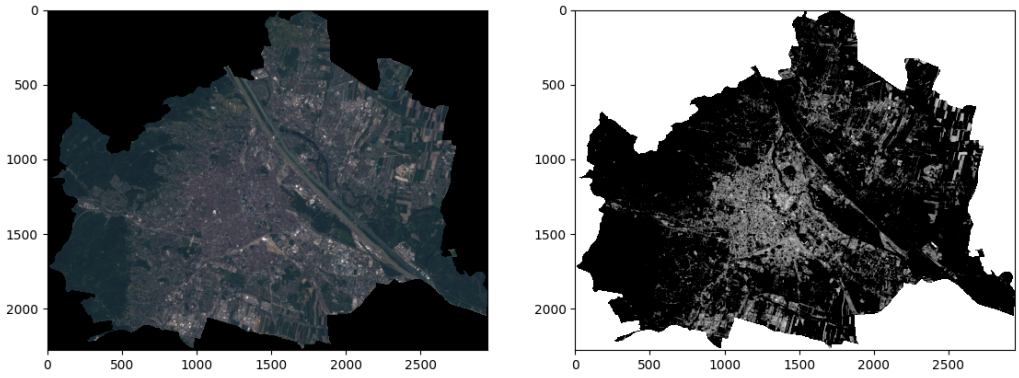

Figure 8: A training example

The choice of the dataset and band extraction setup is to enable backward compatibility. The NDBI is not available for all satellite image collections because the SWIR is only available in some satellite image collections. The USGS Landsat series has only started including SWIR bands in Landsat 4 (1982-1993). All the 6 feature bands do not require SWIR, so it is possible to construct a model that do not require the SWIR band to produce the NDBI that requries the SWIR band. This thus enables the model to backward support image prediction all the way back to Landsat 1-5 MSS collections (1972-1999) that are missing the SWIR

Table 6: Training Data Sources

Group	Regions
Primarily Rural	Aberystwyth, Assisi, Berdyansk, La Spezia, Eureka, Prince Edward Island
Mixed	Amsterdam, Beijing (Province), Brest, Greater London, Madrid (Autonomous Community), Northern Ireland (UK Country), Osaka (Fu)
Primarily Urban	Basel, Berlin (Land), Brussels (Province), Cairo, Chicago, District of Columbia (State), Dublin, Helsinki, Hyderabad, Indianapolis, Lagos, Lisbon, Paris, Prague, Rome, Seattle, Stockholm

band. With this backward support, the supported study period of this model can be extended all the way back to 1972, longer than most existing implementations discussed above.

The formulas for calculating these remote sensing indices are available in the appendix.

Train-test Split

The training dataset covers 34 regions each year between 2014 and 2021. These regions are picked depending on their size, and their distribution of rural and urban areas. The goal is to balance the number of primarily urban areas and the number of mixed/ primarily rural areas. This yielded 13 primarily rural or mixed regions, and 17 primarily urban regions. Table 6 shows the distribution of the various regions in the training dataset.

After re-sizing the data into smaller 1024*1024 pixel tiles, the dataset has 9293 images and is split to the training, development and testing set at a 8:1:1 split. The development set is reserved for testing at the end of each training epoch to prevent overfitting to the training data. The test set is reserved at the end of the training to check model performance. Both the development and test set were not seen in the model as it is learning from the training data.

Data Preprocessing

In the data preprocessing pipeline, each image will go through three feature engineering steps:

1. Band Calibration - The remote sensing data from Landsat 8 requires calibration before visualization because they are not on the commonly used 0-255 scale for RGB colors. I divided these three bands by a calibration factor of 0.4 for these 4 bands as per the Landsat 8 documentation. For the rest of the

remote sensing layers, I performed Min-Max Normalization to normalize them to a 0-1 scale.

2. Image Resizing - These images must be resized to a smaller scale to reduce the computational complexity of the model. I resize all images to a 128*128 pixels.
3. Image Augmentation - At a probability of 0.5, I randomly rotate images to the right by 90 degrees. This is known as an image augmentation technique to help the model generalize better to odd cases of input images.

Method

Convolutional Neural Networks (CNN)

Images are an example of unstructured data that can be difficult to analyze using conventional statistical models. First, these images are usually in the format of a 3-D array of size $(Width, Height, Number\ of\ channels)$. Typically images will have at least three channels of colors - Red, Green and Blue. The colors we see on the image are a mix of these RGB channels. Conventional statistical models do not support data input as a 3-D array. Second, pixels on an image are usually related. An object on an image can be usually understood as a group of pixels cobbled in specific locations to produce a particular shape that makes the object identifiable. To extract information from images, one should understand the image as a network, or more accurately, a graph denoting the relationship and location of pixels. Conventional regression models do not take into account the networked nature of images.

To resolve these two problems, we use a class of models called Convolutional Neural Networks (CNN). Unlike traditional machine learning models , CNNs are made up of layers that makes use of the convolution procedure. In the context of CNNs, convolutions refer to the mathematical operation of reshaping an 3D array to another desired shape. By reshaping them to a specific shape, we focus on specific features on the image, such as edges and specific colors on the image. Figure 9 shows a graphical illustration of the 2D convolution operation used in the CNN.

With these convolutions, the convolutional layers in the neural network essentially conduct automatic feature extraction to capture relevant features on image that can be conducive to generating accurate predictions of

the outcome variable. These extracted features are also known as feature maps that focus on specific areas (e.g. shades, borders, color, lines) of the image.

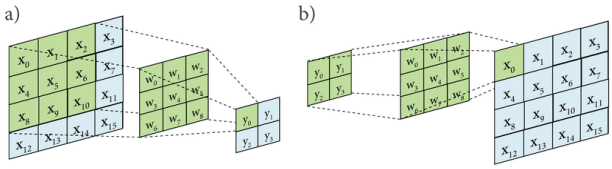

Figure 9: Illustration of the 2D Convolution Operation

Image Regression

To train a model to mimic how humans demarcate built-up and non-built-up areas, there are two approaches: Image Segmentation and Image Regression. Traditionally, scholars build image segmentation models because they care less about the uncertainty around a prediction. Image segmentation models require scholars to define the dependent variable in discrete terms (namely, classes). For example: whether the building is built-up or not; and whether there is an object or not. This approach is limited by the creation of these binary segmentation masks that can lead to data loss. By coercing information to fall into only two discrete classes, we lose the ability to predict partial classes. Partial classes are important to predicting difficult cases, such as the urbanization without growth examples discussed above, or buildings nested inside dense forests.

The same machine learning problem can be re-formulated as a regression problem. Instead of classifying pixels to be discrete classes, we can define a model that predicts the probability of the pixel belonging to a class (e.g. the probability that this pixel is a developed area). The NDBI is a continuous index with no fixed bounds, and thus can be used as a target variable for the image regression problem.

Model Architecture

Since the formulation of the machine learning problem has changed, the model architecture will also have to adapt. One approach is to adapt the famous U-Net architecture from to support regression output. The U-Net architecture is originally used in biomedical image segmentation (Ronneberger et al., 2015), but has also been applied to many other segmentation problems. We can coerce the U-Net architecture to generate a pixel-by-pixel array of NDBI values by modifying the last layer of the model to a 2D Convolutional layer

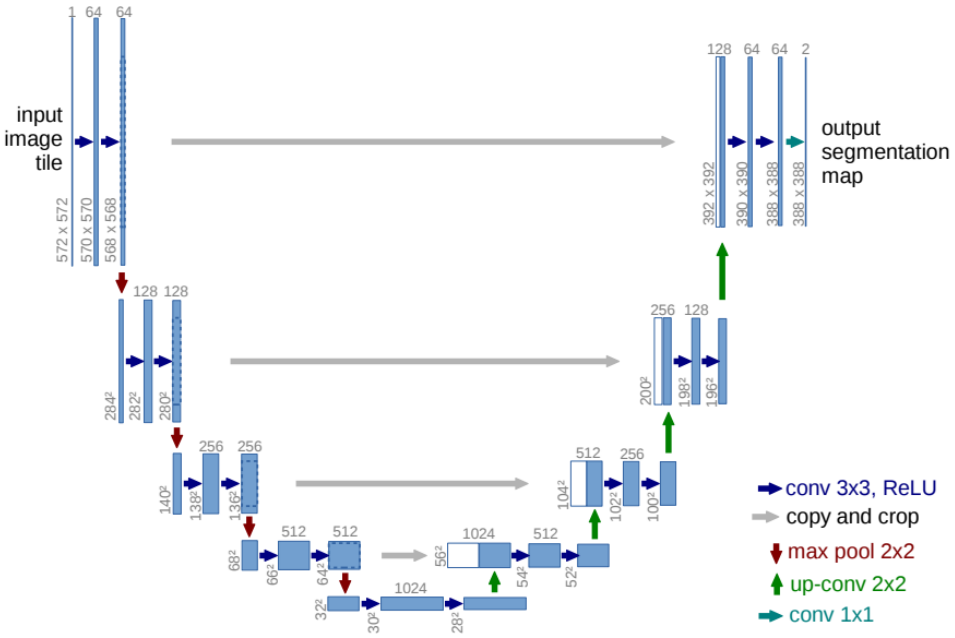

Figure 10: Illustration of the U-Net (Ronneberger et. al., 2015)

with a (1*1) filter with 1 channel and setting the activation function to sigmoid. Changing the activation function to Sigmoid ensures the output of the layer to vary between [0,1].

However, this dataset at less than 10,000 images is considered small. To help overcome this data limitation, we can fit a model by transfer learning. Transfer learning refers to the practice of adapting a pre-trained model to a new machine learning problem. As long as the new problem does not deviate too extremely from the the original problem that the model was trained in, the knowledge learnt in the old problem can be used to solve the new machine learning problem. In this paper, I conducted transfer learning on EfficientNetB0 (Tan and Le, 2020), an object classification model originally developed to run efficiently on small handheld devices such as smartphones and tablets. The EfficientNetB0 is trained on the ImageNet database of a whopping 14,197,122 images. Because the pre-trained model was trained on consuming such a huge dataset, it gets around the limitation of having a small dataset in this paper.

To adapt EfficientNetB0 to our problem, I freeze all layers of the model, and created a custom de-encoder of 4 layers to turn the output to a single numeric output. The layers of the de-encoder are as follows:

1. 2D Average Pooling layer to find the mean of the 1000 propensities belonging to each classes in the

original EfficientNetB0 implementation.

2. A BatchNormalization layer to normalize all outputs to vary between [0,1].
3. Random Dropout at probability $p = 0.5$.
4. Dense layer to aggregate everything to a single output. The single output will vary between [0, IMG_SIZE*IMG_SIZE], where IMG_SIZE is the size of the image rescaled to.

Because EfficientNetB0 requires a 3-channel tensor as input, I have added an extra 2D Convolutional layer at the top of the model to reduce the source image from N_CHANNELS to just 3 channels with a (1*1) filter to create feature maps from the 6 channel features into only 3 channels.

Figure 11 visualizes the transfer learning model architecture. Only the steps other than the EfficientNetB0 layer is learnable in this model, so the number of learnable parameters in the model is drastically reduced.

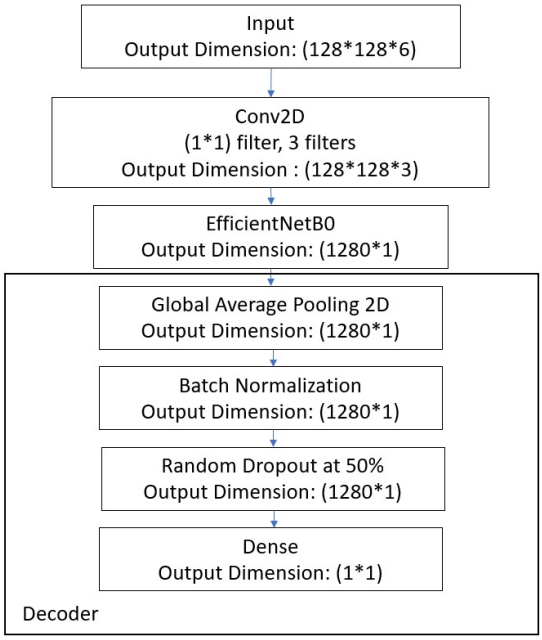

Figure 11: Visualization of the Transfer Learning Implementation

Index Construction

The model generates a 2D array of predictions of size 128*128. These are estimates of the NDBI per pixel, so if we sum all pixels in the 2D array, then we get a rough sense of how high the Normalized Difference Built-up Index (NDBI) is in an image. For each image, the index has a scale of 0-16384, where 0 means that

Table 7: Model Setup

	Loss Function	Optimizer	Learning Rate
6-band U-Net	RMSE	Adam	1e-4
6-band EfficientNetB0 Transfer Learning	RMSE	Lookahead Adam	0.5 to start, sync for each 6 epochs, update half of the slow weights

the city has absolutely no development (completely dark) and 16384 means that the city is completely full of buildings and roads with no nature at all (completely bright).

For each city, the sum of these 2D array predictions constitute a distribution of urban indices for each tile of the city. This city-level distribution forms the backbone of this new index which I call the Satellite Index of Development (SID). We can then compute summary statistics that describe this distribution. I include the sum, mean, median, minimum, maximum and standard deviation of these image-level estimates. I aggregate the index output by finding the sum, mean, median, minimum, maximum and standard deviation for each metropolitan area. This aggregation step is crucial because some metropolitan areas in the dataset (e.g. Beijing, Sao Paulo) are much larger, so a simple summation for the level of development would mistakenly equate the land mass as development. This weighting helps us avoid equating city size to development, since it is possible to have a larger urban population and urban sprawl without increased productivity (Jedwab and Vollrath, 2015).

Model Definition

The model definitions can be summarized in Table 7.

I fitted all models using the Root Mean Squared Error (RMSE) as the loss function. The RMSE is defined as follows:

$$L_{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}$$

In other words, this is the square root of the mean squared differences between the predicted value $\hat{y}_i$ and the observed value y_i. The RMSE tends to penalize the magnitude of the errors made in the prediction, thus it's

a harsher metric to use when evaluating regression model performance. The most ideal value for the loss is 0.00 which means there is no error between the predicted value and the ground truth. The lower the loss, the better.

The choice of optimizers and learning rate are picked based on the previous literature. The Adam optimizer with a 1e-4 learning rate is common in most neural network models. For the transfer learning model, the Lookahead Adam setup is documented to be successful by Rosenfelder (2020) in his formulation of the image regression problem using the EfficientNetB0. The lookahead optimizer breaks the optimization problem into two loops, where the outer loop optimizes for the general direction of the gradient descent and the inner loop optimizes for small variation around this general direction. This operation could ensure higher learning stability because the variance of the graident descent steps are much smaller than the vanilla Stochastic Gradient Descent (SGD) (Zhang et al., 2019).

All models are trained for 40 epochs. The minibatch is set to 128 images per batch for the transfer learning model, and 16 images per batch for the U-Net because of the computational complexity of the model.

All CNN models are trained using TensorFlow 2.9.0 in Python 3.8, using a Nvidia GTX 1060 6GB GPU.

Model Performance

Figure 12 shows an example of the model prediction compared to the source image and ground truth. We see that the predicted NDBI closely tracks that of the ground truth. The only small difference is in the likelihood of the built-up: the ground truth is more ambivalent whereas the model prediction is more certain, as shown by the high contrast difference between the built-up and non-built-up areas.

The performance of the model can also be gauged numerically using two sets of metrics: Machine Learning metrics, and applied relevance. Machine Learning metrics help us gauge the model performance in absolute terms - i.e. how large is the prediction error when predicting on the test set that is set aside from the training data. The machine learning metric reported here is the RMSE on the testing data.

The applied relevance can be tested by checking the correlation between model predictions and existing data on the same set of observations. For this metric, I extracted images in 2014 for 49 cities and used the model

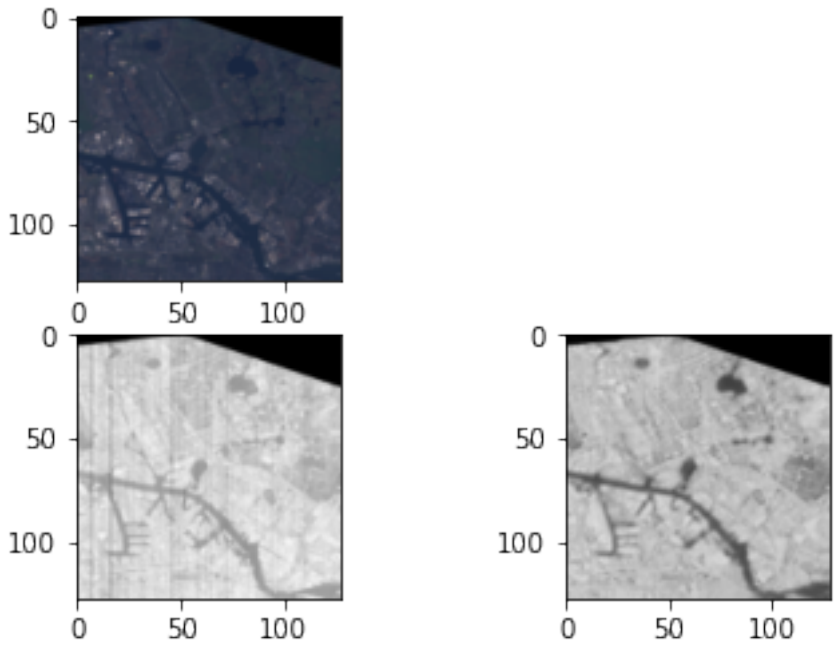

Figure 12: Example of Model Prediction. Upper Left panel is the source image; Lower left panel is the ground truth NDBI; Lower right panel is the predicted NDBI

Table 8: Model Performance

Model	Training RMSE	Testing RMSE	Corr. with Brookings 2014 Data
U-Net	.071	.098	.486
EfficientNetB0 Transfer Learning	.115*	.093*	.467

Note: *- EfficientNetB0 RMSE was reported at the image-level not pixel-level. These are estimates acquired by averaging the image-level RMSE by the size of the image (dividing by 128x128=16384)

to predict their level economic development. I then compute the correlation of the outcome index against the Brookings Institute 2014 city-level GDP data (Berube et al., 2015). Two forms of the index were shown: the weighted sum by city-level population, which gives a rough measure of economic development per capita; and the mean level of development average across image tiles for each city, which gives us a rough measure of the mean level of development holding city size constant. The full list of cities is available in the Appendix E2.

The model fit metadata and their corresponding machine learning metric and correlation with existing data is shown in Table 8.

From table 8, we see that two models are neck-to-neck in terms of generalizability at around .09-.10 RMSE. The U-Net has made only 9.8% error in the outcome, whereas the EfficientNetB0 made only 9.3%. In terms of

applied relevance, the U-net predictions are more correlated with the Brookings 2014 GDP data. The highest correlation that can be achieved is $r = .4855$ when the SID was constructed using the sum of predictions.

For the applied case, I will use the U-net predictions because of its high applied relevance and low prediction error on the NDBI.

Use Case example: Can Political Decentralization reduce Intraregional Inequality in Metropolitan Areas? (2014-2020)

The rest of the paper focuses on an applied example of the SID predictions, namely, to investigate if political decentralization is associated with lower intraregional inequality in metropolitan areas.

Intraregional inequality refers to the unequal distribution of development outcomes within a territory with clearly defined boundaries. Within this territory, certain parts are more developed than others. This is usually manifested in the concentration of financial and human resources in one particular part of the territory vis-à-vis the rest of the territory. The discussion of intraregional inequality stems from the discussion of inequality between "star cities" and their neighboring areas in the US and Western Europe (Le Galès, 2021; Le Galès and Pierson, 2019). For example, in the state of New York, much of the employment opportunities and investment capitals are all clustered around New York City. In this example, the intraregional inequality within New York is said to be increasing as the level of resources and development between New York City and Rochester continues to widen. The focus here is the inequality of growth factors, namely infrastructure (Jedwab and Vollrath, 2015), not income inequality.

In the case of income inequality, the literature measures it with the Theil Index. The index can be decomposed to show that income inequality is composed of two segments: inequality across regions and individuals (Between Variance) and inequality across individuals within a region (Within Variance) (Cowell, 2000: 87–150; Novotný, 2007). This case study is interested in the intraregional inequality (sometimes called spatial inequality) in the case of the distribution of infrastructure within a region.

In decentralized systems, the regional government may enact interventions to combat these inequalities

as long as it has sufficient regional authority from political decentralization. Political decentralization is the devolution of new self-rule and shared rule authority from the national government to subnational governments (Hooghe and Marks, 2003; Hooghe et al., 2016). Under political decentralization, regional authority of a regional government can be further categorized into self-rule and shared rule. Self-rule can be understood as the region's authority to create its legislation and policies, whereas shared rule refers to the authority that a region could exercise to co-legislate on constitutional, fiscal, and other policy matters with the national government (Hooghe et al., 2016). If fiscal authority is shared between the national and regional governments, then the regional government is jointly responsible, along with the national government, for this inequality problem at the regional level. In the case that fiscal authority is completely devolved to the regional government, then the regional government is wholly responsible for this intraregional inequality. As long as the regional government is dedicated to the eradication of these intraregional development biases, they can make use of this regional authority to create programs that combat intraregional inequality (Bojanic and Collins, 2021; Lessmann, 2012; Rubin and Feeley, 1993).

Does political decentralization reduce intraregional inequality, and how?

The literature can agree on the importance of political institutions on inequality reduction but has been divided as to whether political decentralization reduces intraregional inequality. There is a fair number of scholars that argue for a reductive effect, and a fair number of scholars who would argue for a positive effect. Others argue that it is a conditionally negative effect, contingent upon other factors in the relationship. Table 9 summarizes a selection of research in the literature and their findings. However, many of these studies do not go further as to whether the effect of political decentralization comes from the self-rule authority of a region or the shared rule authority of the region. It is important to recognize that self-rule authority and shared rule authority may not necessary have the same effect over intraregional inequality.

Self-rule authority and intraregional inequality

Self-rule authority measures the level of autonomy that the regional government has over a given policy area. In the realm of redistributive social policies, there has been a lot of research explaining how self-rule can

Table 9: Summary of literature on the effect direction of decentralization on interregional income inequality.

Paper	Type of Decentralization	Data	Reported Effect Direction on Interregional Inequality
Rodriguez-Pose & Gill (2004)	Political Decentralization	Brazil, China, India, Mexico, Spain, USA; 1980-1999	(+)
Canaleta et. al. (2004)	Political and Fiscal Decentralization	17 OECD Countries	(-)
Neyapti (2006)	Fiscal Decentralization	54 Countries from 1970s to 1990s	(-)
Ezcurra & Pascual (2008)	Fiscal Decentralization	12 EU Countries; 1980-1999	(-)
Lessmann (2009)	"De Facto" Fiscal Decentralization	23 OECD Countries; 1982-1986 and 1996-2000	(-)
Lessmann (2012)	Political and Fiscal Decentralization	54 Countries; 1980-2009	(-) in developed countries; (+) in developing countries
Tselios et. al. (2012)	Fiscal Decentralization	13 EU countries; 1995-2000	(-)
Ezcurra & Rodriguez-Pose (2013)	Political Decentralization	23 Countries; Period Varies	(+)
Kyriacou et. al. (2013)	Fiscal Decentralization		(+)
Goerl & Steiferling (2014)	Fiscal Decentralization	7 Country Groups; 30-year period	Inverted-U in Size of Government; (+) in transfer dependency
Cavusoglu & Dincer (2015)	Fiscal Decentralization	50 US States; 35 years	(-) in high income areas
Bojanic (2018)	Fiscal Decentralization	12 Countries in the Americas; 1972-2015	(-)
Bojanic & Collins (2021)	Fiscal and Political Decentralization	84 countries; 1980-2016	(+) in Fiscal Decentralization; (-) in political/ administrative decentralization

Note: (+) refers to a positive relationship (worsening inequality) and (-) refers to a negative relationship (reducing inequality).

lead to different redistributive policy outcomes. First, self-rule is said to be a centrifugal force from central government policy, especially when regional governments have a narrower electoral constituency (Toubeau and Vampa, 2021; Wildasin and Wildasin, 1997). With a narrower electoral constituency also come different electoral pressures. Unlike the case of interregional inequality where policy externalities may make the attribution of responsibility unclear to the electorate (Arceneaux and Stein, 2006; Powell and Whitten, 1993), this narrower electorate can more easily attribute the responsibility of widening intraregional inequality to the regional government. The stronger the self-rule authority, the easier it is for the regional constitutent to attribute responsibility since the region has more autonomy to enact policies to reduce intraregional inequality.

Clustering better infrastructural investment or development in certain pockets can upset voters. To the extent that infrastructural development increases the productivity of the worker (Chen et al., 2014; Jedwab and Vollrath, 2015), an unequal access to higher productivity would lead to redistributive pressures (Alesina and Spolaore, 1997, 2003; Beramendi, 2012).

Alternatively, regional governments may use self-rule authority to reduce intraregional inequality as part of a community-building scheme. Regional governments may increase the connectivity between localities and encourage the movement of goods and people across localities, to facilitate the creation of a regional labor market (Miller, 2000) and subsequently the emergence of a regional community. A communitarian inequality reduction policy thus helps the regional government achieve regional, or in some cases, nation-building objectives (Kleider and Toubeau, 2022; Mcewen, 2005).

The electoral pressure and communitarian explanations thus ground the expectation that greater self-rule leads to widening discrepancies between regions on redistributive policies (Kleider et al., 2018; Kleider and Toubeau, 2022: 287; Toubeau and Vampa, 2021). Self-rule authority acts as a conduit, to motivate regional governments to focus their efforts on combating intraregional inequality even regardless of national policy directions on the matter (Kleider et al., 2018), and regardless of what social welfare other regions are providing (Berry et al., 2003; Kleider, 2018; Rodríguez-Pose and Gill, 2004)

However, not all regions are equally prepared to make use of the authority. Regions with a high level of

economic development have sufficient resources to write legislation and enforce them to reduce intraregional inequality (Lessmann, 2012). Regions with lower levels of economic development might find it difficult to enforce legislation to reduce intraregional inequality. These regions are likely to be fulfilling the minimal task of collecting regional and local taxes since they do not have the additional resources to redistribute (Prud'homme, 1995). In addition, granting more administrative and fiscal responsibility to developing regions could lead to rent-seeking behavior instead of improving governance (Cavusoglu and Dincer, 2015; Lessmann, 2012; Prud'homme, 1995). Other research has also shown that less developed regions are less likely to provide public goods and social welfare (Foa and Nemirovskaya, 2016; Gais, 2009). Therefore, one can theorize that the self-rule effect on intraregional inequality would be moderated by the level of economic development of the region. *The more economically developed the region is, the more likely it is to utilize self-rule authority to combat interregional inequality.*

Data

To examine how political decentralization could affect development inequality, I focus on the special case of metropolitan areas. Metropolitan areas have received more and more regional authority over the years. As urban sprawl increases, national governments create a new tier of government dedicated to the governance of urban issues and challenges in metropolitan areas. This kind of regional authority is particularly interesting because metropolitan areas are smaller than most regional governments. Intraregional inequality with respect to infrastructure and urbanization is likely to be much lower since such inequality is increasing in territory. In other words, a larger region encompassing less densely populated areas is more likely to be more unequal in terms of infrastructure and geographical concentration of investments. Therefore, if we could find further reductive effects in metropolitan areas, the effect in the entire country is likely to be larger, and thus the study on intraregional inequality in metropolitan areas constitute a less likely case.

I use the SID predictions of the level of economic development for 50 cities in 2014 as my measure for intraregional inequality and economic development. This list of cities is constructed based on data availability on the Regional Authority Index (RAI) (Hooghe et al., 2021, 2016) and city-level population data. The RAI measures the self-rule and shared rule capacity of regions and metropolitan areas around the world, with the

sole exception of Africa.

Research Design

The Dependent variable is a measure of intraregional inequality using the SID developed in the previous section. I applied the SID model to estimate the level of economic development in the 49 cities listed in Appendix E2. I use the population-weighted coefficient of variation (CV) of the index as a measure for the degree of development inequality in that same area. The CV (Williamson, 1965) is defined as follows:

$$CV_{weighted} = [\sum_{g}(x_g - \bar{x})^2 \frac{p_{it}}{P_t}]^{\frac{1}{2}} \frac{1}{\bar{x}}$$

where x_g refers to the sum of model predictions for the g-th image for the i-th city, p_{it} refers to the population of city i at time t, and P_t refers to the population of the country that city i belongs to at time t. This CV measure is then mean-centered since it is on a very different scale from the rest of the variables in the model. This formulation of the CV weighted both the city and country population, since it is easy to have larger CV due to having a larger population. By weighting the CV this way, this gets at the notion of inequality per capita.

This variation of the weighted CV by population is widely used to measure development inequality in economics (Artelaris and Petrakos, 2016; Huang and Wei, 2019; Williamson, 1965).[1]. The national population data is acquired from the World Bank. It is updated every 5 years since 1950 up to 2020 (World Bank, 2021).

There are two key explanatory variables. I use the self-rule index and the shared rule index from the Regional Authority Index (RAI) 2020 Data (Hooghe and Marks, 2016; Hooghe et al., 2021, 2016). The RAI is a cross-sectional time series dataset measuring the degree of political authority regional governments have amassed over time. It provides data for the covered regions for every year from 1950 to 2018. The aggregate RAI score is further broken down into two kinds of authority: self-rule and shared rule. The self-rule index

[1]I decided not to use the gini coefficient because the index is computed for each image, and thus the gini coefficient can only be computed at the image level not the population level. The weighted CV and gini coefficient are not correlated, Pearson's r = NA, so they may not be measuring the same underlying concept.

measures to what extent the regional government could independently exercise authority and in what areas (Hooghe and Marks, 2016: 16). The shared rule index measures what authority the regional government may co-exercise with the national government (p.35).

I include interaction terms between the two regional authority measures above and the level of economic development in a region. For economic development, I use the weighted sum of the SID prediction as a measure for economic development. This takes the sum of all SID predictions across all tiles in a city and divide it by the population of that city in a particular year. Substantively this can be interpreted as the economic development per capita in a city in a given year. Controlling for population in a city is crucial since cities with larger population like Beijing or São Paulo might have more urban areas to host the larger population, but that alone does not equate to more development. Dividing the measure by population helps us control for the size of the population.

I control for the logarithmic of the city population in 2014 (UN Department of Economic and Social Affairs, 2014). Because the Within Variance term iterates through i individuals, if there are more people living in the same city, it is quite likely that the inequality structure gets more complicated as people are employed in different sectors and different skill levels, earning different wages. I expect there to be a positive relationship between the log of population size and intraregional inequality.

I also control for the level of liberal democracy of the country that the city belongs to. There is an argument about the propensity of authoritarian governments to redistribute resources to maintain social order (Acemoglu and Robinson, 2006; Magaloni, 2006). For the authoritarian states, regime longevity is their main concern. This is particularly true for authoritarian cities that are seen as "too big to fail", and many cities happen to be the center of authority in authoritarian states (e.g. Beijing, Moscow, etc.) - so it is expected the authoritarian governments might put more resources towards reducing intraregional inequality. The data comes from Varieties of Democracy's Liberal Democracy Score (Altman et al., 2021), which estimates the level of liberal democracy for countries every year between 1789 and 2020.

I also control for the ideology of the city government. The literature suggests that left-leaning regional governments are more inclined than right-leaning ones to give precedence to redistribution (Tobeau & Vampa,

2021; Kleider et. al. 2018), so I expect the more left-leaning the city government is, the more likely they will enact redistributive policies to reduce intraregional inequality. The ideology variable is coded on a scale of 1-10, where 10 means the government is extremely left-leaning and 1 means extremely right-leaning. The coding of party ideology is taken from a mix of four sources: The Chapel Hill Expert Survey (CHES) (Jolly et al., 2022; Martínez-Gallardo et al., 2022), ParlGov, V-Party (Lindberg et al., 2022) and Massetti and Schakel (2016). I use the economic left-right ideology measures in these datasets. All ideology measures were harmonized to be on the 1-10 scale to make the measures across datasets comparable. When multiple years are available for the same party, I use the measure closest to the year of observation in the RAI dataset.

I also control for the shared rule authority of a region. Shared rule authority measures the capacity of which a city government could collaborate with the national government on policy issues. Higher shared rule authority make prompt the city government to engage in adjustment-seeking behavior, namely negotiating for discretion with regards to national policy (Agranoff, 2001; Agranoff and McGuire, 1998). Such discretion include regulatory relief, flexibility, wavier; statutory relief; change in national policy; extra funding of existing program; performance as a trade off for greater discretion, and et cetera. The regional government might be able to seek adjustments regarding inequality levels - such that they could get away from not reducing inequality. As such, we might see a positive association between shared rule and intraregional inequality.

Because the dependent variable is heavily right skewed, fitting a typical linear regression model would result in non-normally distributed residuals and thus violating the assumption of the model. Instead, I log-transformed the dependent variable and mean-centered it. With the transformed dependent variable, I fitted a multi-level negative binomial regression model, with a city-level random intercept to control for varying baselines of intraregional inequality across cities [2]. The distribution of the dependent variable before and after the transformation can be seen in figure 13 [3].

[2]There is not enough yearly observations to warrant a year-level random intercept. Incorporating the yearly random intercept would result in model convergence issues. In Appendix E8 I include the yearly random intercept for reference, and the results are robust to the inclusion of the yearly random intercept.

[3]The multi-level negative binomial model was able to relax the assumption of non-normally distributed residuals, but residual analysis in Appendix E9 shows that there are some slight non-linearity in the prediction vs. residual analysis. It shows that the

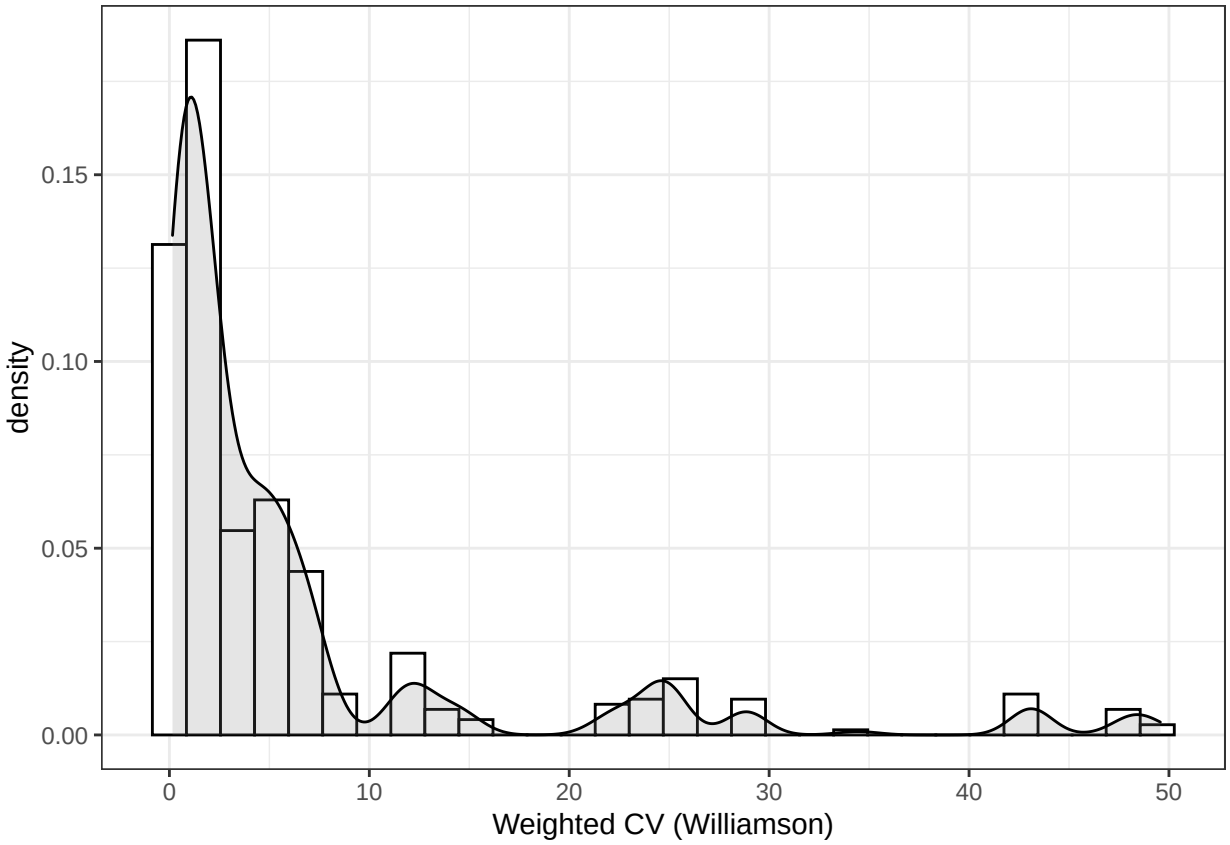

Figure 13: Distribution of the Dependent Variable.

Table 10 shows that there are 143 observations from 30 cities in 22 countries for every year between 2014-2020 after removing missing data. Table 11 presents the descriptive statistics of the dataset used to fit the models. Because the city government ideology variables are not time-varying, those variables will be cross-sectional repeated for every row of the same city. Originally the city-level population data is only available every 5 years, but I interpolated the population levels with spline interpolation. Appendix E2-A3 show the descriptive statistics before the removal of missing data.

	Country	City
1	Australia	Canberra
2	Austria	Wien (Vienna)
3	Bangladesh	Dhaka
4	Belgium	Bruxelles-Brussel
5	Brazil	São Paulo
6	China	Beijing
7	China	Shanghai
8	Ecuador	Quito
9	El Salvador	San Salvador
10	France	Lyon
11	France	Paris
12	France	Toulouse
13	Germany	Berlin
14	Germany	Bremen
15	Germany	Hamburg
16	Hungary	Budapest
17	India	Hyderabad (India)
18	Ireland	Dublin
19	Japan	Kinki M.M.A. (Osaka)
20	Netherlands	s-Gravenhage (The Hague)
21	Norway	Oslo
22	Pakistan	Karachi
23	Peru	Lima
24	Portugal	Lisboa (Lisbon)
25	Russian Federation	Moskva (Moscow)
26	Russian Federation	Sevastopol
27	Russian Federation	Sankt Peterburg (Saint Petersburg)
28	Spain	Barcelona
29	Vietnam	Hà Noi
30	Vietnam	Thành Pho Ho Chí Minh (Ho Chi Minh City)

Table 10: List of Cities in Dataset

model has difficulty in fitting cases with high levels of intraregional inequality due to a lack of samples in that space

Table 11: Descriptive Statistics

	N	Mean	Min	Max	SD
Weighted CV (Williamson)	141	8.458	0.155	48.507	12.633
Economic Development per capita	141	49.350	1.240	574.201	100.041
Regional Authority Index	141	13.078	4	27	7.226
Self-rule Score	141	10.121	4	15	3.106
Shared Rule Score	141	2.957	0	12	4.614
City Population (Thousands)	141	7,251.553	333.194	25,227.610	7,505.654
Liberal Democracy	141	0.536	0.052	0.865	0.312
Left-wing City Government	141	6.232	2.800	9.700	1.508

Results

Table 12: Estimating intraregional inequality in metropolitan areas

	Dependent variable:			
	Weighted CV (Williamson)			
	(1)	(2)	(3)	(4)
Regional Authority Index	−0.020 (0.024)			
Self-rule		−0.002 (0.050)	0.0005 (0.052)	−0.074 (0.051)
Shared Rule		−0.019 (0.052)	−0.024 (0.052)	−0.005 (0.050)
Self-rule * Economic Dev. per capita				−0.274*** (0.033)
Population		0.681*** (0.071)	0.589*** (0.086)	0.684*** (0.082)
Liberal Democracy		−0.376 (0.345)	−0.298 (0.304)	−0.112 (0.328)
Econ Dev. per capita		0.614*** (0.179)	0.605*** (0.181)	4.080*** (0.378)
Left-wing City Government			−0.151 (0.108)	−0.110 (0.102)
Intercept	1.348*** (0.304)	−4.182*** (0.362)	−2.551*** (0.299)	−2.762*** (0.369)
N Cities	30	30	30	30
SD Cities	1.461	1.142	1.124	1.043
Observations	141	141	141	141
Log Likelihood	−282.489	−276.077	−275.705	−274.774
Akaike Inf. Crit.	572.977	568.154	569.411	569.548
Bayesian Inf. Crit.	584.772	591.744	595.949	599.035
Note:	Presented are beta coefficients estimated in a multi-level negative binomial model, with city-level random intercepts. Standard Errors are in parentheses. p<.10+, p<.05*, p<.01**, p<.001***			

Table 12 shows the results of the model estimating intraregional inequality in metropolitan areas. Model 1 regresses the composite measure RAI on intraregional inequality alone, Model 2 breaks it down further into self-rule and shared rule and include controls except city-level government ideology. Model 3 includes the city-level government ideology and Model 4 includes the interaction term between the self-rule measure and economic development.

In Model 1, we see that the composite RAI index alone has no significant effect. Even when we break it down in Models 2 and 3, both self-rule and shared rule authority show no significant effect.

Only when I incorporate the interaction with economic development did I find a significant effect on the interaction between self rule and economic development. As I expected, model 4 shows that higher economic development level tends to be associated with a stronger negative relationship between self-rule and intraregional inequality, β = -0.274,***. This means that as economic development increases, the slope of self-rule on intraregional inequality would decrease. This is further illustrated by figure 14. In this figure, I set the level of economic development to three conditions: Low (25th percentile of the observed economic development levels), Medium (Median of the observed levels) and High (75th percentile of the observed levels) and estimate the levels of intraregional inequality as I increase self-rule. We see that for cities with low and middle levels of economic development the relationship between self rule and intraregional inequality is positive. Only among highly developed cities is the relationship negative, although the most developed cities with lower self rule also have the most intraregional inequality in the sample.

Because of the large number of missing data in the city government ideology variable, we lost many rows of observations. In Appendix E10 I removed the left-wing city government variable to increase the N. Appendix E10 shows that the interaction of self rule and economic development remains in the expected negative direction, but has lost significance. Given the difference in N is only 35 rows, it appears that the inclusion of the city government ideology is quite crucial to the recovery of a significant interaction effect between self-rule and economic development effect. This suggests a possible three-way interaction effect between self rule, economic development and city government ideology. Appendix E11 shows a variation of the model including such a three-way interaction. It appears the three-way interaction effect per se is not significance and close to zero, but the self-rule * economic development interaction effect is much stronger than the 2-way interaction effect model reported above, $\beta = -.580^{**}$. However, that model failed to converge, possibly due to a smaller N, so the results should be taken with a grain of salt.

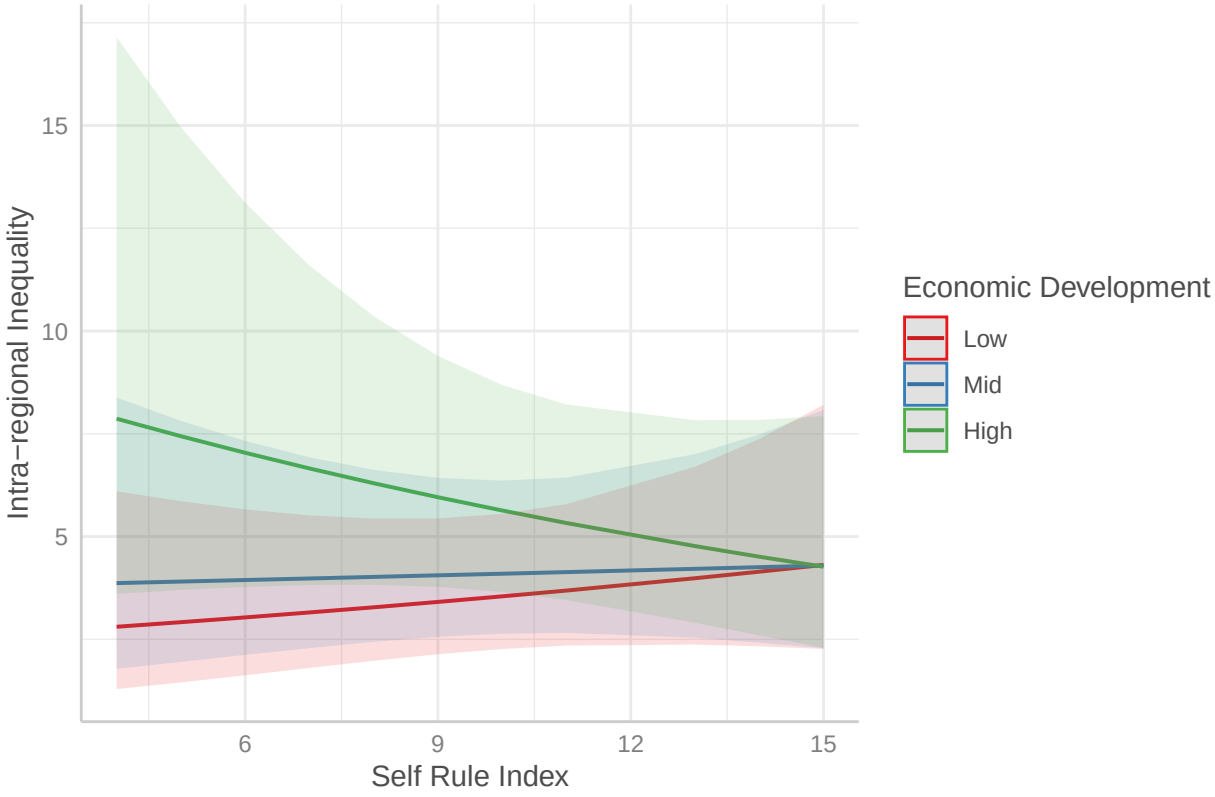

Figure 14: The effect of self-rule authority and Economic Development per capita on Intraregional Inequality

This conditional reductive behavior echos with the literature. For example, some scholars argue that the reductive effect reflects the superior fiscal and administrative capacity for richer countries to utilize regional authority to combat inequality (Cavusoglu and Dincer, 2015; Lessmann, 2012). Local bureaucrats in poorer regions tend to utilize regional authority to make rent (Cavusoglu and Dincer, 2015: 289), and figure 14 shows that: for the least developed cities, more self rule increases intraregional inequality.

Unlike self-rule, shared rule has very little bearing to intraregional inequality regardless of economic development. To the extent that regional governments may want to align their redistributive policies to align with the economic policy of the national government (Kleider et al., 2018), increased shared rule with the two levels of government do not seem to have influence on intraregional inequality. This behavior can reflect the finding that regional governments care more about their own political needs, such as defending the regional welfare state vis-à-vis pressures of privatization (Kleider and Toubeau, 2022; Vampa, 2014).

Other controls display a pattern coherent with existing literature. For example, all models show that intraregional inequality is higher when the city population is higher, highlighting the fiscal challenge of bringing infrastructure equality to more urban dwellers as the city population grows (Brueckner, 1997). In all models, higher economic development is associated with higher levels of intraregional inequality. Considering the study period of 2014-2018, many of the most developed countries were transitioning away from austerity. As scholars predicted, austerity led to more inequality among the developed world (Dagdeviren et al., 2017; Petit, 2010). Higher austerity also suggests that the developed cities will no longer be able to spend equally on all parts of the city limits, so the less developed parts could get less attention in terms of infrastructure, housing and the like. This ultimately leads to higher intraregional inequality. The liberal democracy index has a negative relationship with intraregional inequality, but it is only significant in one model. There is no a priori assumption as to why liberal democracies are more aware of intraregional redistribution, and as such the null effect is not surprising. There is no evidence for left-leaning city governments to combat intraregional inequality more than right-leaning governments since the city government ideology variable has varying effect direction and is not significant in all models. After all, the DV measures infrastructure inequality, not income inequality. Leftist parties maybe more interested in addressing income inequality, not infrastructure (Kleider, 2018; Kleider et al., 2018).

These findings are robust to the alternative explanation of city size. One may argue that the level of intraregional inequality can be explained by the landmass of the city. In Appendix E7 I have included city area in Model 4. City area is coded as the number of 19*19 squared mile [4] tiles used to measure the city in the dataset. The larger the number of tiles required, the larger the landmass of a city. Appendix E6 shows that the conditional negative association of self-rule and economic development is still there, albeit slightly weakened by the inclusion of city area.

Discussion

This paper makes two contributions to the literature. First, it introduces a novel method that gets around or even minimizes the problems that existing measures of subnational economic development have. It does not fix the geographical unit to be an arbitrary sized grid. Unlike nightlights data, it is not subject to regulatory risks from the lights-off policy that many Western states have enacted on, nor the bottom-coding problem that leads to lower prediction accuracy for regions in the developing world (Chen and Nordhaus, 2011).

This novel method will help address many data availability issues surrounding economic development below the national level. Daytime Satellite Images are readily available for scientific research. The method is not restricted by scale: the researcher can specify ROIs of their choice, be it at the street-level, county-level, city-level, regional-level or the like. This technique transcends administrative borders. This flexibility is particularly crucial for some aspects of subnational political research, for instance, the explanation for intraregional inequality shown here, or inter-regional cooperation, and inter-municipal collaboration where the data no longer follows administrative borders (Keating, 1998; Swianiewicz, 2010). The flexibility extends to the temporal dimension since the Landsat 8 dataset has a faster refresh cadence than most hand-crafted datasets, and the machine learning model that I develop here help generalize to older satellite images that goes all the way back to the 1970s.

Second, this paper provides an example of how we could make use of the unstructured data that exist out

[4] Or 30.75km by 30.75km. The Landsat 8 images have a scale of 30 meters per pixel.

there to construct measures relevant for the social sciences. The CNN used here is able to process hundreds of images in minutes, and is able to construct a reasonably valid measure for regional economic indicators where conducting on-the-ground survey could be expensive or difficult (e.g. Ulaan Baatar - one of the examples in the prediction dataset). Application of machine learning techniques would be invaluable to the social sciences as it helps us measure things we could never had easily measured before.

That being said, the strategy of using urbanization as a proxy for development is a simplification of the ground truth regarding economic development. The model is performing very well in measuring the infrastructure that drives economic development (Jedwab and Vollrath, 2015). However, it is not possible to capture the human geography side of the story, for example, the productivity of the workforce in the city. In densely populated urban areas (such as São Paulo), the machine learning model would have difficulty learning the level of economic development per capita due to massive urban sprawl. This can be addressed in future research by linking outputs from the current SID model to additional learners using tabular and/or qualitative data of a city's level of economic development per capita to help the algorithm differentiate between urbanized, unequal cities and urbanized, more equal cities.

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Appendix: Can Economic Integration reduce social unrest? Evidence from China, Hong Kong and Macau

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A. Impact of Trade Liberalization on Social Unrest in Hong Kong and Macau, 1994-2018.

A1: Descriptive Statistics

Descriptive statistics across Hong Kong and Macau:

Table 16: Descriptive Statistics of the Empirical Analysis

	Mean	Median	Std. Dev.	Min	Max
Confidence in 1C2S %	0.653	0.696	0.157	0.376	0.902
Dissent in 1C2S %	0.247	0.231	0.146	0.045	0.584
UEI	8.040	6.354	4.540	3.291	19.627
Dependence	194.544	23.747	207.367	9.090	529.906
Total Trade (Billion USD)	368,768.800	354,201.400	381,991.500	2,249.088	1,139,859.000

Descriptive Statistics by region:

Table 17: Descriptive statistics by region.

	Mean	SD	Min	Max
	Hong Kong			
Confidence in 1C2S pc.	0.56	0.1	0.42	0.74
No Confidence in 1C2S pc.	0.33	0.1	0.2	0.5
UEI	8.64	4.28	4.48	16.24
Dependence	18.75	4.75	10.95	24.16
Trade Volume (bn. USD)	676190.07	269974.52	351953.4	1139859.44
RGDPe (2011 Intl Dollar).	295812.03	69757.95	187624.44	413570.16
N	24			

Table 18: Descriptive statistics by region.

	Mean	SD	Min	Max
	Macau			
Confidence in 1C2S pc.	0.8	0.06	0.7	0.9
No Confidence in 1C2S pc.	0.11	0.06	0.04	0.23
UEI	5.97	3.22	3.29	13.01
Dependence	429.48	57.78	325.15	529.91
Trade Volume (bn. USD)	7884.89	2806.56	2540.29	12739.12
RGDPe (2011 Intl Dollar).	37840.47	22143.21	11657.3	72913.15
N	19			

A2: Time Series Plot of Trade Data

The implementation of the CEPA in 2003 is highlighted by a vertical dash line in the following plots.

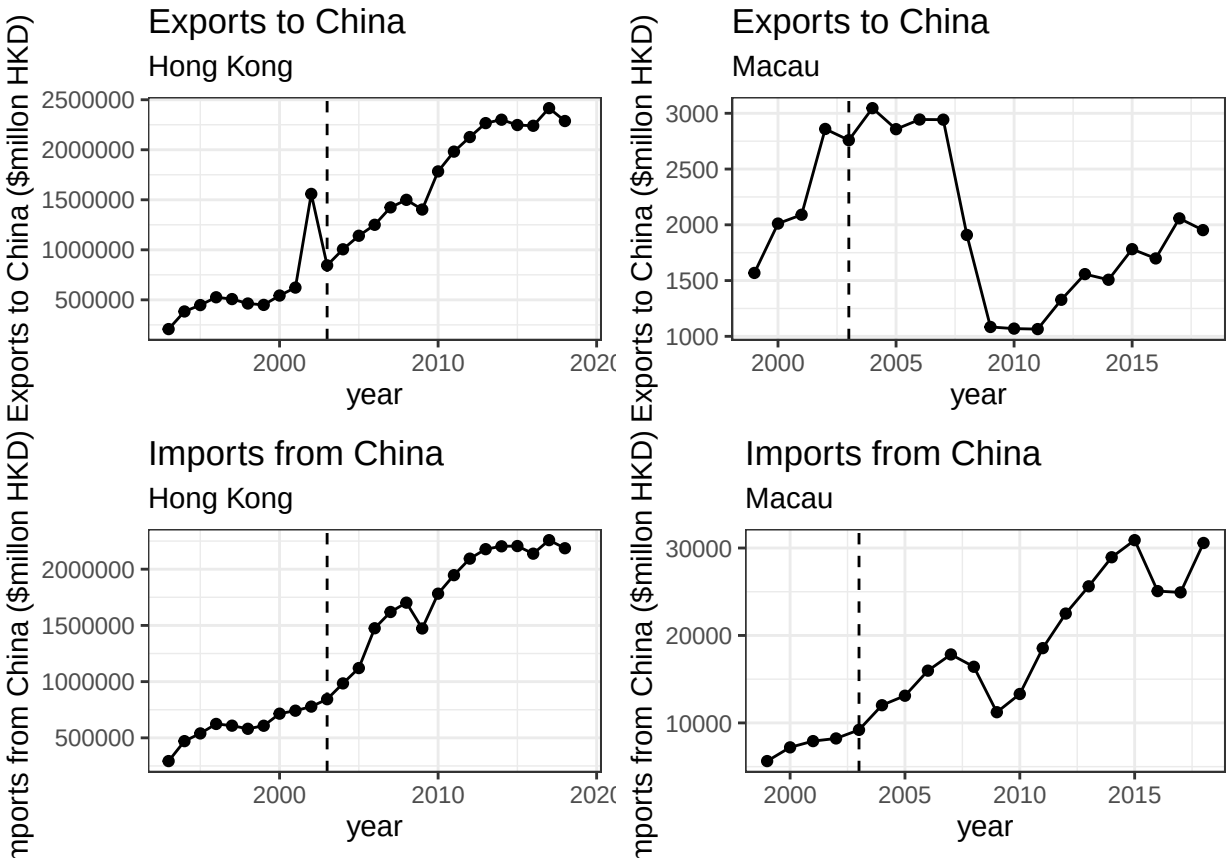


Figure 18: Trade Data Series in Hong Kong and Macau, 1994-2018

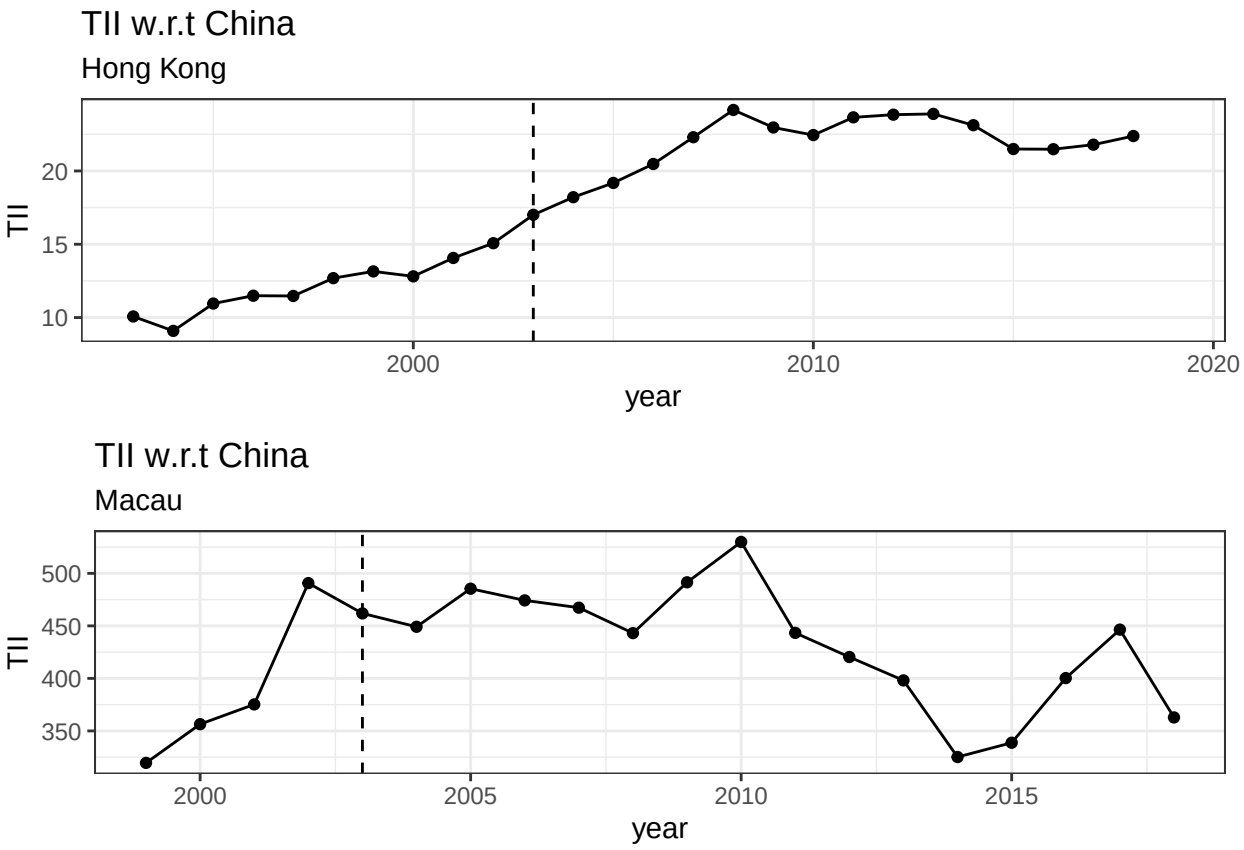


Figure 19: Trade Intensity Index with regards to China, 1994-2018

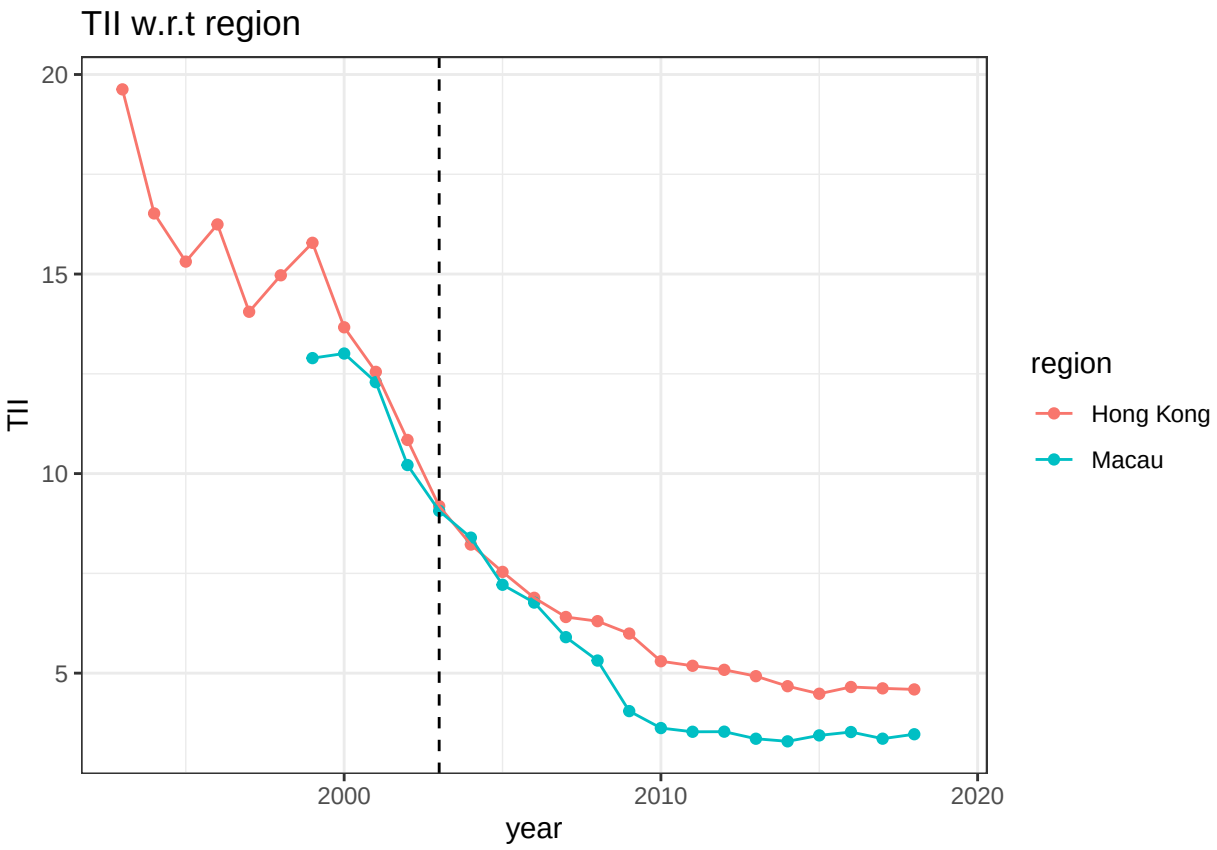


Figure 20: Trade Intensity Index with regards to Hong Kong and Macau, 1997-2019

A3 : Frequentist Estimation with Panel (Fixed Effects) Estimators

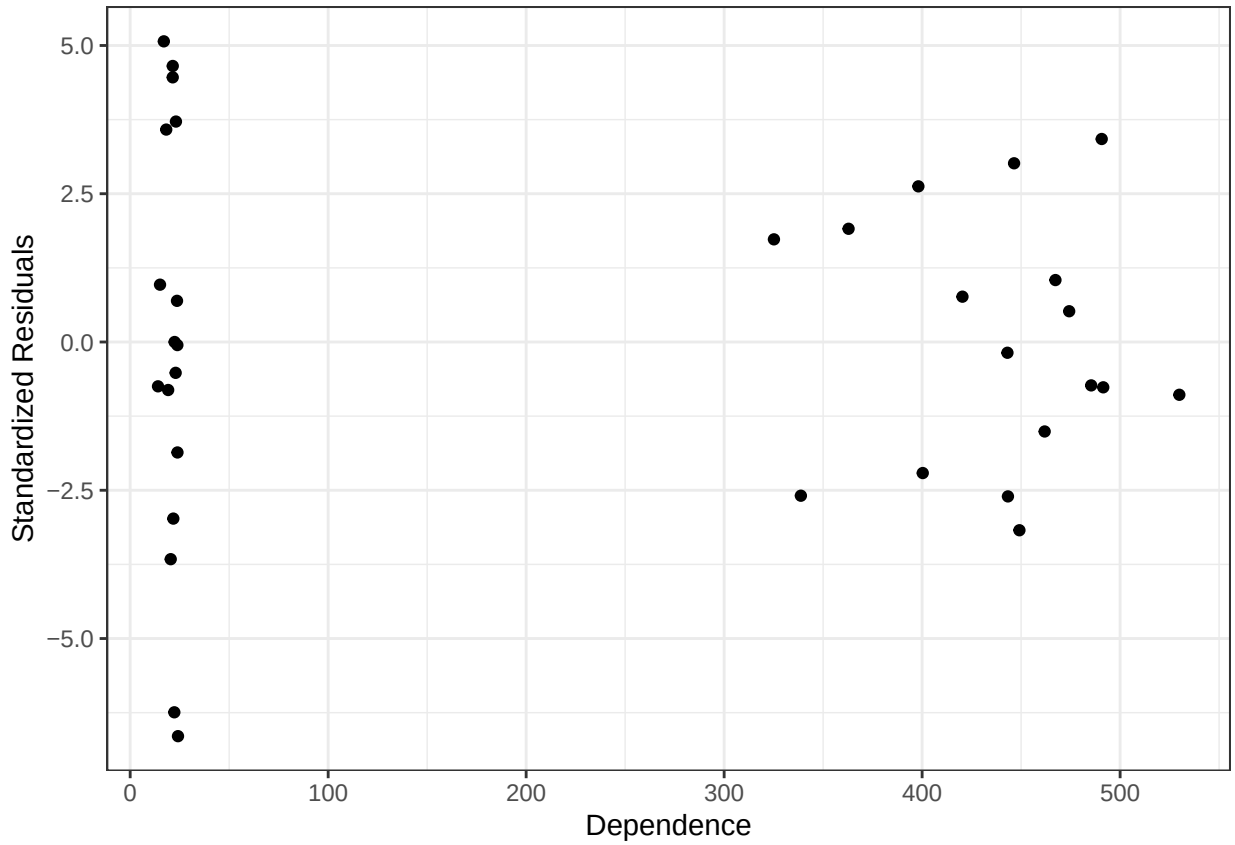
Table 19: Estimation by multivariate regression

	Percentage of people not confident in the 1C2S		
	(1)	(2)	(3)
UEI	0.197 (0.395)	2.345*** (0.560)	3.653* (1.627)
Dependence	−0.060* (0.027)	−0.014 (0.024)	−0.022 (0.039)
Trade Volume	0.00002* (0.00001)	0.0001*** (0.00001)	0.0001*** (0.00002)
FDI			−0.023 (0.019)
Stock Market Joint Movement			−0.0003 (0.001)
HZMB			1.397 (4.052)
HK-Shenzhen ERL			3.288 (6.599)
Hengqin Island Joint Development			−2.523 (4.722)
Dependence * UEI		−0.008*** (0.002)	−0.010* (0.004)
Observations	46	46	34
R^2	0.296	0.545	0.656
Adjusted R^2	0.227	0.488	0.507
F Statistic	5.741** (df = 3; 41)	11.981*** (df = 4; 40)	4.879** (df = 9; 23)

Note: *p<0.05; **p<0.01; ***p<0.001
Presented are the results estimated by the one-way Fixed Effects Model.
Standard errors are in parentheses.

A4: Diagnostics of the Frequentist Models

Distribution of Residuals:



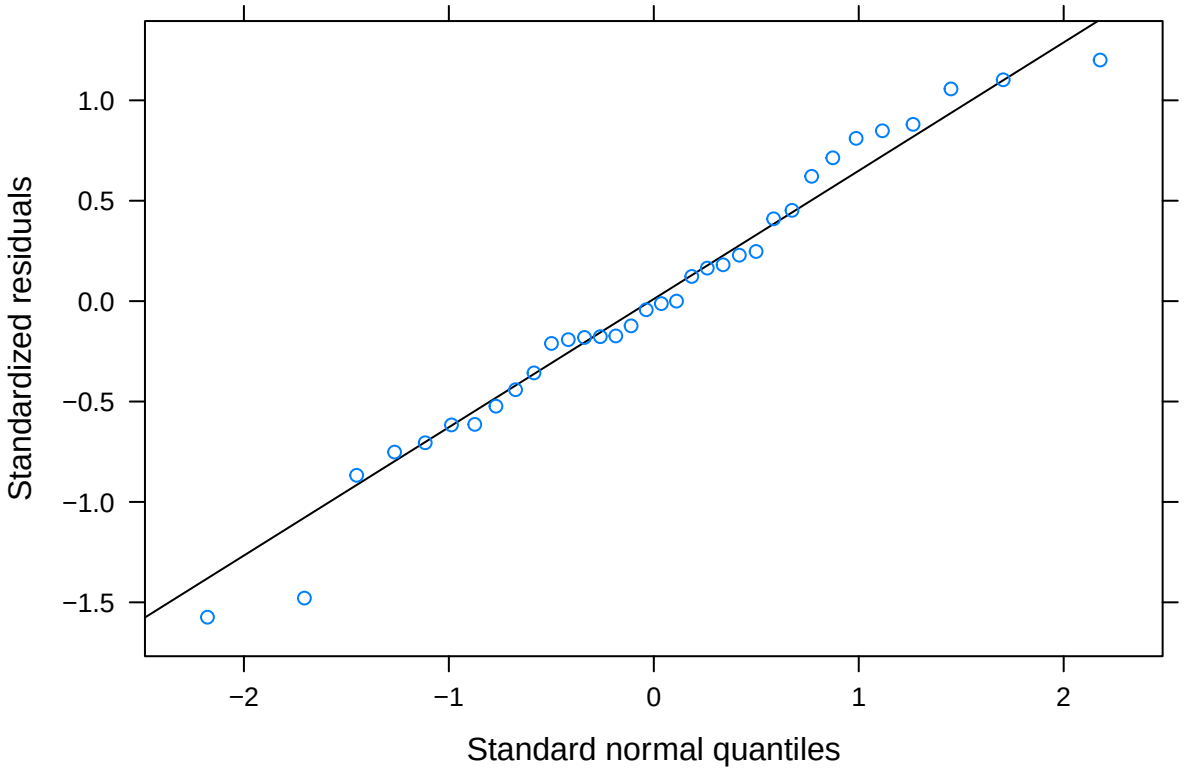
Homogeneity of variance:

```
## Analysis of Variance Table
##
## Response: residuals_abs2
##           Df Sum Sq Mean Sq F value  Pr(>F)
## region     1  550.4  550.36  5.2258 0.02902 *
## Residuals 32 3370.1  105.32
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The only clear pattern emerging from the residuals is that the residual distributions are quite different between the Hong Kong observations and Macau observations due to Macau having extremely high dependence. The Levene Test also shows that the distribution of variance is dependent on the region. While this may damage the robustness of our estimates in the multi-level models, note that we have acquired the same results from the panel models reported in section A3. The panel model is only looking at within-case fixed effects, so the estimated effect is not dependent on the region. Therefore, we can still say the results are

robust to case selection, as well as estimation technique.

Normality of residuals:



Overall the standardized residuals almost form a straight diagonal line to standard normal quantiles. This suggests that the residuals resemble a normal distribution.

A5. Diagnostics of the Bayesian Model

The Model

When fitting this multi-level zero-inflated negative binomial model (ZINB), we assume the following:

$$y_i \sim N(\mu, \sigma_i^2)$$

$$\mu = \boldsymbol{\eta} + \mathbf{X}\boldsymbol{\beta}$$

$$\eta_{year} \sim N(0, 1)$$

$$\eta_{region} \sim N(0, 1)$$

$$\gamma \sim Gamma(.01, .01)$$

$$\tau \sim Beta(1, 1)$$

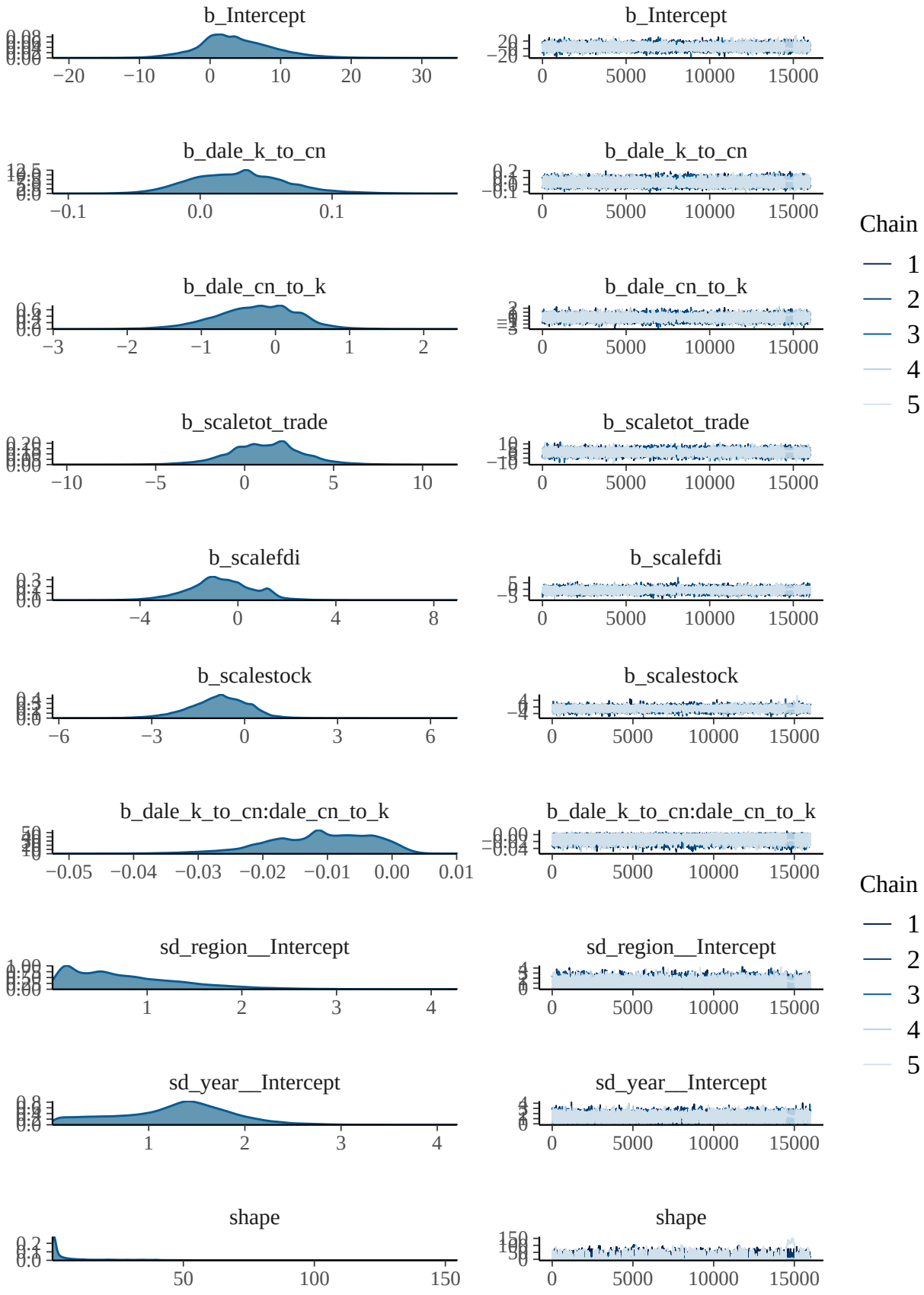
where the two ηs refer to the random intercepts for region and years respectively, γ refers to the zero inflation parameter of the ZINB, and τ refers to the probability of success. A strong prior of $\eta \sim N(0, 1)$ is imposed for computational purposes, as in prior runs the ηs tend to drift around very large numbers.

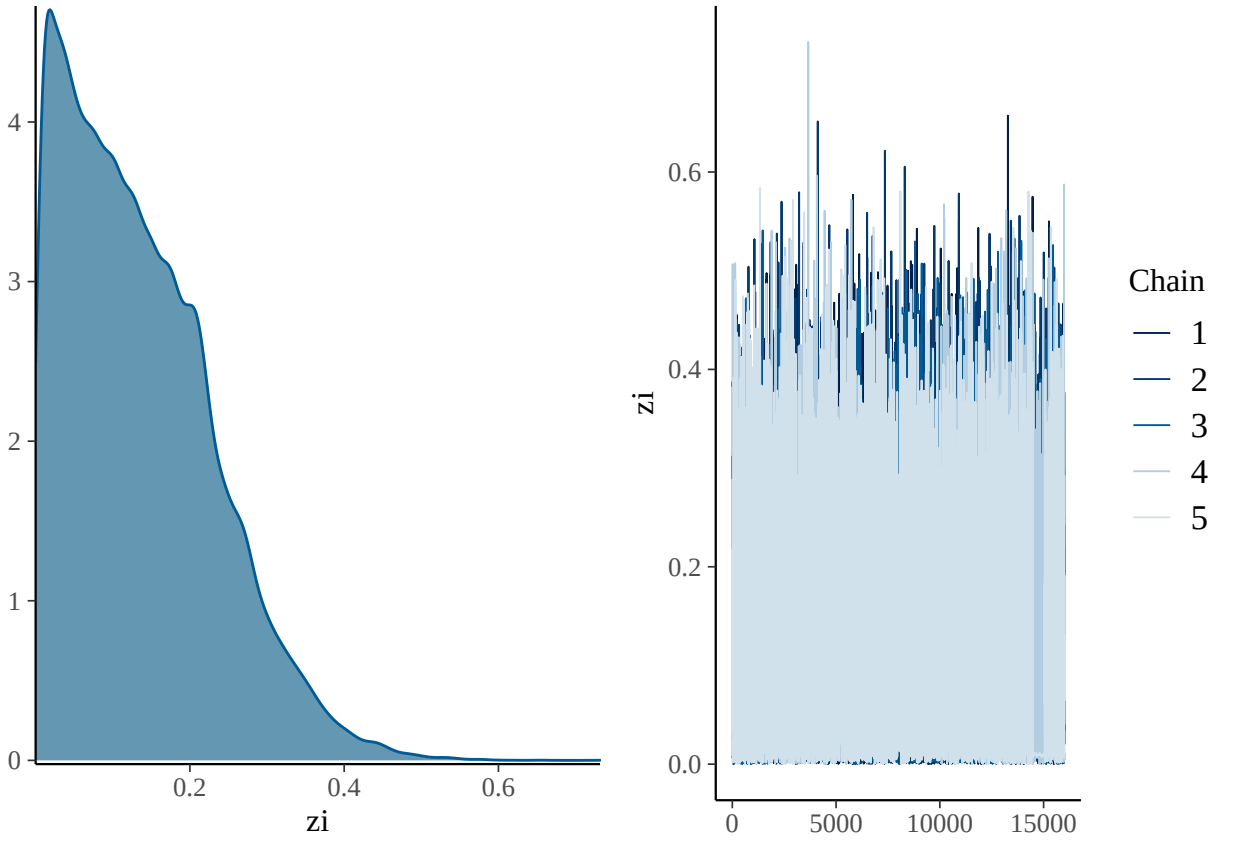
I also had to drop the event dummies because they would lead to the problem of complete separation. Both Frequentist and Bayesian estimation failed after including the event dummies. Considering that from the frequentist estimation none of the event dummies achieved statistical evidence, dropping these should not affect effect estimation.

Point Estimates and Critical Intervals

	Mean Number of Protests	
Predictors	Incidence Rate Ratios	CI 95%
Intercept	23.51	0.00–3350298.55
Dependence	1.03	0.97-1.11
UEI	0.80	0.25-2.09
Trade Volume	3.37	0.05-195.38
FDI	0.49	0.03-5.82
Stock Market Integration	0.46	0.06-2.28
UEI * Dependence	0.99	0.97-1.00
Random Effects		
σ^2	677.90	
τ_{00}	243.32	
ICC	0.80	
N Region	2	
N Year	18	
Observations	34	
Marginal R2/ Conditional R2	0.119/ 0.628	

Coefficient Distribution and MCMC Convergence

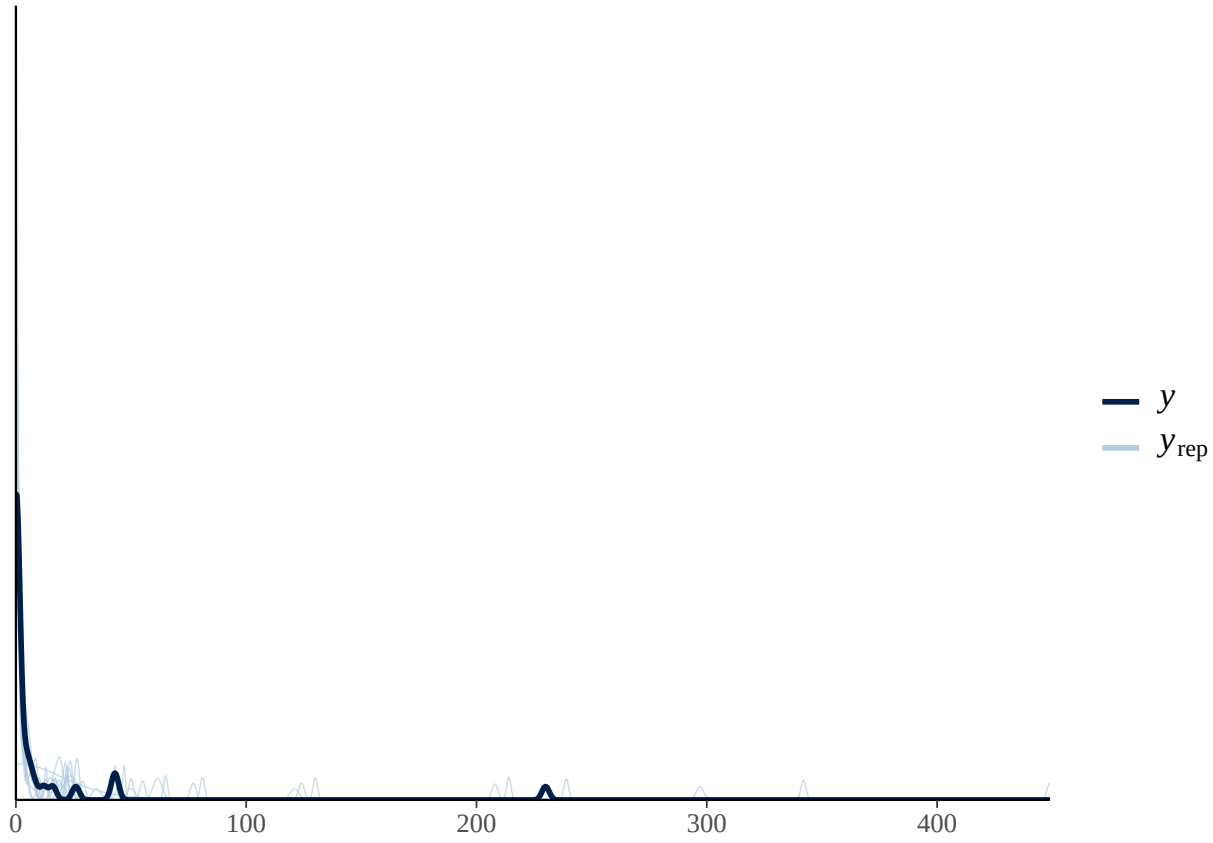




Note that the ZINB would run into computational issues if we variables are measured on drastically different scales. This is particularly the case for total trade volume, FDI and stock market joint movement which are measured in large quantities. To avoid this, I mean-centered these variables. Here, `dale_k_to_cn` refers to the Trade Intensity Index (TTI) for a region towards China; `dale_cn_to_k` refers to the TTI for China towards a peripheral region; `scaletot_trade` refers to the total trade volume in goods at the regional level; `scalefdi` refers to the FDI volume at the regional level; `scalestock` refers to the stock market joint movement in a particular region.

In this model, the MCMC chains have converged and remained stationary in the last 10000 samples from the posterior. This suggests that the model has converged well.

Posterior Predictive Check



The Posterior Predictive Check allows us to compare the predicted mean numbers of protest drawn from the posterior (y_{rep}) to the observed value y. In this plot we can see the posterior behaved quite well, with a minor exception that it tends to predict the mean number to be around 50 whereas the observed distribution has no cases in which this is true.

A6: Models including GDP

The above table presents the results of table 2 when we include log GDP per capita, using data from the Penn's World Table 7.1.

It is true that in model 5, our interaction variable between dependence and UEI lost statistical significance, but note that the effect is still in the expected direction. In addition, I suspect the lost significance is due to high multicollinearity between Log GDP per capita and total trade. The following Variance Inflation Factor (VIF) values suggest that this is true, as log GDP per capita has a highly inflated VIF value at 18.475, which far surpasses the rule of thumb for no multicollinearity at 10. Furthermore, the correlation between log GDP per capita and total trade volume is at a whopping `0.808`, which suggests that we would not be

Table 20: Estimation by multivariate regression

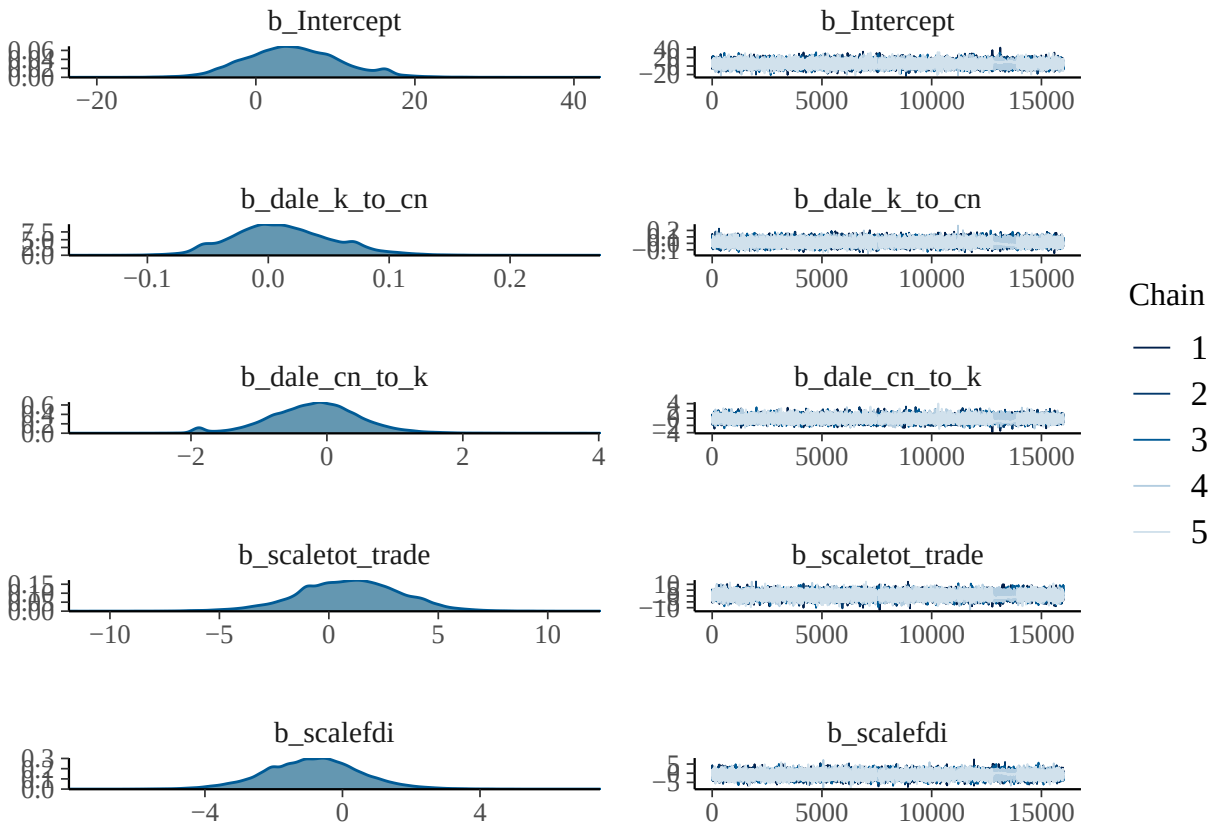
	Percentage of people not confident in the 1C2S		
	(1)	(2)	(3)
Dependence	−0.023 (0.019)	0.001 (0.018)	0.024 (0.034)
UEI	1.209** (0.466)	1.703** (0.565)	3.343* (1.324)
Trade Volume	0.00003*** (0.00001)	0.00004*** (0.00001)	0.0001*** (0.00001)
FDI			−0.020 (0.017)
Stock Market Joint Movement			−0.001 (0.001)
HZMB			0.564 (3.777)
HK-Shenzhen ERL			2.167 (6.002)
Hengqin Joint Development			−2.334 (4.302)
Log GDP	−10.333*** (2.676)	−8.016*** (2.241)	−11.390*** (3.024)
Dependence * UEI		−0.003* (0.001)	−0.005 (0.003)
Intercept	125.265*** (26.806)	91.308*** (23.170)	114.440*** (29.307)
Observations	43	43	34
Log Likelihood	-142.828	-146.582	-118.114
Akaike Inf. Crit.	301.655	311.164	264.228
Bayesian Inf. Crit.	315.745	327.015	285.597

Note: *p<0.05; **p<0.01; ***p<0.001
Presented are the results estimated by linear mixed-effects regression.
with random intercepts varying by region and year of the observation.
Standard errors are in parentheses.

able to acquire accurate estimates if we were to control for GDP simultaneously having total trade volume as one of our covariates. Given that in the literature the theory is about trade volume with international partners, I decided to go with trade volume instead of log GDP per capita.

dale_k_to_cn	dale_cn_to_k	tot_trade
71.303261	12.576585	45.403527
fdi	stock	bridge_pulse
21.184734	1.925483	1.442674
railway_pulse	henqin_pulse	I(log(rgdpe))
1.365854	1.363824	18.475142

dale_k_to_cn:dale_cn_to_k 22.857222


b_Intercept
b_Intercept
b_dale_k_to_cn
b_dale_k_to_cn
b_dale_cn_to_k
b_dale_cn_to_k
b_scaletot_trade
b_scaletot_trade
b_scalefdi
b_scalefdi
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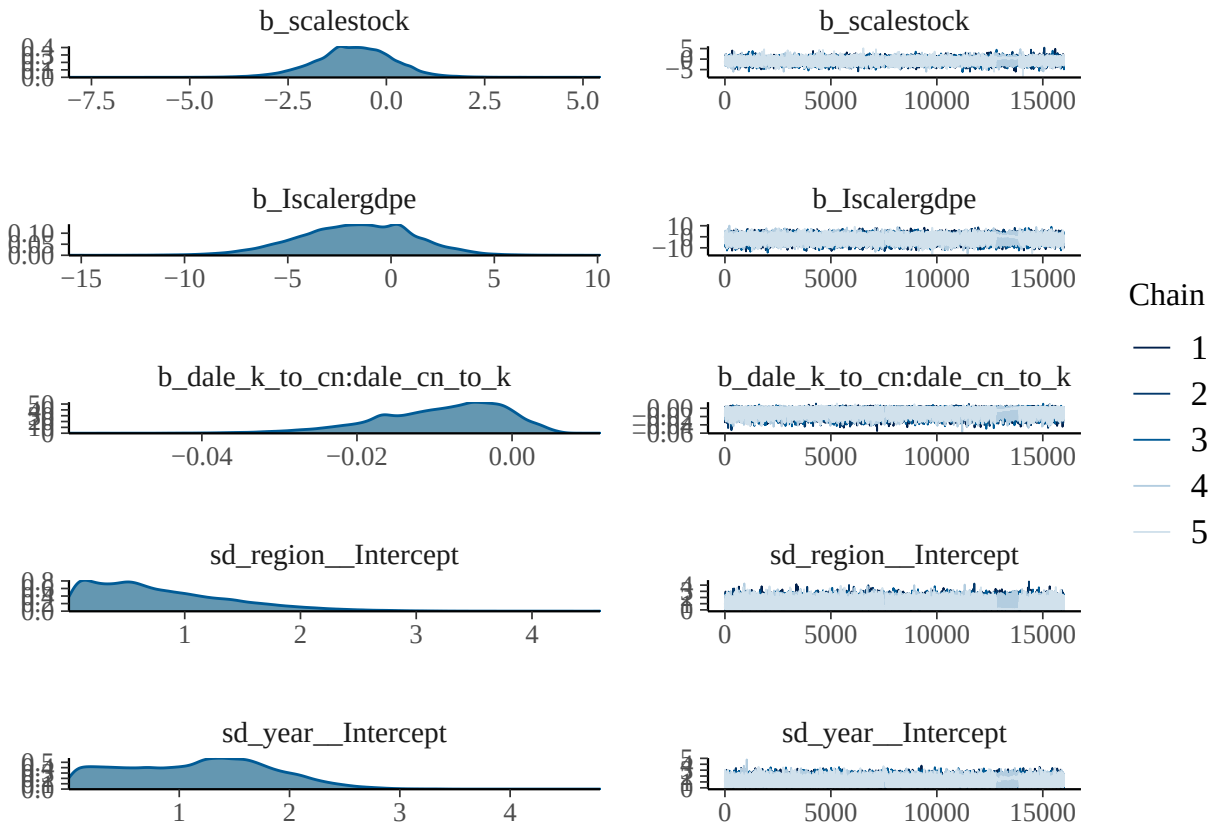
b_scalestock
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b_dale_k_to_cn:dale_cn_to_k
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sd_year__Intercept
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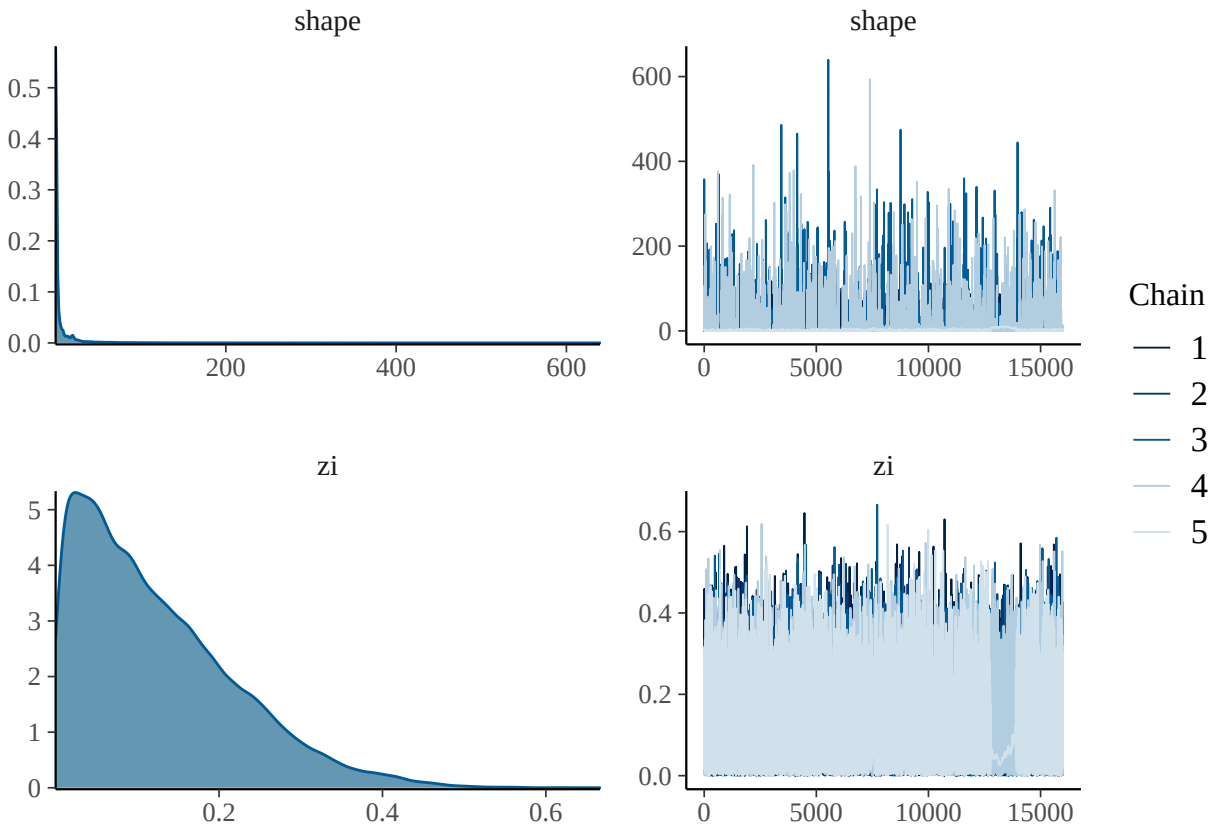
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0.2
0.1
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400
600
0
5000
10000
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0.6
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0.2
Chain
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A7: Models Including Gini Coefficient

Table 21: Estimation by multivariate regression

	Percentage of people not confident in the 1C2S		
	(1)	(2)	(3)
Dependence	−0.026** (0.008)	−0.003 (0.018)	0.029 (0.034)
UEI	0.236 (0.326)	2.115*** (0.538)	2.794* (1.400)
Trade Volume	0.00002*** (0.00000)	0.00005*** (0.00001)	0.0001*** (0.00002)
FDI			−0.021 (0.016)
Stock Market Joint Movement			0.00003 (0.001)
HZMB			3.756 (4.431)
HK-Shenzhen ERL			4.046 (6.077)
Hengqin Joint Development			−5.037 (4.162)
Gini Coefficient			−168.029* (73.461)
Dependence * UEI		−0.007*** (0.002)	−0.005 (0.003)
Intercept	21.302*** (5.158)	1.012 (19.616)	59.949* (26.477)
Observations	46	46	34
Log Likelihood	-163.822	-163.573	-116.261
Akaike Inf. Crit.	341.644	343.145	260.523
Bayesian Inf. Crit.	354.445	357.774	281.892

Note: *p<0.05; **p<0.01; ***p<0.001
Presented are the results estimated by linear mixed-effects regression.
with random intercepts varying by region and year of the observation.
Standard errors are in parentheses.

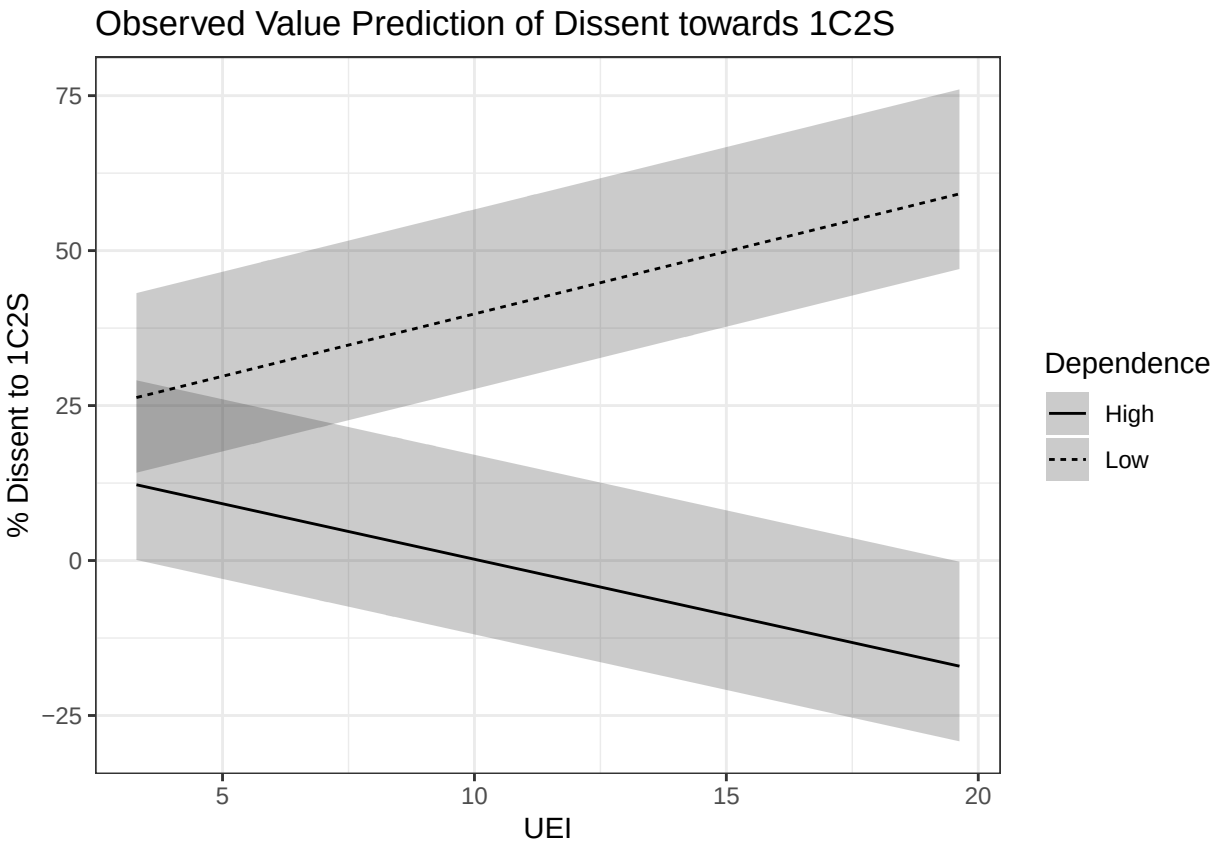
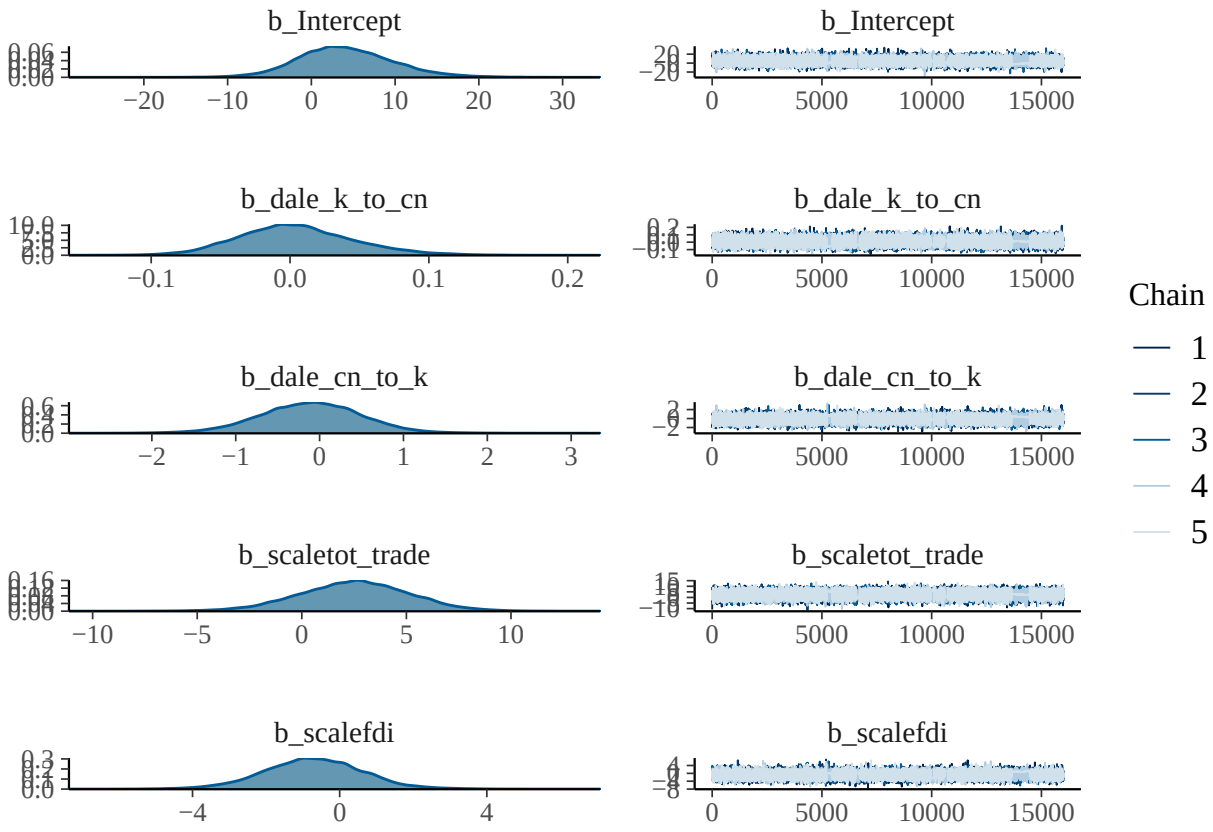


Figure 21: Predicting dissent towards 1C2S


b_Intercept
b_Intercept
b_dale_k_to_cn
b_dale_k_to_cn
b_dale_cn_to_k
b_dale_cn_to_k
b_scaletot_trade
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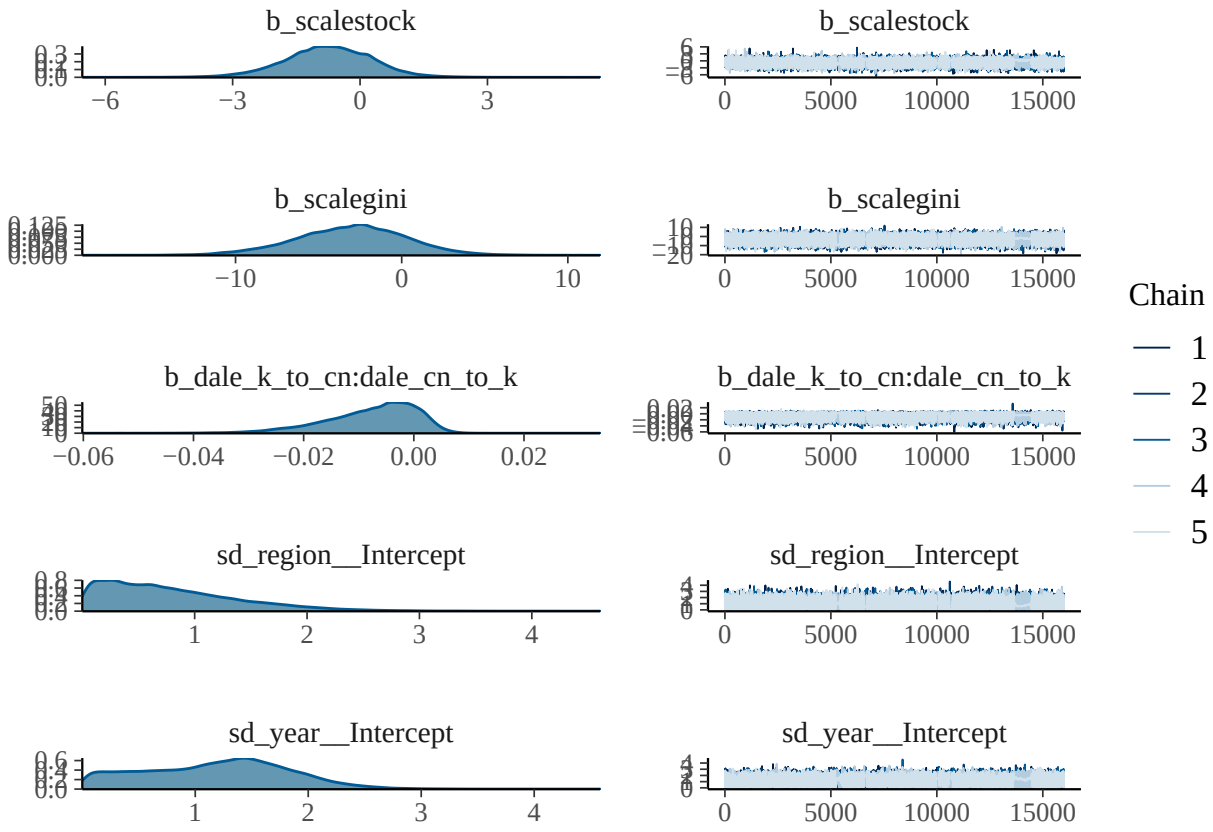
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b_scalegini
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b_dale_k_to_cn:dale_cn_to_k
sd_region__Intercept
sd_region__Intercept
sd_year__Intercept
sd_year__Intercept
Chain
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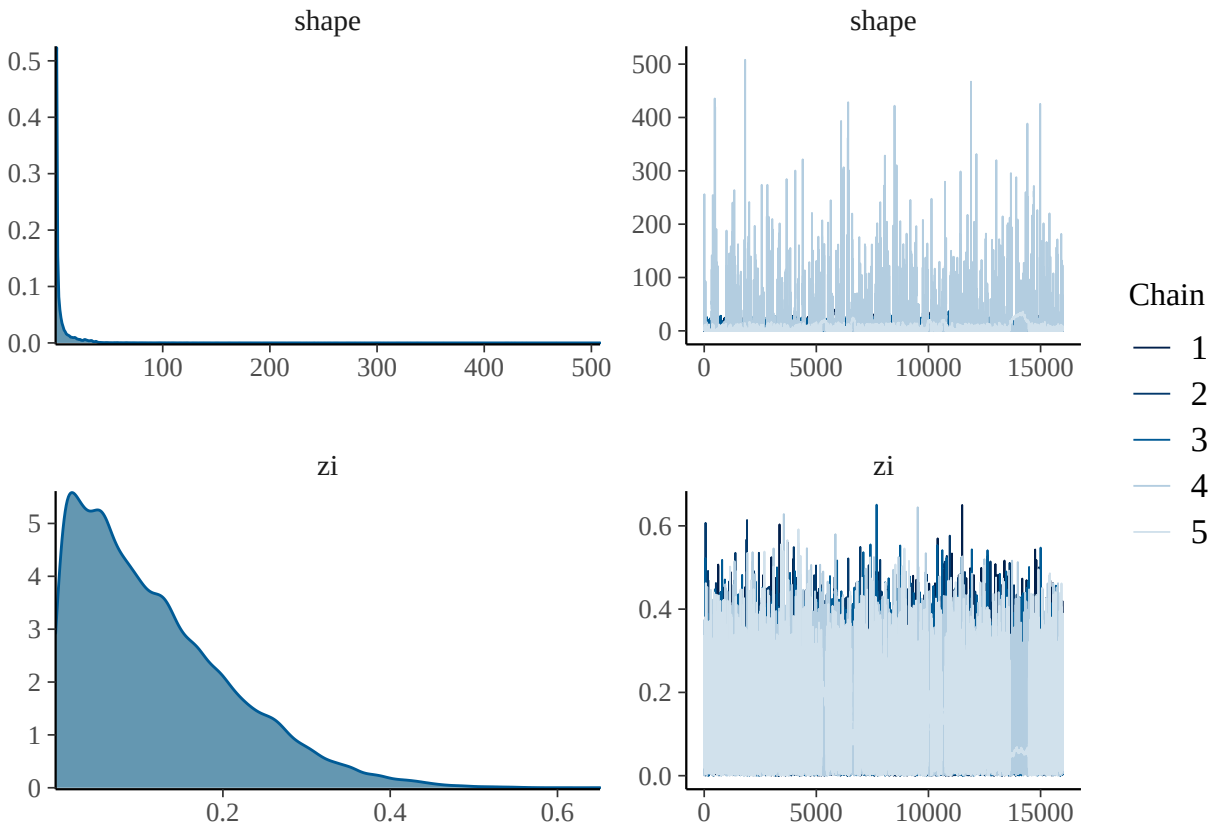


B. Fiscal Decentralization, Economic Dependence and Protests in China, 2000-2019

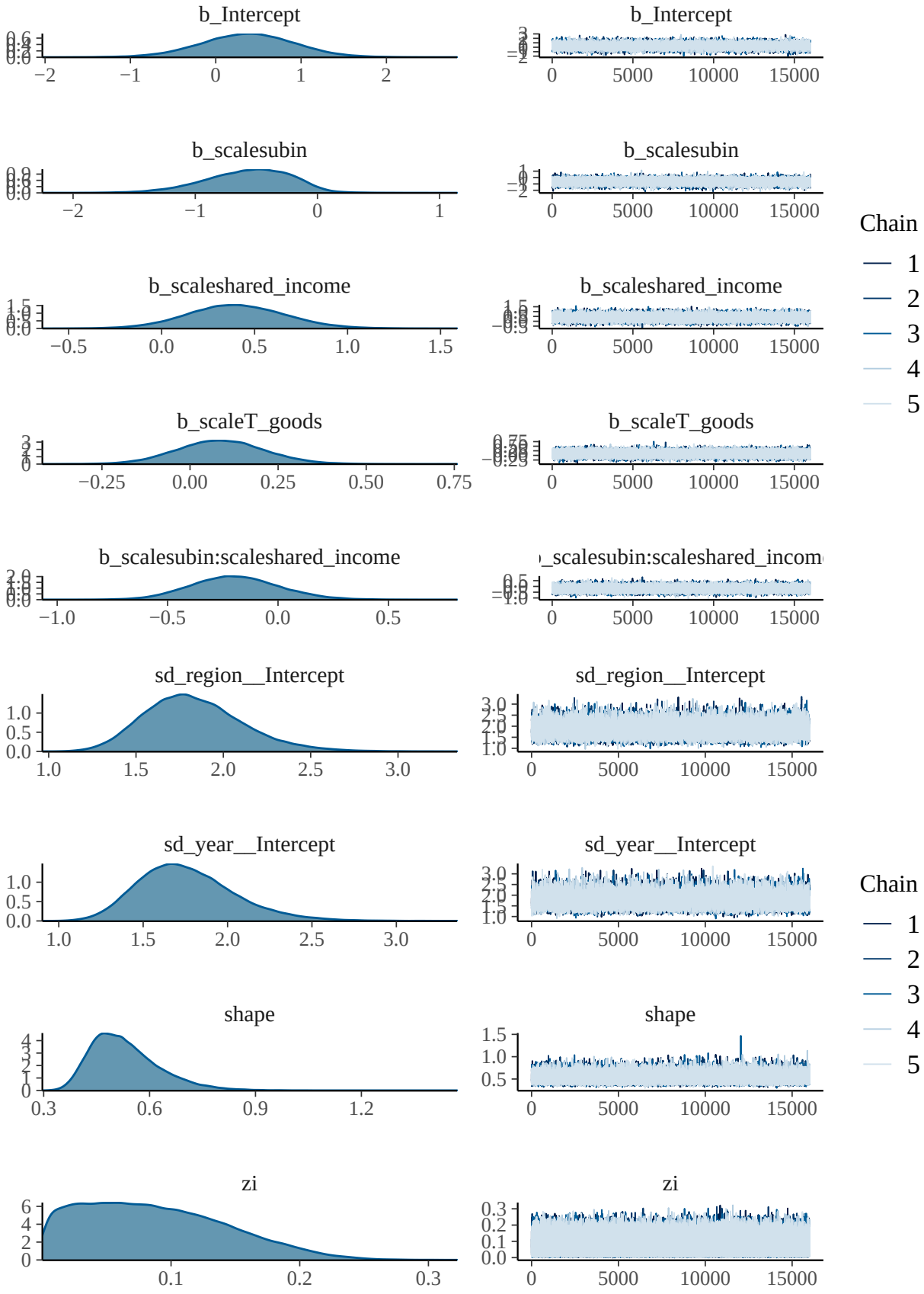
B1: The Model

See Section A5

B2: Point Estimates and Critical Intervals

	Mean Number of Protests	
Predictors	Incidence Rate Ratios	CI 95%
Intercept	1.46	0.49-4.23
UEI	0.58	0.27-1.03
Dependence	1.49	0.91-2.52
Trade Volume	1.09	0.86-1.40
UEI * Dependence	0.82	0.57-1.23
Random Effects		
σ^2	2868.98	
τ_{00}	7.36	
ICC	1.00	
N Year	19	
N Region	31	
Observations	5.88	
Marginal R2/ Conditional R2	0.000 - 0.640	

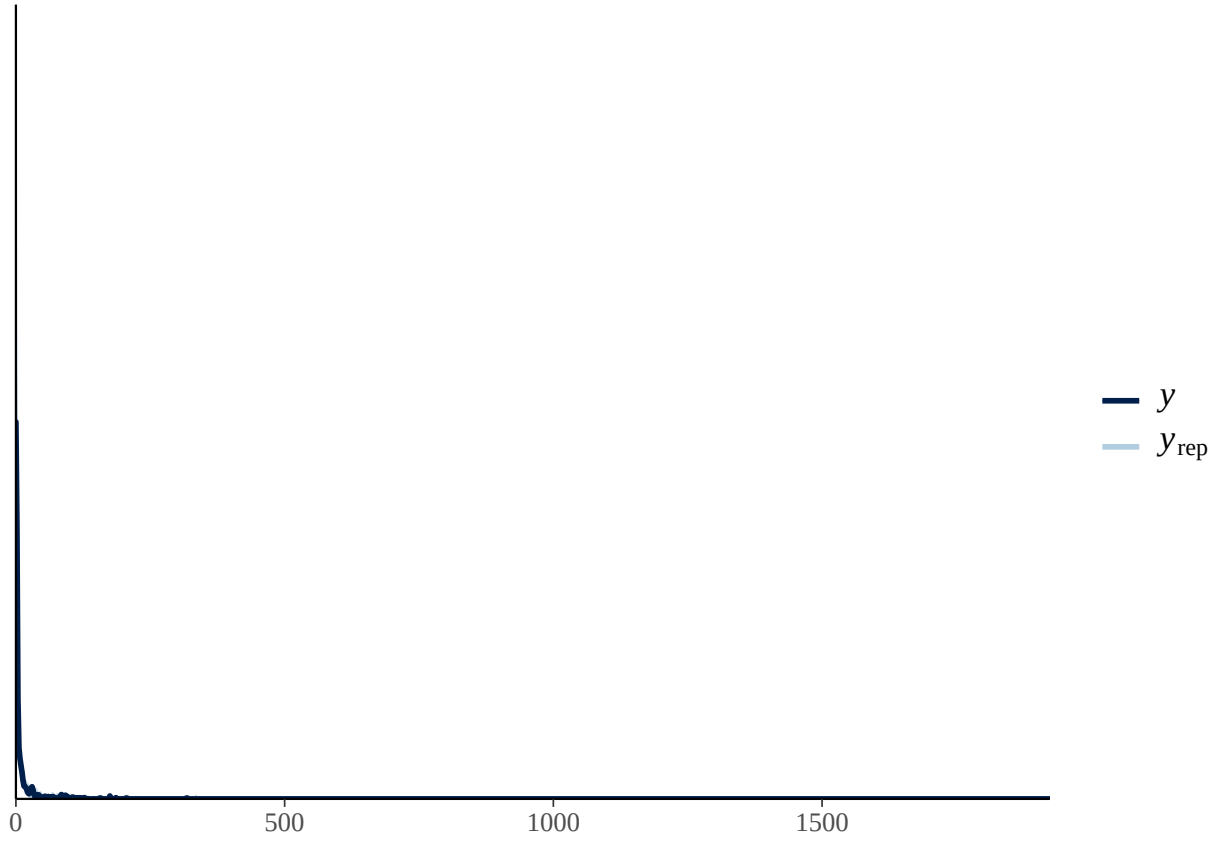
B3: Coefficient Distribution and MCMC Convergence



Again, I mean-centered all variables to ease the computational difficulty for the model. Here, `scalesubin` refers to the subsidies provided by the central government; `scaleshared_income` refers to the total amount of shared income at the provincial level with the central government, `scaleT_goods` refers to the total trade volume in goods at the provincial level.

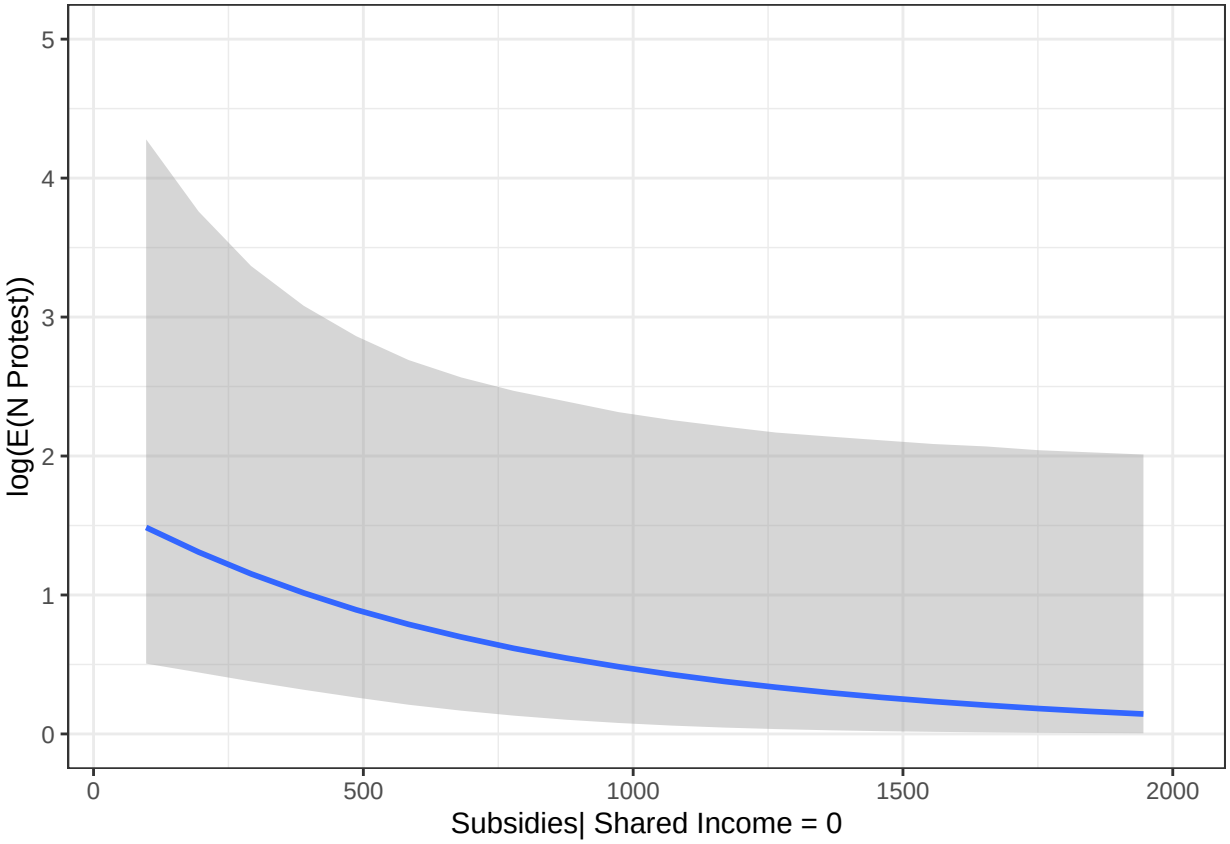
Again, the MCMC chains have achieved stationarity around 10000 samples from the posterior, suggesting that the model has converged.

B4: Predictive Posterior Check



This model has almost correctly predicted all observed counts of protest, thus we should be confident in the accuracy of the posterior draws.

B5: Conditional Effects for Subsidies



Appendix: Can municipal amalgamation lead to a higher voter turnout - the case of Norway

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C. Does municipal amalgamation reduce voter turnout in local elections? A municipal-level analysis

C1. Correlation Matrix

Table 24: Correlation Matrix

	Amalagamation	Population (2015)	Labor Votes (2015)	Center Votes (2015)	Urban Population (2015)
Amalagamation	1	0.303	-0.097	-0.011	-0.459
Population (2015)	0.303	1	-0.026	-0.273	0.074
Labor Votes (2015)	-0.097	-0.026	1	-0.157	0.130
Center Votes (2015)	-0.011	-0.273	-0.157	1	-0.425
Urban Population (2015)	-0.459	0.074	0.130	-0.425	1
Population over 65 (2015)	-0.632	-0.415	0.145	0.176	0.172
Basic Education (2015)	-0.721	-0.426	0.193	-0.009	0.316
Upper Secondary Education (2015)	-0.799	-0.440	0.086	0.147	0.372
Higher Education (2015)	-0.721	-0.072	0.080	-0.165	0.673
Turnout	0.012	-0.111	-0.164	0.224	-0.315
1995	-0.012	-0.005	-0.001	0.0001	-0.002
1999	-0.012	-0.005	-0.001	0.0001	-0.002
2003	-0.012	-0.005	-0.001	0.0001	-0.002
2007	-0.011	-0.005	0.001	-0.001	-0.001
2011	-0.011	-0.005	-0.002	0.001	-0.003
2015	0.037	0.010	0.003	-0.0001	0.006
2019	0.019	0.014	0.001	0.0002	0.003

Table 25: Correlation Matrix (Cont'd)

	Population over 65 (2015)	Basic Education (2015)	Upper Secondary Education (2015)
Amalagamation	-0.632	-0.721	-0.799
Population (2015)	-0.415	-0.426	-0.440
Labor Votes (2015)	0.145	0.193	0.086
Center Votes (2015)	0.176	-0.009	0.147
Urban Population (2015)	0.172	0.316	0.372
Population over 65 (2015)	1	0.852	0.857
Basic Education (2015)	0.852	1	0.786
Upper Secondary Education (2015)	0.857	0.786	1
Higher Education (2015)	0.509	0.482	0.683
Turnout	0.034	-0.092	-0.001
1995	-0.025	-0.010	-0.011
1999	-0.025	-0.010	-0.011
2003	-0.025	-0.010	-0.011
2007	-0.025	-0.010	-0.011
2011	-0.025	-0.010	-0.011
2015	0.073	0.029	0.032
2019	0.048	0.018	0.020

Table 26: Correlation Matrix (Cont'd)

	Higher Education (2015)	Turnout	1995	1999	2003	2007	2011	2015	2019
Amalagamation	-0.721	0.012	-0.012	-0.012	-0.012	-0.011	-0.011	0.037	0.019
Population (2015)	-0.072	-0.111	-0.005	-0.005	-0.005	-0.005	-0.005	0.010	0.014
Labor Votes (2015)	0.080	-0.164	-0.001	-0.001	-0.001	0.001	-0.002	0.003	0.001
Center Votes (2015)	-0.165	0.224	0.0001	0.0001	0.0001	-0.001	0.001	-0.0001	0.0002
Urban Population (2015)	0.673	-0.315	-0.002	-0.002	-0.002	-0.001	-0.003	0.006	0.003
Population over 65 (2015)	0.509	0.034	-0.025	-0.025	-0.025	-0.025	-0.025	0.073	0.048
Basic Education (2015)	0.482	-0.092	-0.010	-0.010	-0.010	-0.010	-0.010	0.029	0.018
Upper Secondary Education (2015)	0.683	-0.001	-0.011	-0.011	-0.011	-0.011	-0.011	0.032	0.020
Higher Education (2015)	1	-0.110	-0.003	-0.003	-0.003	-0.003	-0.004	0.008	0.006
Turnout	-0.110	1	0.026	-0.057	-0.216	0.016	0.144	-0.090	0.175
1995	-0.003	0.026	1	-0.162	-0.162	-0.162	-0.162	-0.171	-0.169
1999	-0.003	-0.057	-0.162	1	-0.162	-0.162	-0.162	-0.171	-0.169
2003	-0.003	-0.216	-0.162	-0.162	1	-0.162	-0.162	-0.171	-0.169
2007	-0.003	0.016	-0.162	-0.162	-0.162	1	-0.162	-0.171	-0.169
2011	-0.004	0.144	-0.162	-0.162	-0.162	-0.162	1	-0.171	-0.169
2015	0.008	-0.090	-0.171	-0.171	-0.171	-0.171	-0.171	1	-0.178
2019	0.006	0.175	-0.169	-0.169	-0.169	-0.169	-0.169	-0.178	1

C2. DID assumptions check

For the DID design to work, there should be parallel trends: the trend of voter turnout between amalgamated and un-amalagamted municipalities should be parallel to each other before the reform, and the change in voter turnout should only occur after reform. This assumption could be violated if the difference in voter turnout had already occurred before treatment assignment.

Figure 18 illustrates the trends of the amalgamated and control municipalities over time. The error bars indicate the 95% Confidence Interval of the turnout rate. We see that from 2011-2015, the turnout for the merged and unmerged municipalities are parallel to each other, so the parallel trends assumption holds.

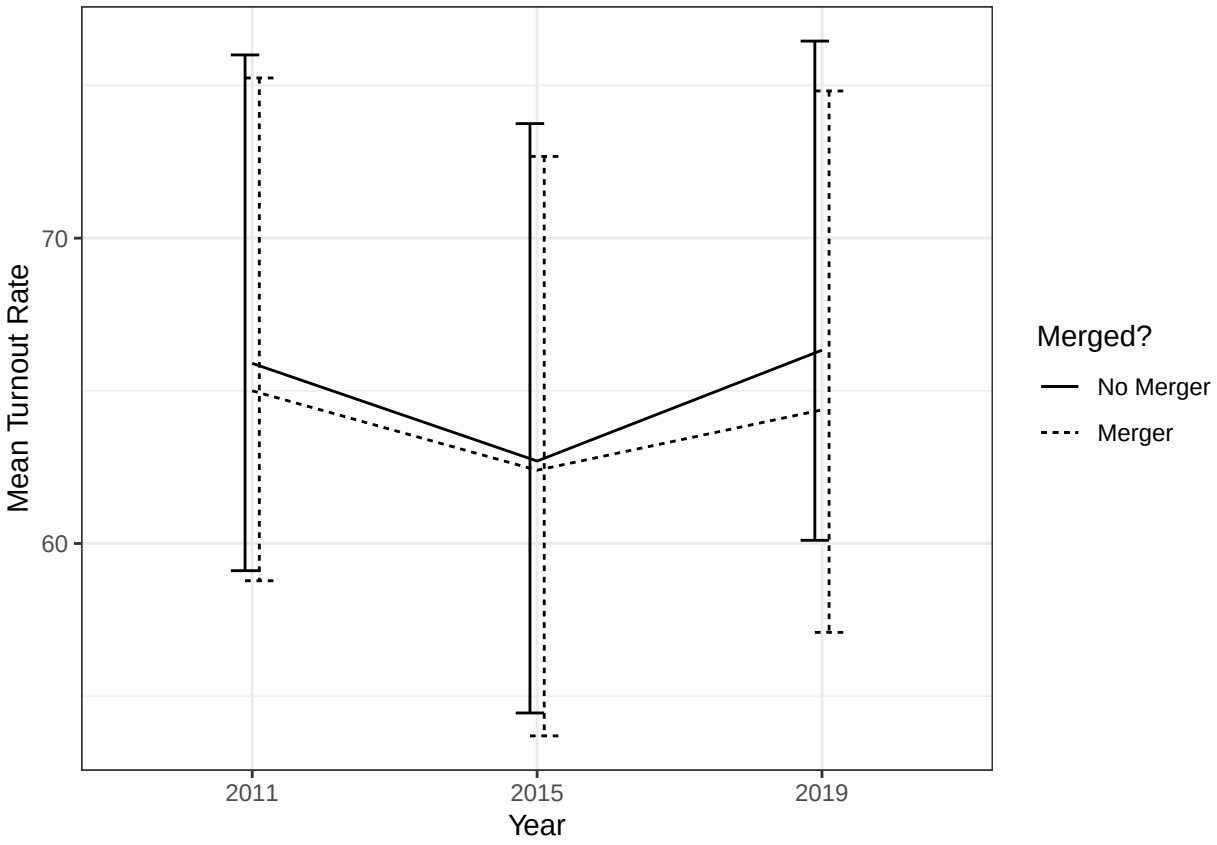
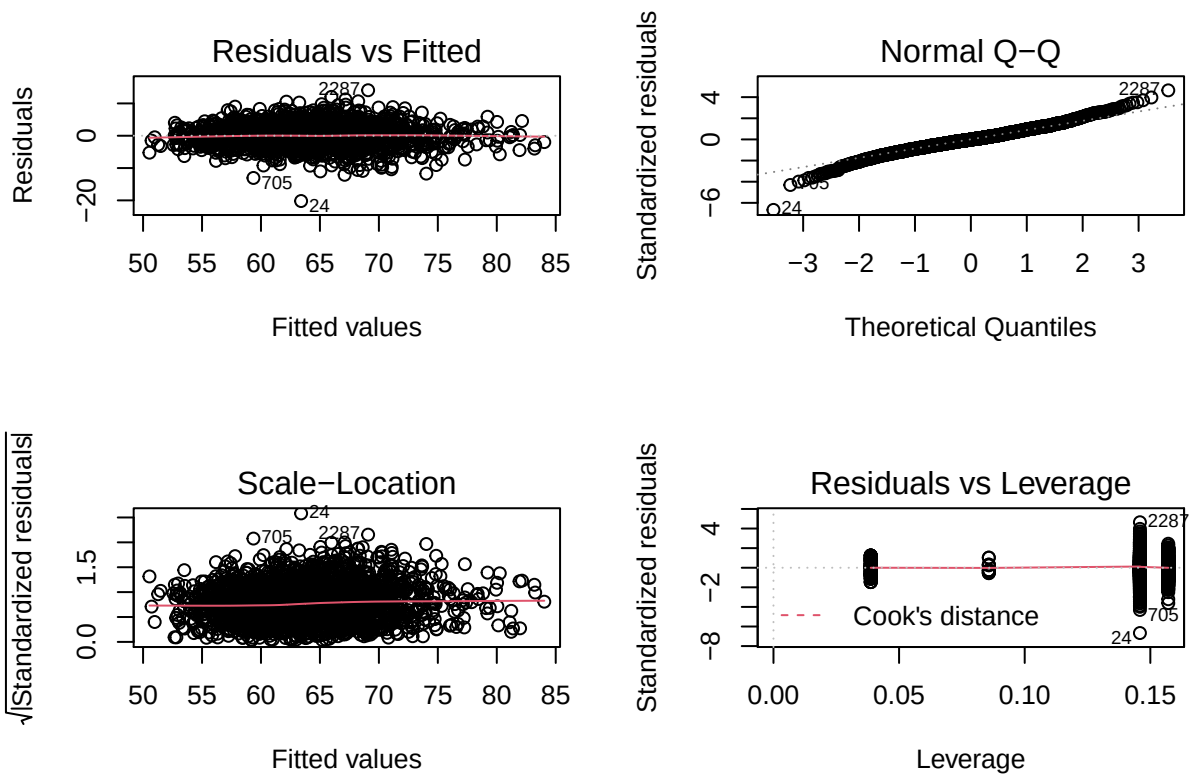


Figure 18: Testing the Parallel Trends Assumption

C3. Model Diagnostics



The above plots help us diagnose any problems that might violate the assumption of OLS. First, the fitted values/ residuals plots (upper left & lower left panels) help us test for heteroskedasticity in the errors. If the plot shows a particular correlation between the fitted values and the residuals, then the errors are hetereoskedastic and must be corrected. These plots show no particular correlation between the fitted values and the residuals, so we have no evidence showing heteroskedasticity in the Dynamic DID model presented.

The upper right hand panel shows the quantile-to-quantile (QQ plots). These plots compare the residuals estimated in the model against the theoretical quantiles found in a normal distribution. This helps us diagnose the fit of the residuals to a normal distribution. OLS assumes that errors are distributed normal, so if the errors are not distributed normal, an alternative error structure must be specified to estimate the model. In the model we see that most values fall on the diagonal line in the plot, which suggests that the errors are distributed normal. There are 2-3 outliers in the models above, but given that our N is much larger, this does not constitute a problem for inference.

The discussion of outliers brought us to the bottom right panel. These residuals/leverage plots help us diagnose influential observations. If an observation is highly influential in the dataset and that there are high

levels of errors (i.e. high residuals), then this observation would be influential for model estimation. Influential outliers for the error term should be dropped. In the model we see that residuals could get as high as +4 or -4, but their leverage is quite low at around 0.15. While they are large residuals, they are not influential enough on our results to warrant action. Therefore there is no adjustment required for these observations.

C4. Effects of Sister Municipality

Table 27: Predicting Voter Turnout in the 2019 Norwegian Local Election

	Dependent variable:
	Turnout
Sister Municipality	−0.623 (1.402)
1999	−2.237 (1.402)
2003	−4.633** (1.402)
2007	−1.390 (1.402)
2011	0.623 (1.402)
2015	−3.420* (1.402)
2019	−1.344 (1.402)
Sister Municipality * 1999	1.833 (1.983)
Sister Municipality * 2003	1.917 (1.983)
Sister Municipality * 2007	2.427 (1.983)
Sister Municipality * 2011	0.990 (1.983)
Sister Municipality * 2015	1.877 (1.983)
Sister Municipality * 2019	2.681 (1.983)
Intercept	66.103*** (0.991)
Observations	420
R^2	0.090
Adjusted R^2	0.061
Residual Std. Error	5.429 (df = 406)
F Statistic	3.094*** (df = 13; 406)
Note:	p<.10+, p<.05*, p<.01**, p<.001***

C5. Test of Placebo Effect, 2011-2015 Voter Turnout change in Norway

Table 28: Aggregate-level Effects of Amalgamation on Local Voter Turnout in Norway, 2019

Term	Beta	SE	T-Statistic	P Value
Intercept	59.675	1.252	47.647	0***
Amalgamated	3.712	1.805	2.057	0.04*
1999	-1.247	0.275	-4.538	0***
2003	-3.509	0.275	-12.774	0***
2007	-0.156	0.275	-0.570	0.569
2011	1.809	0.275	6.586	0***
2015	-1.354	0.275	-4.929	0***
2019	2.649	0.275	9.641	0***
Amalgamated*1999	0.333	0.659	0.506	0.613
Amalgamated*2003	0.204	0.659	0.310	0.757
Amalgamated*2007	-0.009	0.659	-0.013	0.99
Amalgamated*2011	-0.692	0.659	-1.051	0.293
Amalgamated*2015	-1.381	0.659	-2.096	0.036*
Amalgamated*2019	-2.857	0.659	-4.337	0***

Notes: Shown are the beta estimates and their standard errors of a dynamic DID model with municipal-level fixed effects. The municipal-level fixed effects coefficients were not shown for the sake of simplicity.

From Table 28, we see that the DID estimates for 2015 was significant at the p<.05* level. To analyze further whether there is a placebo effect, I regress the turnout levels in each year by amalgamation:

Table 29: Test of a Placebo Effect using Change in Local Voter Turnout, 1999-2015.

	Dependent variable:						
	2019	2015	2011	2007	2003	1999	1995
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Amalgamated	−2.419**	−0.519	−0.174	0.855	1.084	1.089	0.551
	(0.604)	(0.689)	(0.662)	(0.695)	(0.711)	(0.749)	(0.754)
Intercept	67.019**	63.085**	66.293**	64.076**	60.743**	62.995**	64.367**
	(0.275)	(0.324)	(0.282)	(0.295)	(0.302)	(0.318)	(0.320)
Observations	436	444	409	410	411	411	411
R^2	0.036	0.001	0.0002	0.004	0.006	0.005	0.001
Adjusted R^2	0.033	−0.001	−0.002	0.001	0.003	0.003	−0.001
Residual Std. Error	5.106 (df = 434)	6.022 (df = 442)	5.157 (df = 407)	5.415 (df = 408)	5.536 (df = 409)	5.835 (df = 409)	5.876 (df = 409)
F Statistic	16.023** (df = 1; 434)	0.566 (df = 1; 442)	0.069 (df = 1; 407)	1.513 (df = 1; 408)	2.325 (df = 1; 409)	2.114 (df = 1; 409)	0.533 (df = 1; 409)

Note: Presented are estimated beta coefficients of amalgamation on turnout in different years using OLS.
Standard Errors are in parentheses.
p<.10+, p<.05*, p<.01**, p<.001***

From the table above we see that there is no placebo effect of municipal amalgamation. Using the amalgamation treatment to predict the turnout levels in 1999-2019, only the 2019 levels were correlated with amalgamation.

D. How Does municipal amalgamation increase voter turnout in local elections? An individual-level analysis

D1. Descriptive Statistics

Table 30: Descriptive Statistics of Continuous Variables

	N	Mean	SD	Min	Max
Attachment to Municipality	1,227	4.042	0.921	1	5
Reason to vote: Civic Duty	1,227	4.311	0.971	1	5
Reason to vote: Influence Municipal Politics	1,227	4.265	0.861	1	5
Reason to vote: Reward/Punish Local Politicians	1,227	2.835	1.394	1	5
Reason to vote: Reward/Punish National Politicians	1,227	2.794	1.412	1	5
Reason to vote: Safeguard Municipal Interests	1,227	4.330	0.866	1	5
Salience of amalgamation reform	1,227	3.979	1.025	1	5
Politics too complicated	1,227	3.771	1.690	1	7
Political Efficacy	1,227	2.627	0.798	1	5

Table 31: Descriptive Statistics of Binary Variables

	N	Pr(Y=1)
Amalgamation	1,227	0.372
Opposed to Reform	1,227	0.343
Voted	1,227	0.933
Female	1,227	0.473

Table 32: Descriptive Statistics of Categorical Variables

Variable/ Categories	N
Size	
Sparsely Inhabitated Area	129
Village	193
Small/Medium Sized Town	318
Suburbs of a City	282
City	305
County of Residence	
Akershus	169
Oslo	218
Ã~stfold	48
Vestfold	51
Hedmark	33
Oppland	25
Buskerud	55
Telemark	28
Vest-Adger	42
Aust-Adger	20
Rogaland	108
Hordaland	141
Sogn og Fjordane	17
MÃ¸re og Romsdal	52
TrÃ¸ndelag	124
Nordland	46
Troms	41
Finmark	9
Education	
Finished at most Elementary Education	79
Finished at most Upper Secondary Education	342
Finished some Higher Education	806
Year of Birth	
Born on 1939 or earlier	33
1940-1949	216
1950-1959	286
1960-1969	278
1970-1979	205
1980-1989	115
Born on or after 1990	94

D2. Correlation Matrix

Table 33: Correlation Matrix

	Amalagamation	Population (2015)	Labor Votes (2015)	Center Votes (2015)
Amalagamation	1	0.303	-0.097	-0.011
Population (2015)	0.303	1	-0.026	-0.273
Labor Votes (2015)	-0.097	-0.026	1	-0.157
Center Votes (2015)	-0.011	-0.273	-0.157	1
Urban Population (2015)	-0.459	0.074	0.130	-0.425
Population over 65 (2015)	-0.632	-0.415	0.145	0.176
Basic Education (2015)	-0.721	-0.426	0.193	-0.009
Upper Secondary Education (2015)	-0.799	-0.440	0.086	0.147
Higher Education (2015)	-0.721	-0.072	0.080	-0.165
Turnout	0.012	-0.111	-0.164	0.224
1995	-0.012	-0.005	-0.001	0.0001
1999	-0.012	-0.005	-0.001	0.0001
2003	-0.012	-0.005	-0.001	0.0001
2007	-0.011	-0.005	0.001	-0.001
2011	-0.011	-0.005	-0.002	0.001
2015	0.037	0.010	0.003	-0.0001
2019	0.019	0.014	0.001	0.0002

Table 34: Correlation Matrix (Cont'd)

	Urban Population (2015)	Population over 65 (2015)	Basic Education (2015)
Amalagamation	-0.459	-0.632	-0.721
Population (2015)	0.074	-0.415	-0.426
Labor Votes (2015)	0.130	0.145	0.193
Center Votes (2015)	-0.425	0.176	-0.009
Urban Population (2015)	1	0.172	0.316
Population over 65 (2015)	0.172	1	0.852
Basic Education (2015)	0.316	0.852	1
Upper Secondary Education (2015)	0.372	0.857	0.786
Higher Education (2015)	0.673	0.509	0.482
Turnout	-0.315	0.034	-0.092
1995	-0.002	-0.025	-0.010
1999	-0.002	-0.025	-0.010
2003	-0.002	-0.025	-0.010
2007	-0.001	-0.025	-0.010
2011	-0.003	-0.025	-0.010
2015	0.006	0.073	0.029
2019	0.003	0.048	0.018

Table 35: Correlation Matrix (Cont'd)

	Upper Secondary Education (2015)	Higher Education (2015)	Turnout	1995	1999	2003	2007
Amalagamation	-0.799	-0.721	0.012	-0.012	-0.012	-0.012	-0.011
Population (2015)	-0.440	-0.072	-0.111	-0.005	-0.005	-0.005	-0.005
Labor Votes (2015)	0.086	0.080	-0.164	-0.001	-0.001	-0.001	0.001
Center Votes (2015)	0.147	-0.165	0.224	0.0001	0.0001	0.0001	-0.001
Urban Population (2015)	0.372	0.673	-0.315	-0.002	-0.002	-0.002	-0.001
Population over 65 (2015)	0.857	0.509	0.034	-0.025	-0.025	-0.025	-0.025
Basic Education (2015)	0.786	0.482	-0.092	-0.010	-0.010	-0.010	-0.010
Upper Secondary Education (2015)	1	0.683	-0.001	-0.011	-0.011	-0.011	-0.011
Higher Education (2015)	0.683	1	-0.110	-0.003	-0.003	-0.003	-0.003
Turnout	-0.001	-0.110	1	0.026	-0.057	-0.216	0.016
1995	-0.011	-0.003	0.026	1	-0.162	-0.162	-0.162
1999	-0.011	-0.003	-0.057	-0.162	1	-0.162	-0.162
2003	-0.011	-0.003	-0.216	-0.162	-0.162	1	-0.162
2007	-0.011	-0.003	0.016	-0.162	-0.162	-0.162	1
2011	-0.011	-0.004	0.144	-0.162	-0.162	-0.162	-0.162
2015	0.032	0.008	-0.090	-0.171	-0.171	-0.171	-0.171
2019	0.020	0.006	0.175	-0.169	-0.169	-0.169	-0.169

D3. Matching Results

Table 36: Descriptive Statistics of Continuous Variables

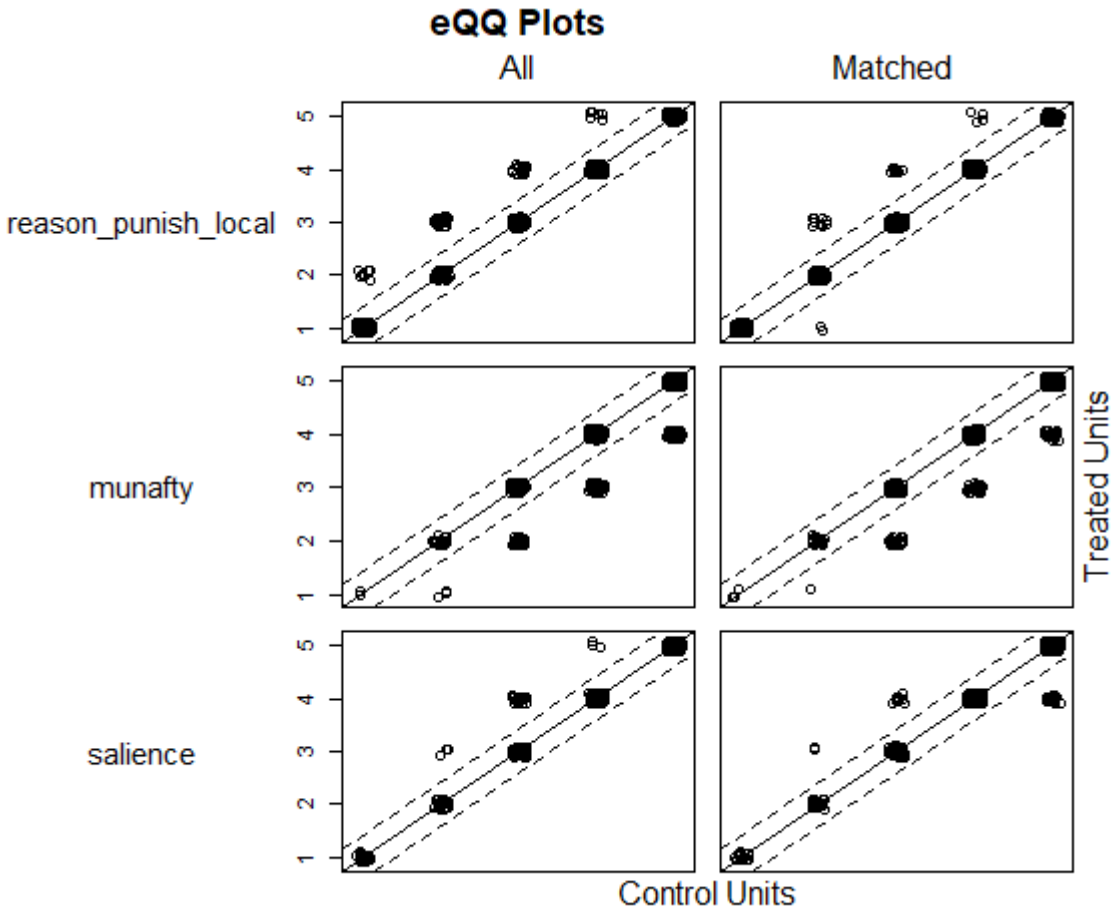
	N	Mean	SD	Min	Max
Attachment to Municipality	914	3.995	0.942	1	5
Reason to vote: Civic Duty	914	4.316	0.968	1	5
Reason to vote: Influence Municipal Politics	914	4.251	0.869	1	5
Reason to vote: Reward/Punish Local Politicians	914	2.891	1.388	1	5
Reason to vote: Reward/Punish National Politicians	914	2.851	1.391	1	5
Reason to vote: Safeguard Municipal Interests	914	4.328	0.874	1	5
Salience of amalgamation reform	914	4.025	1.021	1	5
Politics too complicated	914	3.837	1.684	1	7
Political Efficacy	914	2.638	0.796	1	5

Table 37: Descriptive Statistics of Binary Variables

	N	Pr(Y=1)
Amalgamation	914	0.500
Opposed to Reform	914	0.348
Voted	914	0.931
Female	914	0.474

Table 38: Descriptive Statistics of Categorical Variables

Variable/ Categories	N
Size	
Sparsely Inhabitated Area	90
Village	165
Small/Medium Sized Town	268
Suburbs of a City	233
City	158
County of Residence	
Akershus	168
Oslo	21
Ã~stfold	47
Vestfold	51
Hedmark	3
Oppland	14
Buskerud	54
Telemark	10
Vest-Adger	42
Aust-Adger	11
Rogaland	107
Hordaland	137
Sogn og Fjordane	17
MÃ¸re og Romsdal	52
TrÃ¸ndelag	124
Nordland	25
Troms	26
Finmark	5
Education	
Finished at most Elementary Education	63
Finished at most Upper Secondary Education	271
Finished some Higher Education	580
Year of Birth	
Born on 1939 or earlier	25
1940-1949	162
1950-1959	204
1960-1969	222
1970-1979	152
1980-1989	78
Born on or after 1990	71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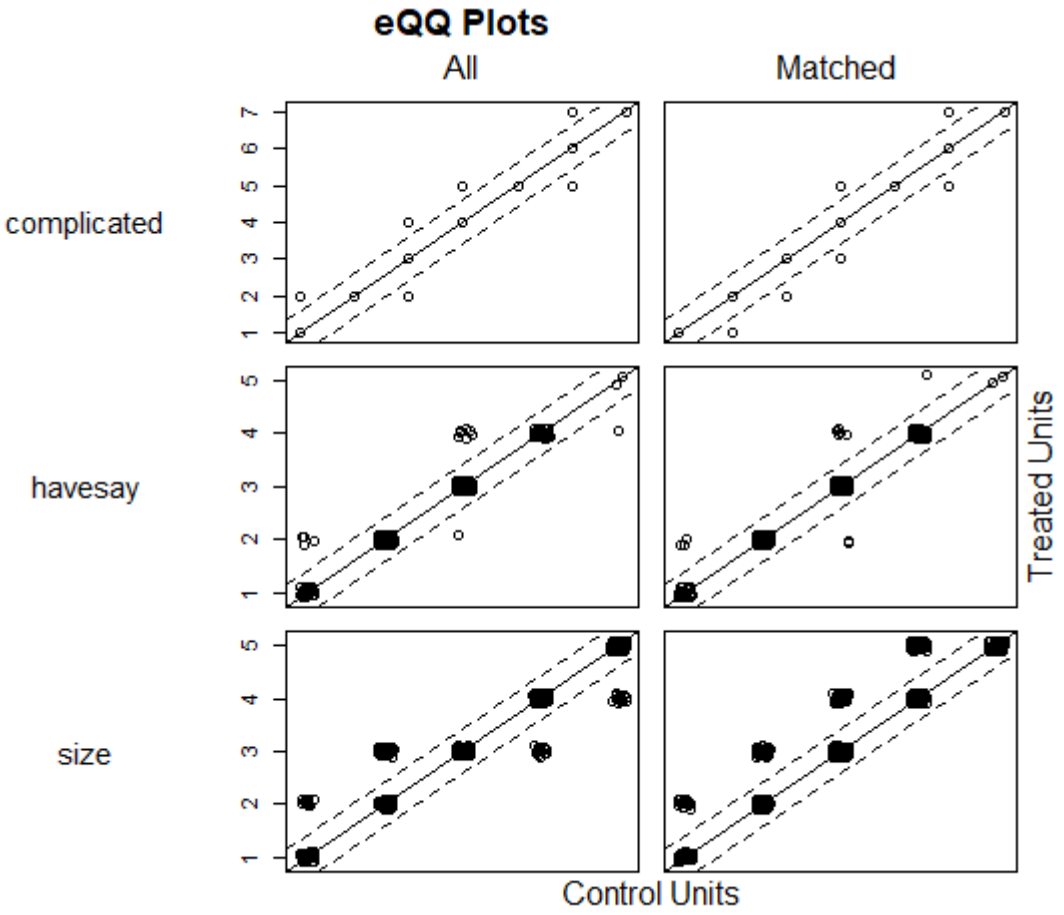
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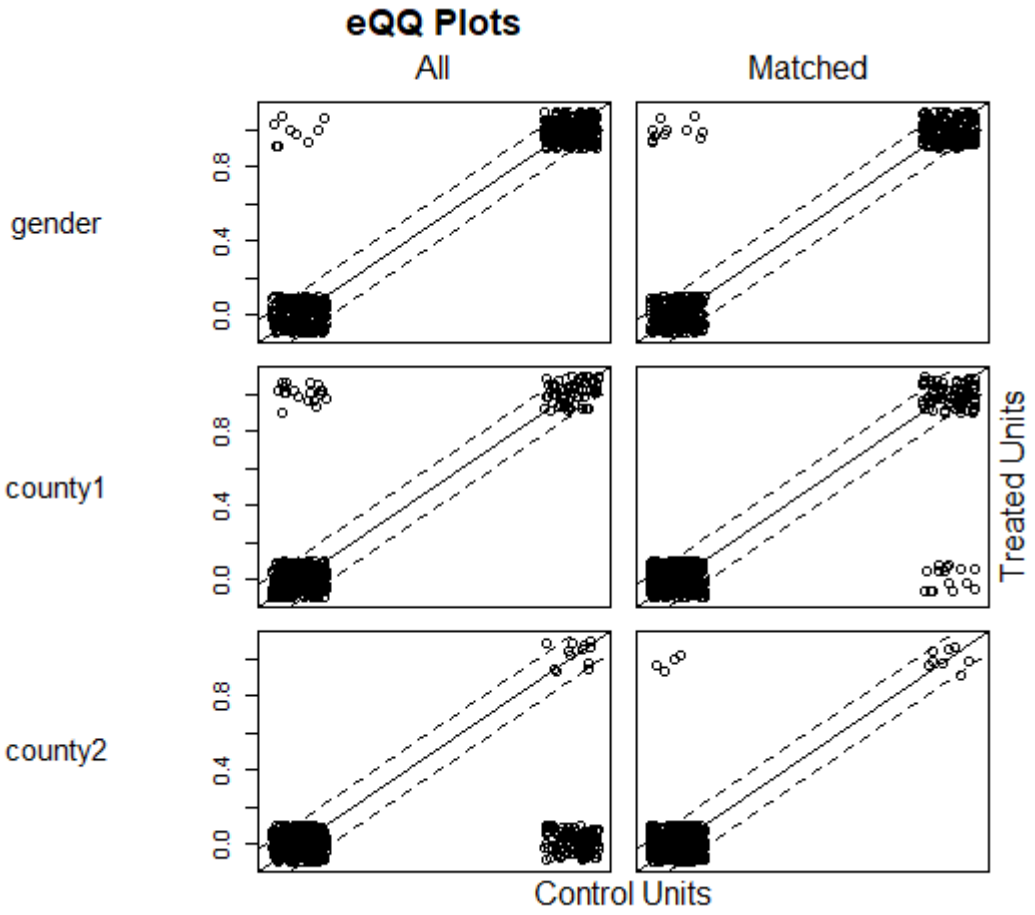
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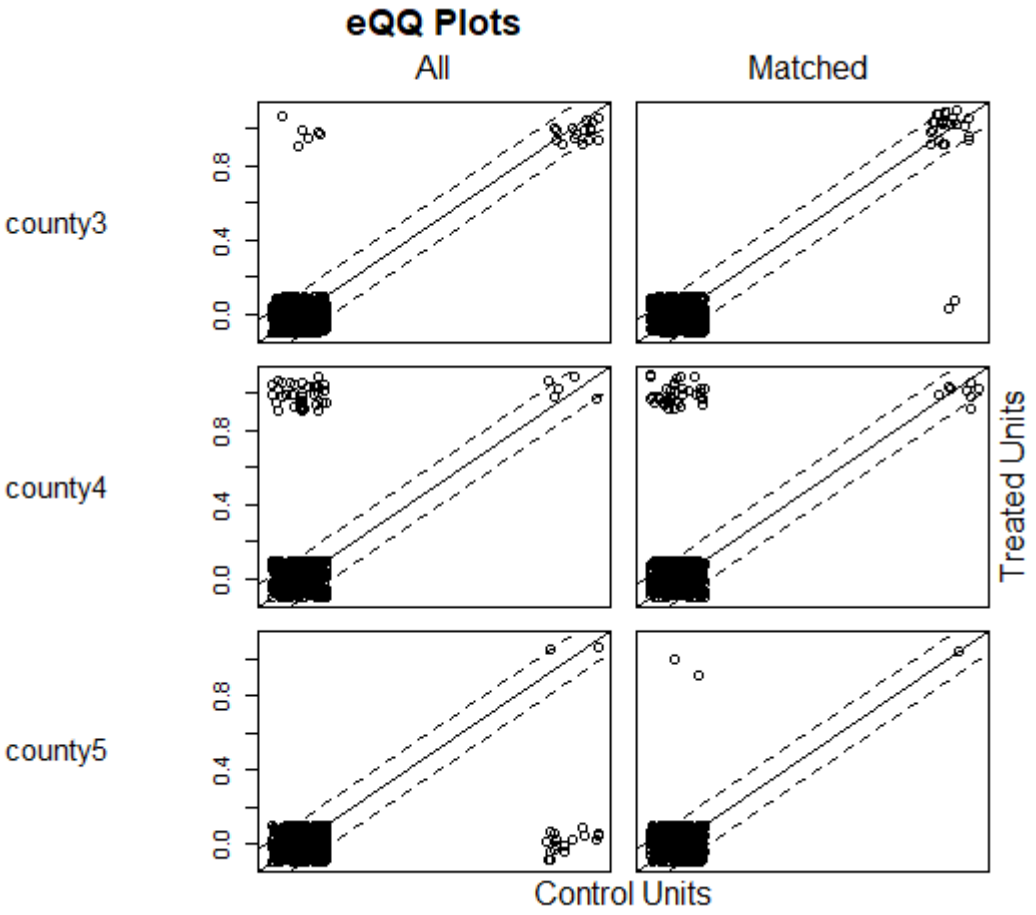
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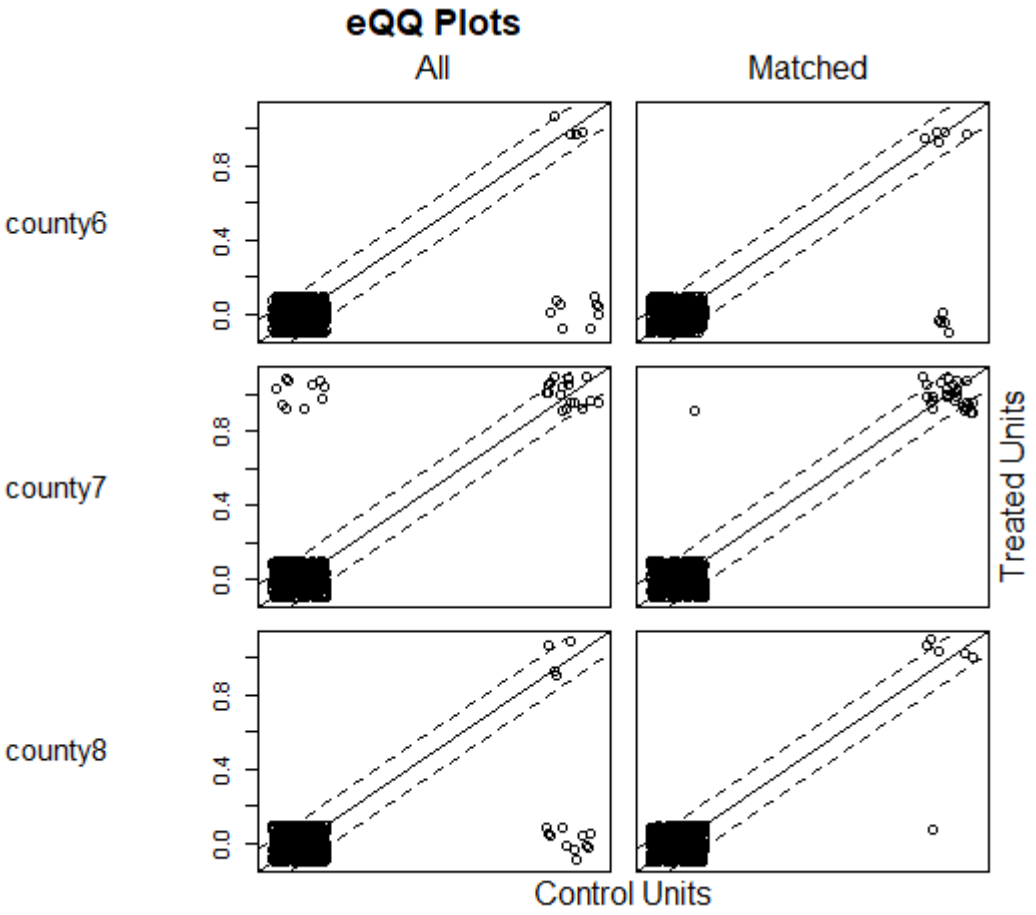
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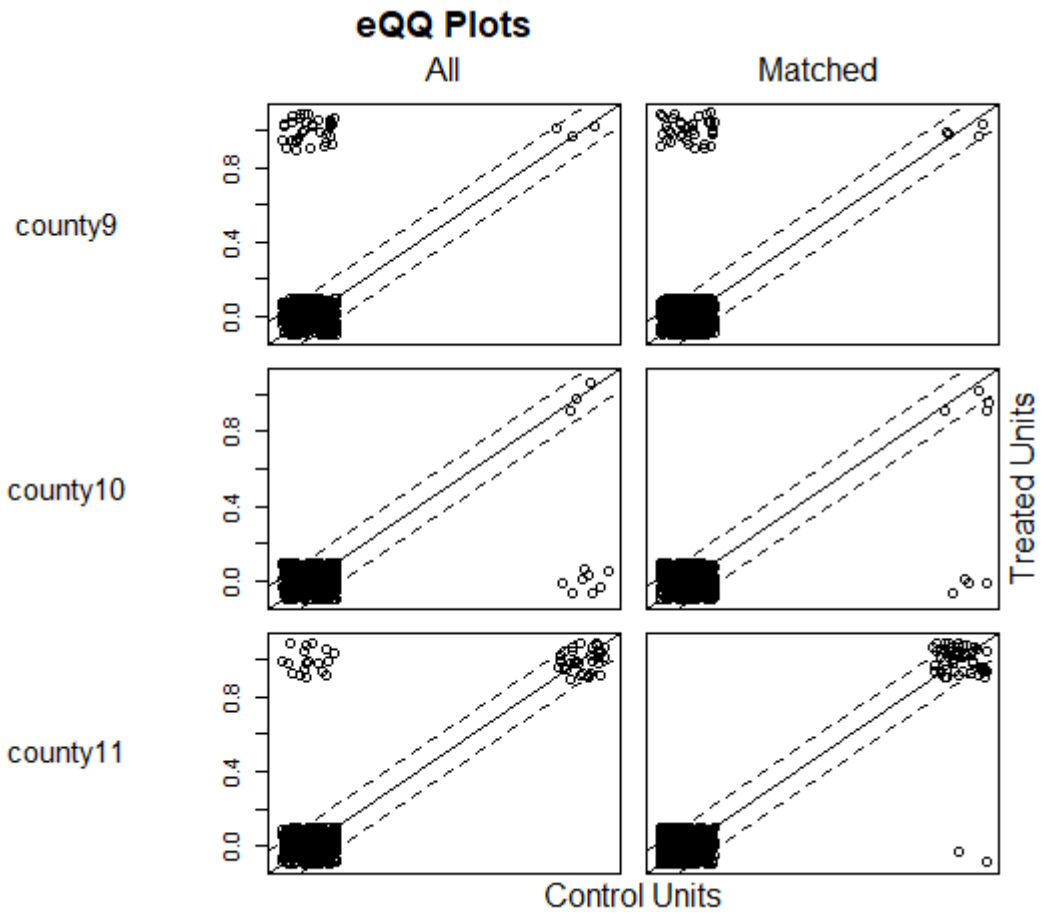
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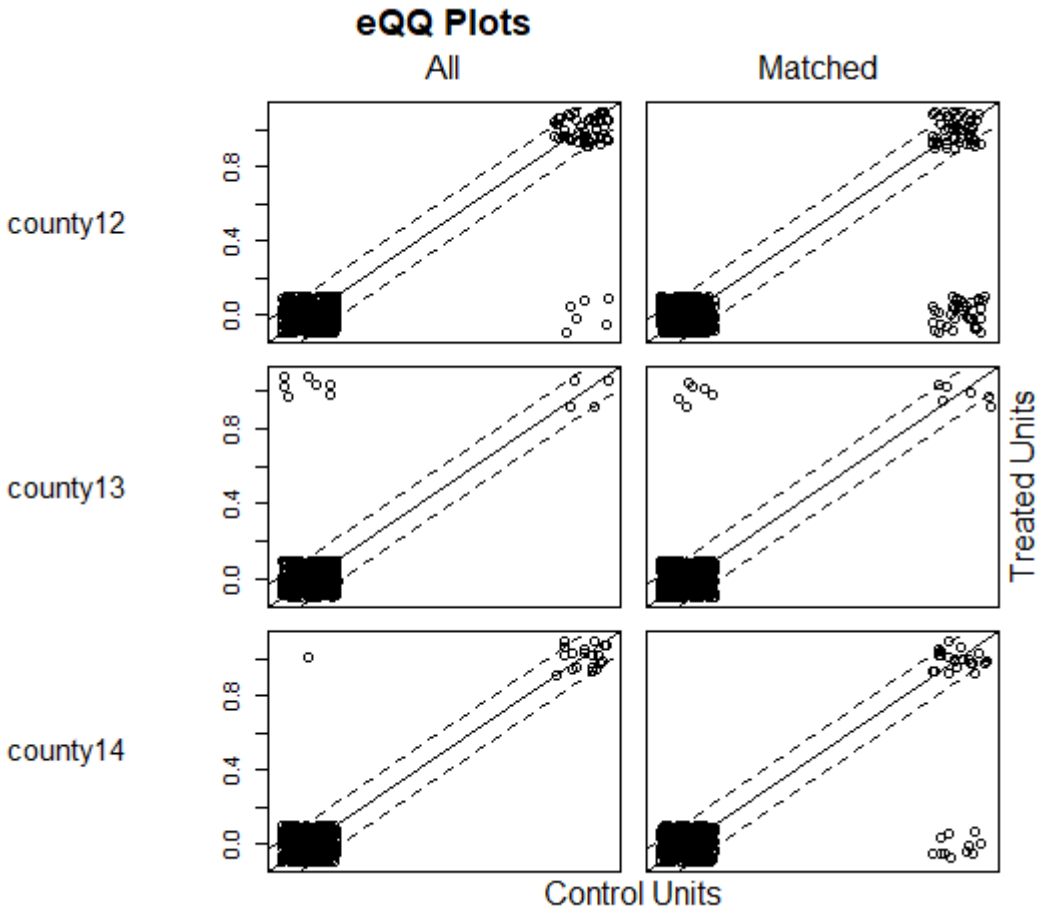
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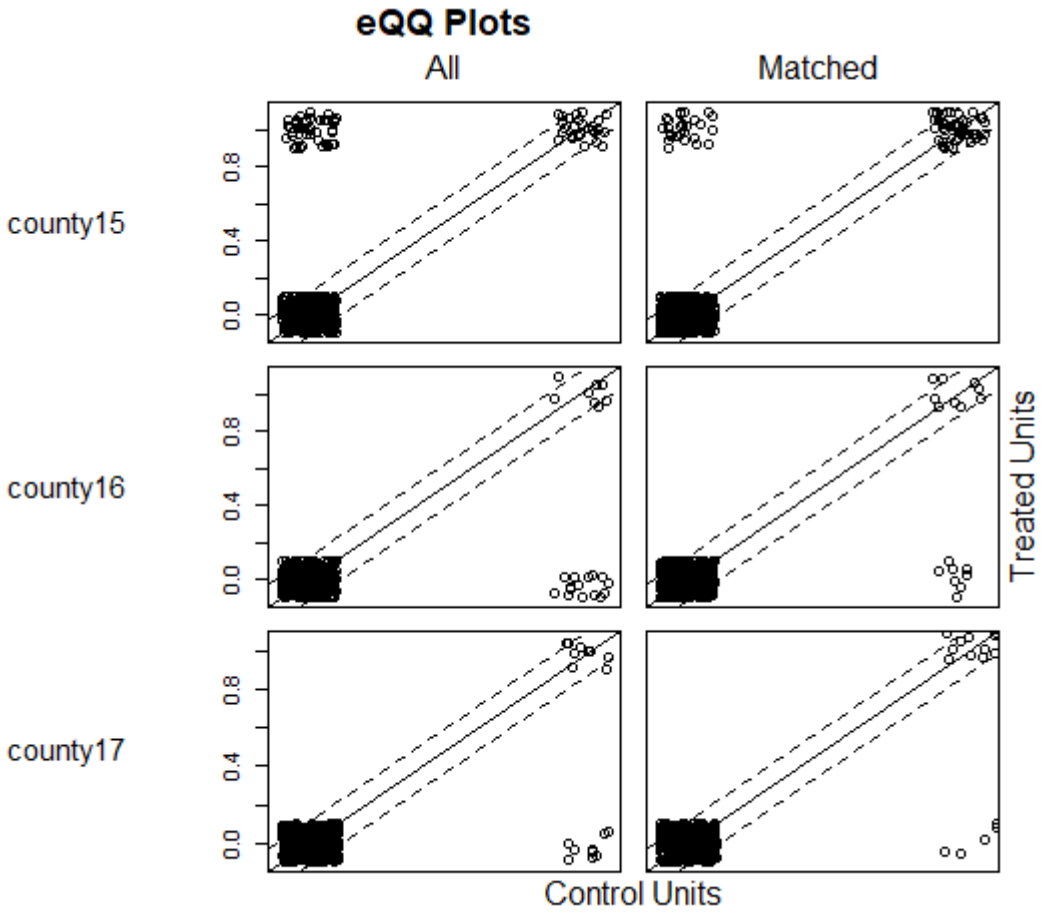
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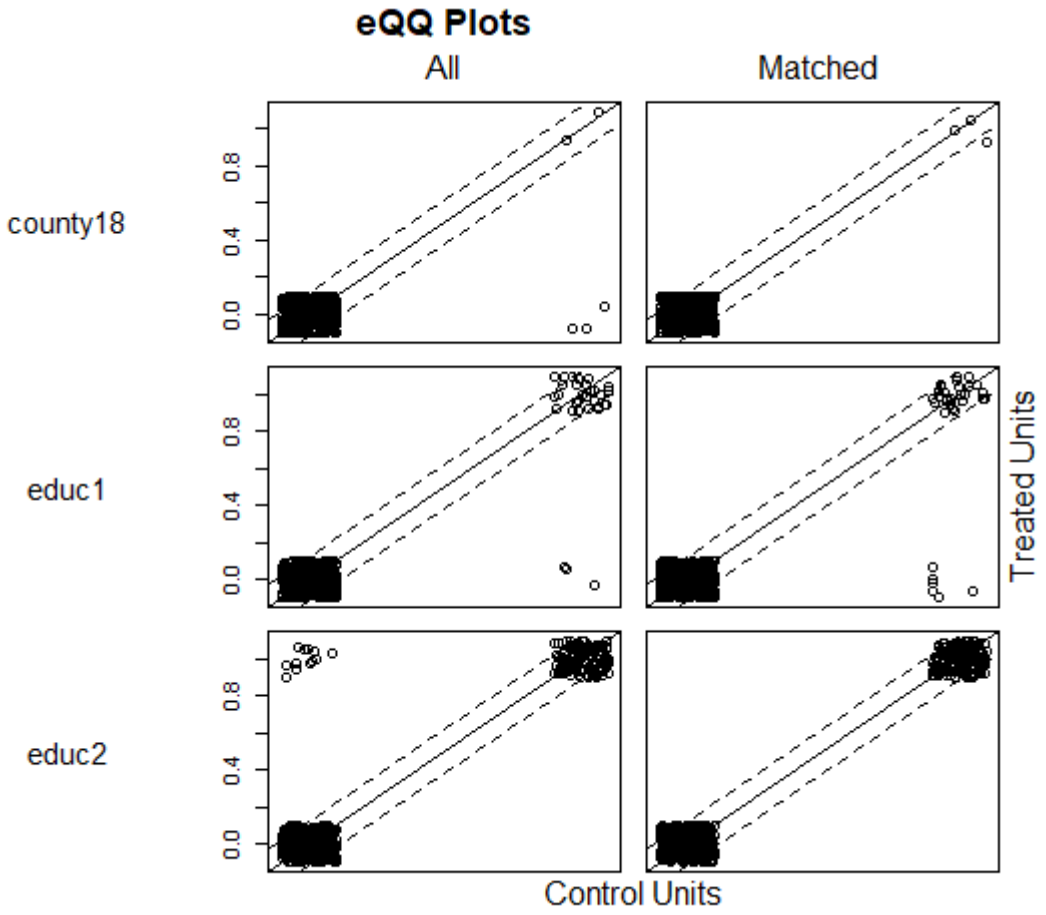
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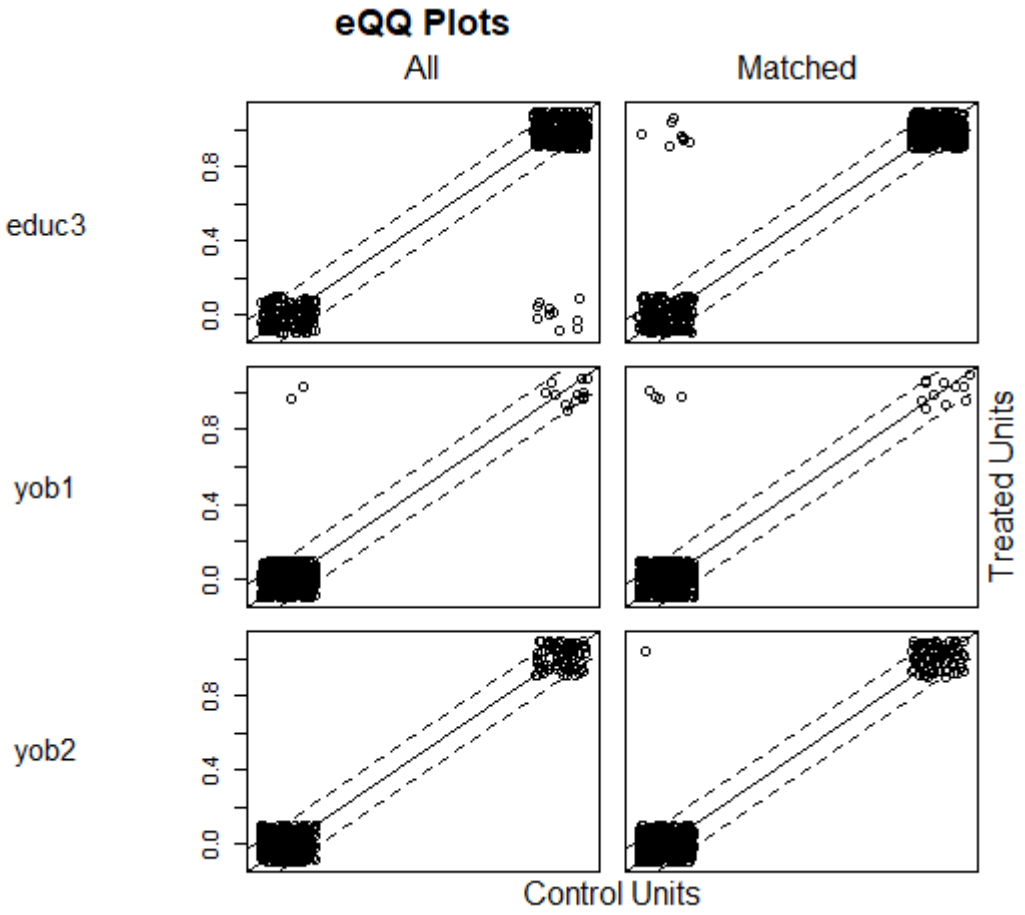
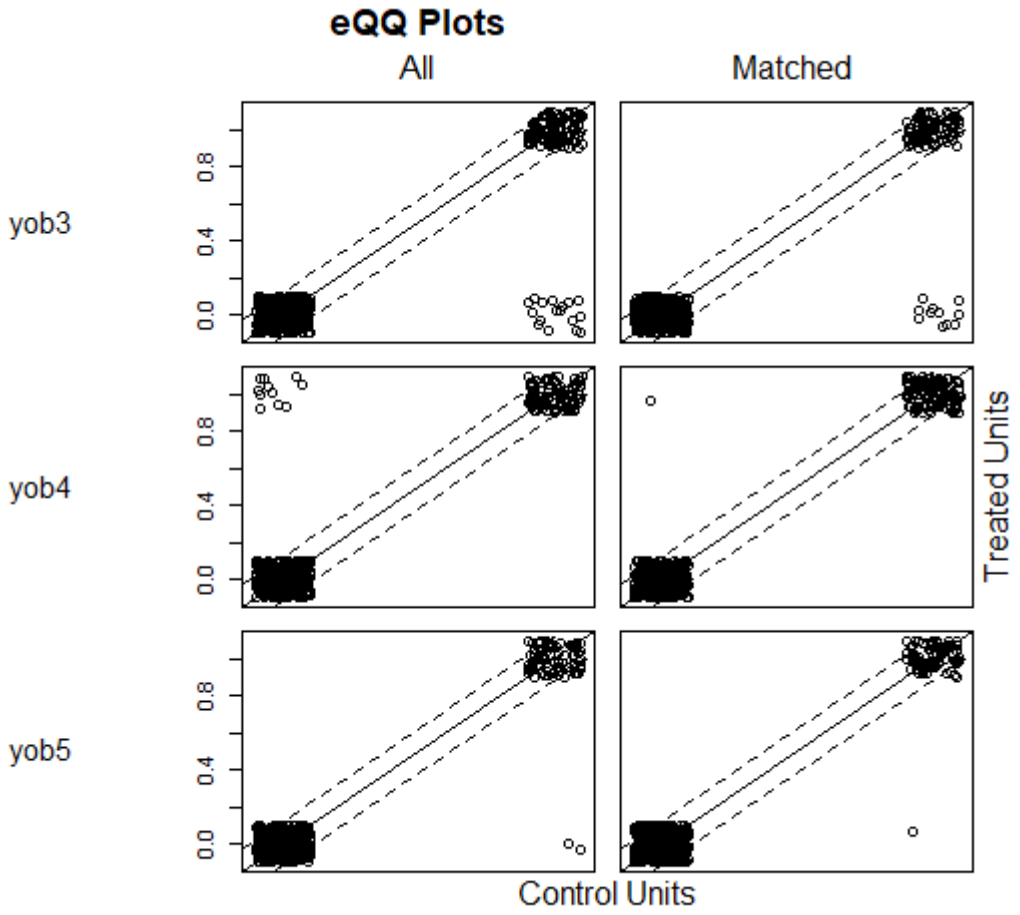
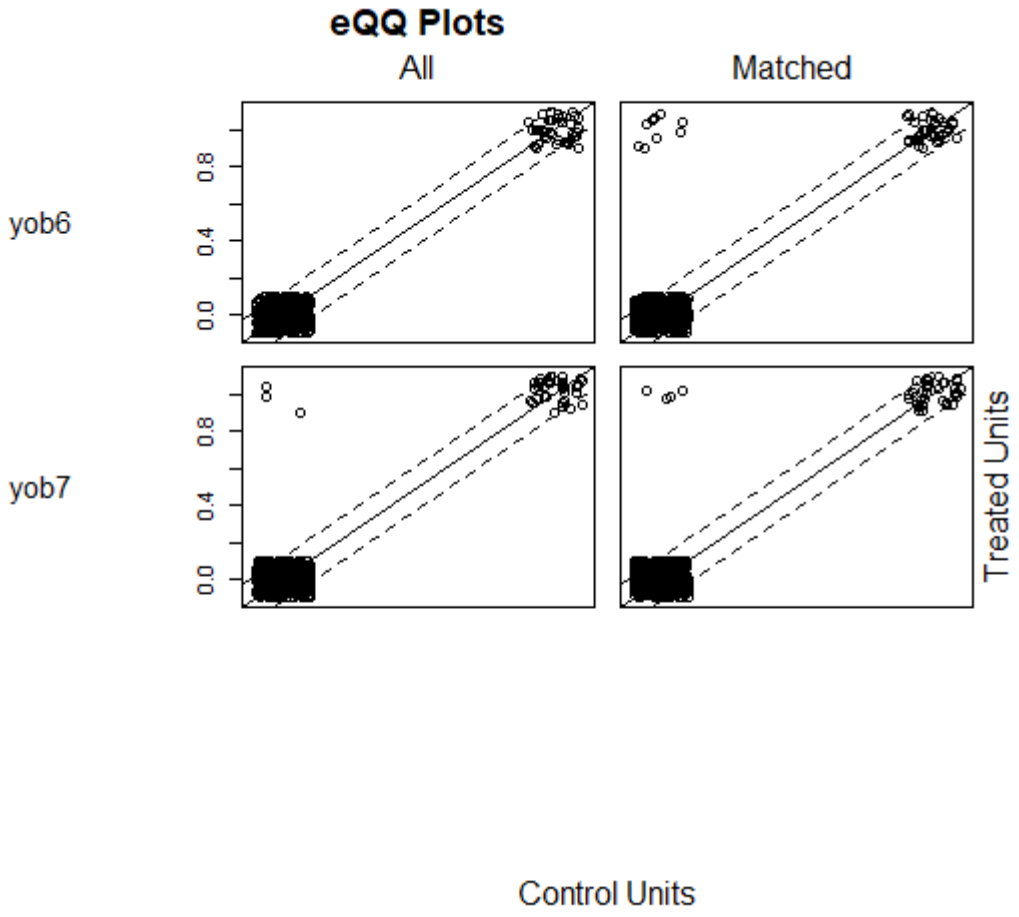
Treated Units
Control Units


eQQ Plots
All
Matched
educ3
yob1
yob2
0.0
0.4
0.8
Treated Units
Control Units


eQQ Plots
All
Matched
yob3
yob4
yob5
0.0
0.4
0.8
Treated Units
Control Units



These plots show that the matched distribution closely resembles that of the pre-match distribution.

Table 39: Descriptive Statistics of Continuous Variables by Treatment Group

	N Control	Mean Control	SD Control	N Treated	Mean Treated	SD Treated
Municipal Attachment	596	4	0.929	318	3.984	0.968
Reason for voting: Civic Duty	596	4.307	0.959	318	4.333	0.987
Reason for voting: Influence Municipal Politics	596	4.228	0.841	318	4.292	0.919
Reason for voting: Reward/Punish Local Politicians	596	2.844	1.366	318	2.978	1.426
Reason for voting: Reward/Punish National Politicians	596	2.740	1.374	318	3.060	1.403
Reason for voting: Safeguard Municipal Interests	596	4.320	0.842	318	4.343	0.932
Salience of Amalgamation Reforms	596	3.941	1.018	318	4.182	1.010
Finds politics too complicated	596	3.701	1.645	318	4.091	1.728
Political Efficacy	596	2.725	0.783	318	2.475	0.797

Table 40: Descriptive Statistics of Dichotomous Variables by Treatment Group

	N Control	Pr(Y=1)	N Treated	Pr(Y=1)
Opposed to Reform	596	0	318	1
Voted	596	0.946	318	0.903
Female	596	0.440	318	0.538

Table 41: Descriptive Statistics of Categorical Variables by Treatment Group

Amalgamation	Variable	N
	Size	
No	Sparsely Populated	45
No	A village	94
No	Small/Medium Sized Town	177
No	Suburb of a city	164
No	City	116
Yes	Sparsely Populated	45
Yes	A village	71
Yes	Small/Medium Sized Town	91
Yes	Suburb of a city	69
Yes	City	42
	County	
No	Akershus	101
No	Oslo	14
No	Ã-stfold	30
No	Vestfold	38
No	Oppland	9
No	Buskerud	37
No	Telemark	5
No	Vest-Agder	31
No	Aust-Agder	7
No	Rogaland	74
No	Hordaland	94
No	Sogn og Fjordane	11
No	MÃ¸re og Romsdal	32
No	TrÃ¸ndelag	79
No	Nordland	15
No	Troms	18
No	Finnmark	1
Yes	Akershus	67
Yes	Oslo	7
Yes	Ã-stfold	17
Yes	Vestfold	13
Yes	Hedmark	3
Yes	Oppland	5
Yes	Buskerud	17
Yes	Telemark	5
Yes	Vest-Agder	11
Yes	Aust-Agder	4
Yes	Rogaland	33
Yes	Hordaland	43
Yes	Sogn og Fjordane	6
Yes	MÃ¸re og Romsdal	20
Yes	TrÃ¸ndelag	45
Yes	Nordland	10
Yes	Troms	8
Yes	Finnmark	4
	Highest Level of Education	
No	No education/elementary school	30
No	Upper secondary education	148
No	University/University college	418
Yes	No education/elementary school	33
Yes	Upper secondary education	123
Yes	University/University college	162
	Year of Birth	
No	1939 or earlier	18
No	1940-1949	98
No	1950-1959	132
No	1960-1969	148
No	1970-1979	108
No	1980-1989	50
No	1990 or later	42
Yes	1939 or earlier	7
Yes	1940-1949	64
Yes	1950-1959	72
Yes	1960-1969	74
Yes	1970-1979	44
Yes	1980-1989	28
Yes	1990 or later	29

D4. Estimation Results

Table 42: Predicting the probability of voting at the individual level

	Dependent variable:		
	Municipal Attachment	Importance of holding local politicians accountable	Voted in 2019
	ordered logistic	*ordered logistic*	*logistic*
	(1)	(2)	(3)
Amalgamated	-0.340^{*} (0.132)	0.080 (0.138)	0.102 (0.293)
Reason to vote: Civic Duty	0.228^{**} (0.075)	-0.023 (0.081)	0.574^{***} (0.135)
Reason to vote: Influence municipal politics	-0.106 (0.091)	0.241^{*} (0.096)	0.603^{***} (0.173)
Coercive Amalgamation	-0.274^{+} (0.140)	-0.633^{***} (0.147)	-0.161 (0.286)
Reason to vote: Reward/Punish Local Politicians	0.063 (0.064)	1.371^{***} (0.070)	0.266^{*} (0.135)
Reason to vote: Reward/Punish National Politicians	0.355^{***} (0.086)	0.412^{***} (0.102)	0.185 (0.167)
Reason to vote: Safeguard municipal interests	-0.041 (0.066)		-0.522^{***} (0.155)
Municipal Attachment		-0.013 (0.078)	0.438^{**} (0.141)
Salience of Amalgamation Reforms	0.052 (0.068)	0.030 (0.072)	-0.310^{*} (0.152)
Municipal Size	0.080 (0.058)	-0.099 (0.061)	-0.212^{+} (0.123)
Finds politics too complicated	0.059 (0.042)	0.097^{*} (0.044)	0.052 (0.092)
Political Efficacy	0.126 (0.086)	-0.197^{*} (0.089)	0.675^{***} (0.193)
Female	-0.076 (0.137)	-0.151 (0.140)	-0.321 (0.297)
Upper Secondary Education	-0.617^{***} (0.177)	0.312^{+} (0.190)	0.196 (0.346)
Higher Education	-0.695^{***} (0.194)	0.116 (0.207)	0.918^{*} (0.422)
YOB: 1940-1949	-0.329 (0.541)	0.319 (0.532)	-14.726 (882.189)
YOB: 1950-1959	-0.272 (0.537)	0.504 (0.528)	-14.695 (882.189)
YOB: 1960-1969	-0.755 (0.526)	0.088 (0.520)	-14.813 (882.189)
YOB: 1970-1979	-0.846 (0.534)	0.253 (0.525)	-14.659 (882.189)
YOB: 1980-1989	-0.563 (0.558)	-0.099 (0.556)	-16.240 (882.189)
YOB: 1990 or later	-0.834 (0.539)	0.178 (0.537)	-15.323 (882.189)
Intercept			10.906 (882.190)
Observations	849	849	914
Log Likelihood			-197.061
Akaike Inf. Crit.			438.122

Note: Presented are estimated coefficients using the Logistic link function. Mediator models are estimated as ordinal logistic regression models. Whereas the outcome model is estimated as a logistic regression model. p<.10+, p<.05*, p<.01**, p<.001***

D5. Sensitivity Analysis

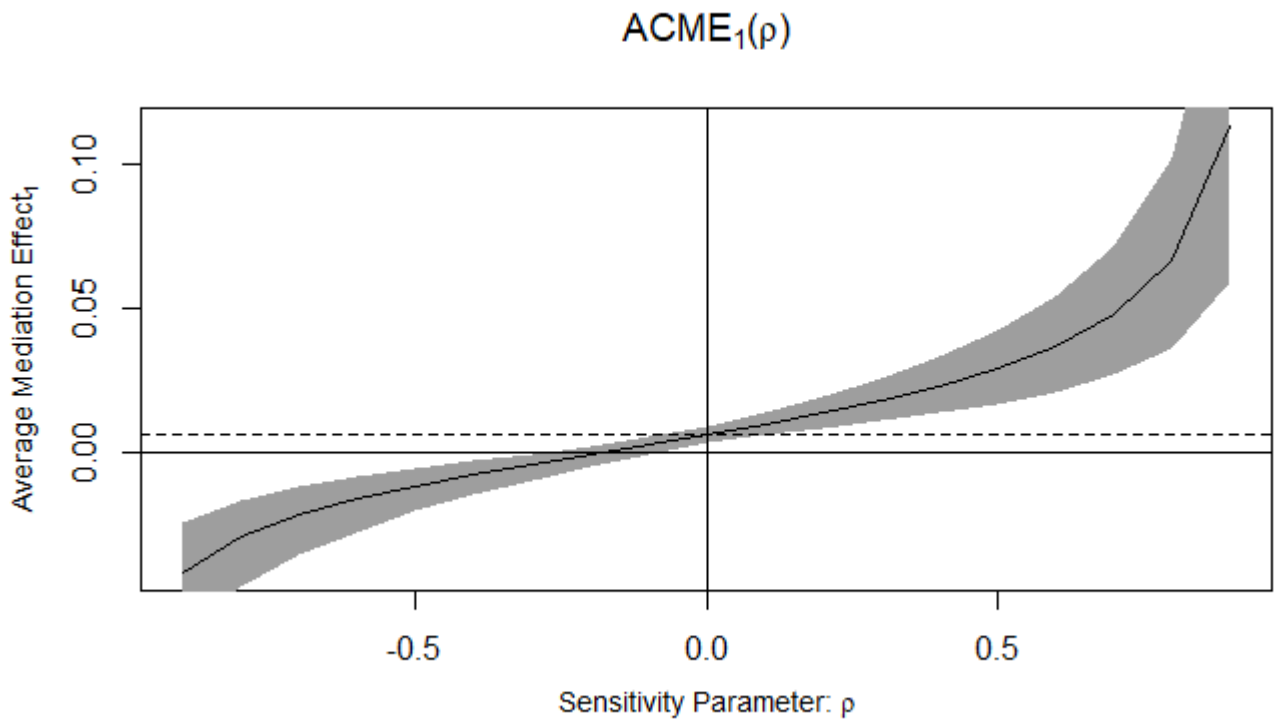


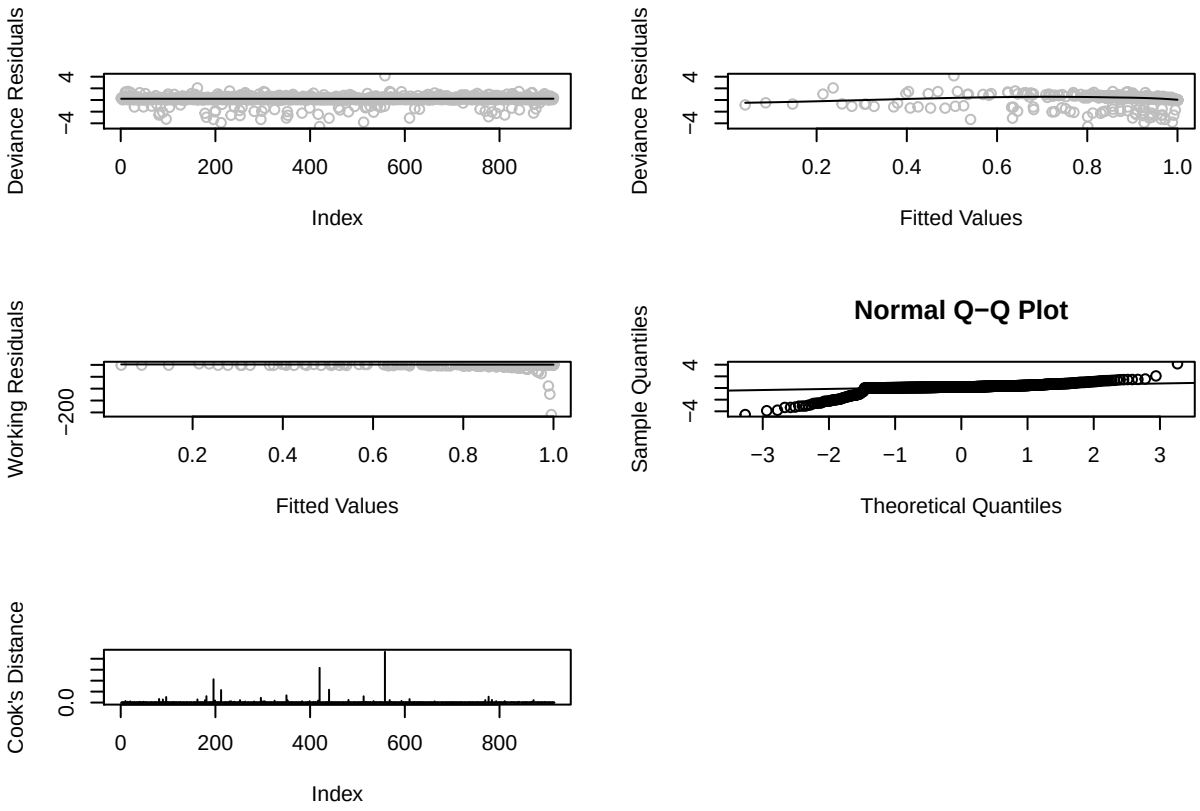
Figure 19: Sensitivity Analysis of the Local Accountability Model for the treated group

In the sensitivity analysis [1], we test how much the ACME will cross 0 and become null when ρ changes. ρ is defined as the correlation between the error of the regression over the mediator (ϵ_{2i}) and the regression over the outcome ϵ_{3i}. This plot shows that the ACME will become 0 when $\rho \approx -.15$. This suggests that the error of the component regression models cannot be negatively correlated otherwise the ACME would no longer be positive. It shows that the model is quite sensitive to the sequential ignorability assumption.

[1] To get around technical limitations of the 'mediate' package, this sensitivity analysis is conducted by refitting the ordered logistic regression over the mediator as a regular linear regression model. The actual estimates might be different due to the re-estimation so the results should be taken with a grain of salt.

D6. Model Diagnostics

Model testing for municipal attachment



The above plots help us diagnose any violation of the assumptions of a binomial GLM. Perhaps the most clear problem is the potential issue of slight heteroskedasticity as fitted values go lower. The issue stems from the issue of over-reporting, and thus a majority of the observations report that they have voted in the election. We lack observations that say they have not voted. In this sense, the residuals are now a function of the predicted values of voting - the lower it is, the larger the error.

To alleviate the hetereoskedasticity, one possible way is to replace the standard errors with robust standard errors. The table below reports the results after adjusting for heteroskedasticity. We see that the main findings of this paper hold. The Municipal Attachment variable still has a positive effect at the $p < .01$ level, and the Local Accountability still has a negative effect at the $p < .001$ level.

Table 43: Predicting the probability of voting at the individual level

	Dependent variable:
	Municipal Attachment
Coercive Amalgamation	−0.161 (0.399)
Amalgamated	0.102 (0.343)
Reason to vote: Civic Duty	0.574*** (0.150)
Reason to vote: Influence municipal politics	0.603** (0.196)
Reason to vote: Reward/Punish Local Politicians	−0.522*** (0.158)
Reason to vote: Reward/Punish National Politicians	0.266+ (0.141)
Reason to vote: Safeguard municipal interests	0.185 (0.213)
Municipal Attachment	0.438* (0.177)
Salience of Amalgamation Reforms	−0.310 (0.206)
Municipal Size	−0.212 (0.170)
Finds politics too complicated	0.052 (0.098)
Political Efficacy	0.675* (0.279)
Female	−0.321 (0.349)
Upper Secondary Education	0.196 (0.554)
Higher Education	0.918 (0.628)
YOB: 1940-1949	−14.726*** (0.759)
YOB: 1950-1959	−14.695*** (0.812)
YOB: 1960-1969	−14.813*** (0.779)
YOB: 1970-1979	−14.659*** (0.828)
YOB: 1980-1989	−16.240*** (0.809)
YOB: 1990 or later	−15.323*** (0.914)
Intercept	10.906*** (1.753)
Observations	914
Log Likelihood	−197.061
Akaike Inf. Crit.	438.122

Note: Presented are estimated beta coefficients using the Logistic link function. Robust Standard Errors are in parentheses. p<.10+, p<.05*, p<.01**, p<.001***

D7. Alternative Model Estimates with IPE variables

Table 44: Robustness of the effect of punitive voting vis-a-vis internal political efficacy

	Dependent variable:	
	Political Efficacy	Voted in 2019
	ordered logistic	*logistic*
	(1)	(2)
Amalgamated	0.205 (0.136)	0.102 (0.293)
Reason to vote: Civic Duty	0.168^{*} (0.076)	0.574^{***} (0.135)
Reason to vote: Influence municipal politics	0.176^{+} (0.091)	0.603^{***} (0.173)
Opposed to Amalgamation	-0.474^{***} (0.143)	−0.161 (0.286)
Reason to vote: Reward/Punish National Politicians	−0.034 (0.066)	0.266^{*} (0.135)
Reason to vote: Safeguard municipal interests	0.147^{+} (0.088)	0.185 (0.167)
Reason to vote: Reward/Punish Local Politicians	-0.141^{*} (0.069)	-0.522^{***} (0.155)
Salience of Amalgamation Reforms	−0.049 (0.071)	-0.310^{*} (0.152)
Municipal Size	0.037 (0.059)	-0.212^{+} (0.123)
Finds politics too complicated	-0.185^{***} (0.044)	0.052 (0.092)
Political Efficacy		0.675^{***} (0.193)
Municipal Attachment	0.137^{+} (0.075)	0.438^{**} (0.141)
Female	0.227 (0.141)	−0.321 (0.297)
Upper Secondary Education	0.778^{***} (0.180)	0.196 (0.346)
Higher Education	1.107^{***} (0.196)	0.918^{*} (0.422)
YOB: 1940-1949	−0.462 (0.576)	−14.726 (882.189)
YOB: 1950-1959	−0.366 (0.574)	−14.695 (882.189)
YOB: 1960-1969	−0.647 (0.565)	−14.813 (882.189)
YOB: 1970-1979	−0.415 (0.574)	−14.659 (882.189)
YOB: 1980-1989	−0.784 (0.593)	−16.240 (882.189)
YOB: 1990 or later	0.233 (0.580)	−15.323 (882.189)
Intercept		10.906 (882.190)
Observations	849	914
Log Likelihood		−197.061
Akaike Inf. Crit.		438.122

Note: Presented are estimated coefficients using the Logistic link function. Mediator models are estimated as ordinal logistic regression models. Whereas the outcome model is estimated as a logistic regression model. p<.10+, p<.05*, p<.01**, p<.001***

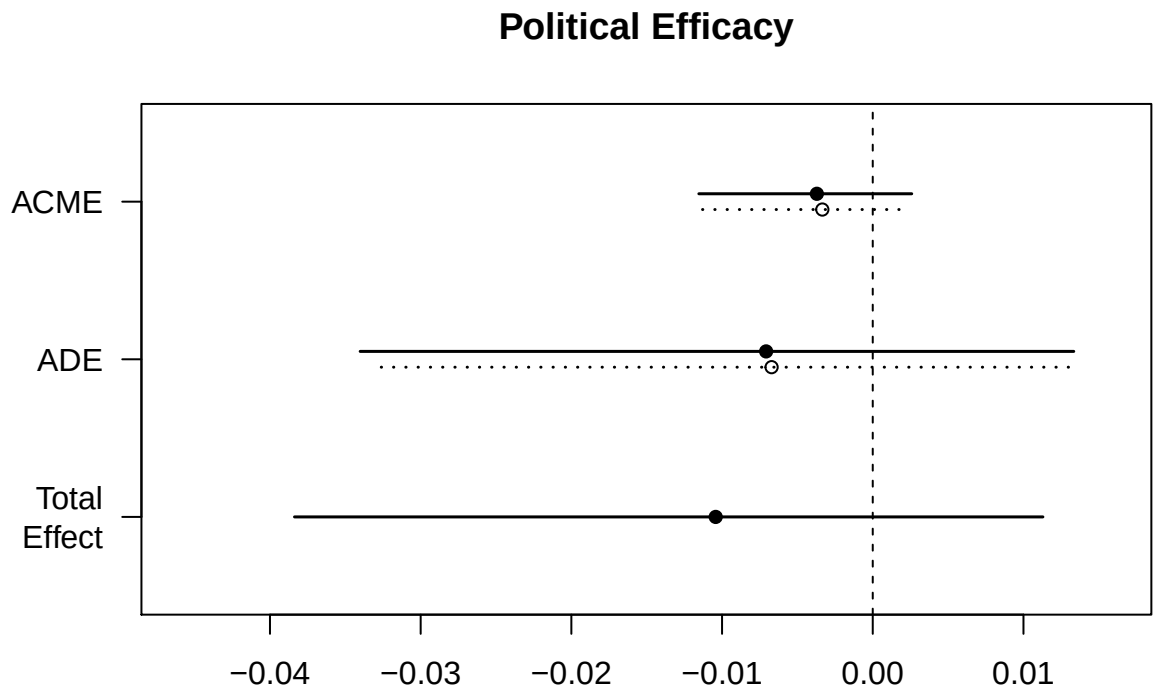


Figure 20: ACME of Political Efficacy

D8. Alternative Model Estimates with Municipal Size

Table 45: Robustness of the effect of punitive voting vis-a-vis internal political efficacy

	Dependent variable:	
	Political Efficacy	Voted in 2019
	ordered logistic	*logistic*
	(1)	(2)
Amalgamated	0.374^{**} (0.129)	0.102 (0.293)
Reason to vote: Civic Duty	0.152^{*} (0.073)	0.574^{***} (0.135)
Reason to vote: Influence municipal politics	−0.016 (0.087)	0.603^{***} (0.173)
Opposed to Amalgamation	−0.073 (0.136)	−0.161 (0.286)
Reason to vote: Reward/Punish National Politicians	0.084 (0.064)	0.266^{*} (0.135)
Reason to vote: Safeguard municipal interests	−0.064 (0.081)	0.185 (0.167)
Reason to vote: Reward/Punish Local Politicians	-0.149^{*} (0.068)	-0.522^{***} (0.155)
Salience of Amalgamation Reforms	-0.161^{*} (0.065)	-0.310^{*} (0.152)
Municipal Size		-0.212^{+} (0.123)
Political Efficacy	0.051 (0.083)	0.675^{***} (0.193)
Finds politics too complicated	-0.179^{***} (0.041)	0.052 (0.092)
Municipal Attachment	0.066 (0.071)	0.438^{**} (0.141)
Female	-0.257^{+} (0.132)	−0.321 (0.297)
Upper Secondary Education	−0.048 (0.172)	0.196 (0.346)
Higher Education	0.589^{**} (0.189)	0.918^{*} (0.422)
YOB: 1940-1949	-1.308^{*} (0.513)	−14.726 (882.189)
YOB: 1950-1959	-0.979^{+} (0.507)	−14.695 (882.189)
YOB: 1960-1969	-0.980^{*} (0.498)	−14.813 (882.189)
YOB: 1970-1979	−0.817 (0.507)	−14.659 (882.189)
YOB: 1980-1989	−0.506 (0.523)	−16.240 (882.189)
YOB: 1990 or later	0.109 (0.515)	−15.323 (882.189)
Intercept		10.906 (882.190)
Observations	849	914
Log Likelihood		−197.061
Akaike Inf. Crit.		438.122

Note: Presented are estimated coefficients using the Logistic link function. Mediator models are estimated as ordinal logistic regression models. Whereas the outcome model is estimated as a logistic regression model. p<.10+, p<.05*, p<.01**, p<.001***

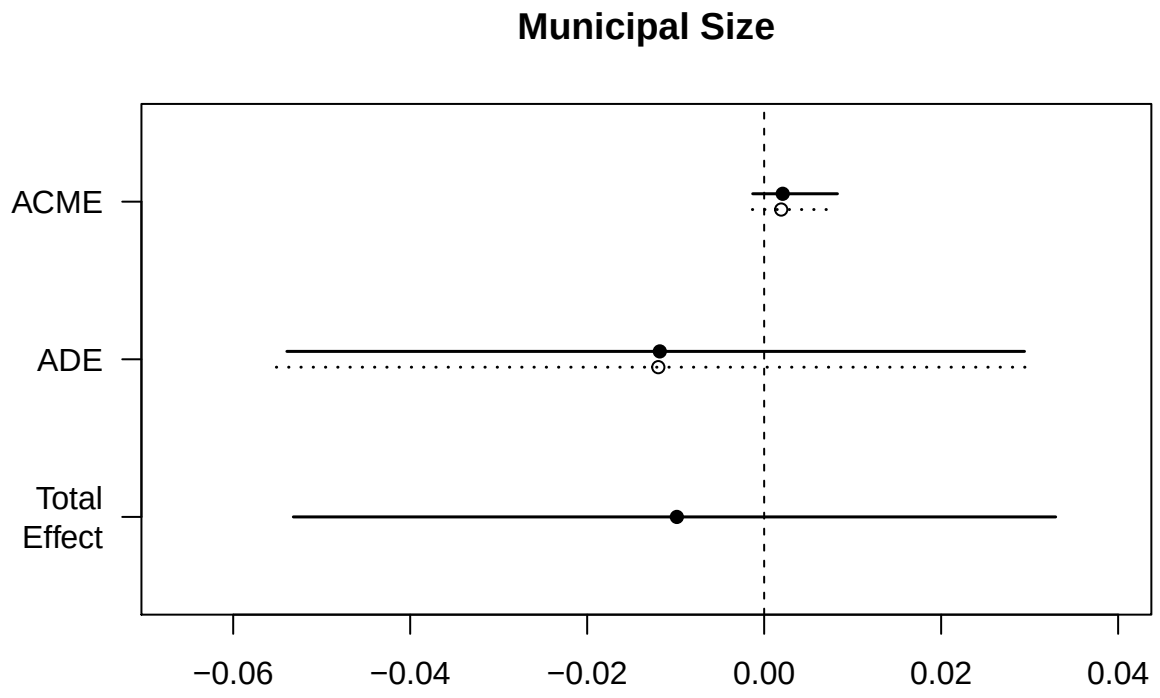


Figure 21: ACME of Municipal Size

Appendix: Satellite Index of Development: A novel way to measure subnational development with daytime satellite images

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E1. Remote Sensing Indices

- Normalized Difference Vegetation Index (NDVI):

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

Where NIR refers to the near infrared band.

- Enhanced Vegetation Index (EVI):

$$EVI = 2.5 * \frac{NIR - Red}{NIR + (Red * 6) - (Blue * 7.5) + 1}$$

The parameters $G = 2.5$, $C1 = 6$, $C2 = 7.5$ and $L = 1$ are known parameters for computing the EVI given Landsat 8 images (USGS, n.d.).

- Normalized Difference Water Index (NDWI):

$$NDWI = \frac{NIR - Green}{NIR + Green}$$

Where NIR refers to the near infrared band.

E2. List of Cities in Dataset

	Country	City
1	Australia	Canberra
2	Austria	Vienna
3	Bangladesh	Dhaka
4	Belgium	Brussels
5	Brazil	SaoPaulo
6	Canada	Montreal
7	Canada	Toronto
8	China	Beijing
9	China	Shanghai
10	Colombia	Bogota
11	Croatia	Zagreb
12	Denmark	Copenhagen
13	Ecuador	Quito
14	El Salvador	SanSalvador
15	Finland	Helsinki
16	France	Lyon
17	France	Paris
18	France	Toulouse
19	Germany	Berlin
20	Germany	Bremen
21	Germany	Hamburg
22	Hungary	Budapest
23	India	Delhi
24	India	Hyderabad
25	India	Mumbai

Table 46: List of Cities in Dataset

	Country	City
26	Ireland	Dublin
27	Italy	Rome
28	Japan	Kyoto
29	Japan	Nagoya
30	Japan	Osaka
31	Netherlands	DenHaag
32	Netherlands	Rotterdam
33	Norway	Oslo
34	Pakistan	Karachi
35	Peru	Lima
36	Poland	Warsaw
37	Portugal	Lisbon
38	Portugal	Porto
39	Romania	Bucharest
40	Russian Federation	Moscow
41	Russian Federation	Sevastopol
42	Russian Federation	StPetersburg
43	Spain	Barcelona
44	Sweden	Stockholm
45	United Kingdom	Birmingham
46	United Kingdom	London
47	United Kingdom	Manchester
48	Vietnam	Hanoi
49	Vietnam	HoChiMinh

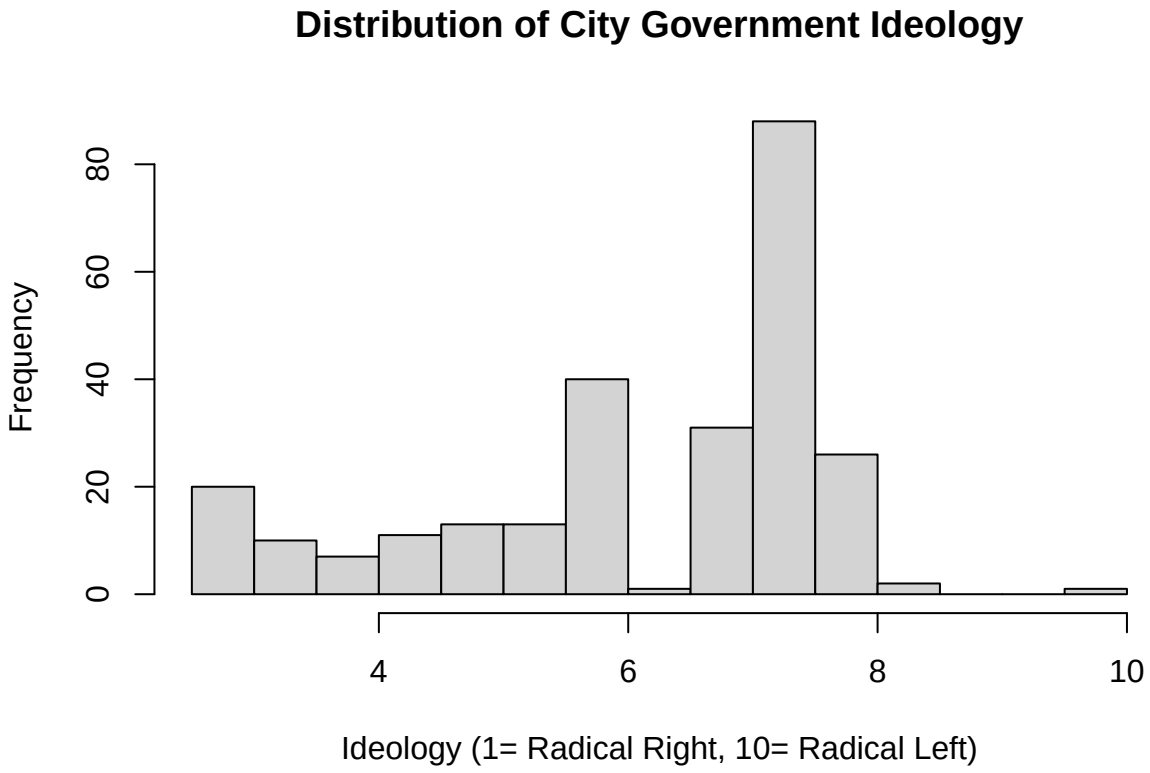
Table 47: List of Cities in Dataset (Continued)

E3. Descriptive Statistics

Table 48: Descriptive Statistics

	N	Mean	SD	Min	Max
SID Sum	524	94,044.270	115,782.500	55.911	799,798.700
SID Min	524	1,015.348	1,884.042	0.022	7,486.492
SID Max	524	11,094.450	2,443.954	54.203	15,358.250
SID Mean	524	5,358.175	1,830.639	0.726	9,918.507
SID SD	524	3,816.156	1,083.194	6.174	6,729.340
National Population (thousands)	524	201,061.100	374,452.300	3,899	1,412,360
City Population (thousands)	524	6,523.904	7,317.585	330.943	29,347.620
V-DEM Liberal Democracy	524	0.602	0.279	0.043	0.891
Weighted SUM SID	524	38.434	70.982	0.038	574.201
CV Williamson	524	6.318	10.025	0.155	49.569
Regional Authority Index (RAI)	524	11.452	6.596	1	27
RAI Self-rule	524	9.557	3.603	1	15
RAI Shared rule	524	1.895	3.893	0	12
City Government Ideology	524	6.182	1.510	2.800	9.700

E4. City Government Ideology Distribution



This variable has to be encoded from various sources. First, I look up the city council's election closest to the year 2014, since this is the year where all the time-invariant covariates are taken from. I check the winning party and code accordingly. If it's a coalition, I code for the coalition leader. I then look through all 4 of my data sources: ParlGov, V-Party, Chapel Hill Expert Survey (CHES) and Schakel (2013). The lookup priority is: ParlGov, V-Party, CHES, then Schakel (2013). So whenever a match is found in a higher priority dataset, the data from that dataset will be used and I move on to the next party. For party ideology scores from Schakel (2013) that runs on the 1-6 scale, they will be rescaled as such using the formula: $((10-1)/(6-1)) * (p-6) + 10$, where p is the ideology score from Schakel (2013). For all ideology scores, I use the economic left-right score.

Most city governments are left-leaning, with heavy concentration between 6-8, but over all the distribution of city government ideology resembles a left-skewed normal distribution.

E5. Correlation Matrix of Variables

The correlations computed below use the model frame from the last model reported in the main text, so they will have the smallest N, N=141, N city = 30.

Table 49: Correlation Matrix

	SID Sum	SID Min	SID Max	SID Mean	SID SD
SID Sum	1	-0.215	0.112	-0.143	0.192
SID Min	-0.215	1	-0.276	0.658	-0.340
SID Max	0.112	-0.276	1	-0.100	0.795
SID Mean	-0.143	0.658	-0.100	1	-0.093
SID SD	0.192	-0.340	0.795	-0.093	1
National Population (thousands)	0.640	-0.187	0.345	0.302	0.396
City Population (thousands)	0.389	0.328	0.042	0.391	0.045
V-DEM Liberal Democracy	-0.608	-0.071	-0.157	-0.443	-0.074
Weighted SUM SID	0.433	-0.440	0.139	-0.533	0.106
Weighted CV SID	-0.288	-0.296	0.195	-0.520	0.160
RAI Self-rule	-0.418	-0.101	-0.342	-0.372	-0.276
RAI Shared rule	-0.172	-0.243	-0.302	-0.266	-0.199
Brookings 2014 GDP Est. (Million $)	0.486	0.377	0.096	0.428	0.232

Table 50: Correlation Matrix

	National Population (thousands)	City Population (thousands)	V-DEM Liberal Democracy	Weighted SUM SID
SID Sum	0.640	0.389	-0.608	0.433
SID Min	-0.187	0.328	-0.071	-0.440
SID Max	0.345	0.042	-0.157	0.139
SID Mean	0.302	0.391	-0.443	-0.533
SID SD	0.396	0.045	-0.074	0.106
National Population (thousands)	1	0.539	-0.822	0.060
City Population (thousands)	0.539	1	-0.581	-0.436
V-DEM Liberal Democracy	-0.822	-0.581	1	0.032
Weighted SUM SID	0.060	-0.436	0.032	1
Weighted CV SID	-0.406	-0.593	0.492	0.558
RAI Self-rule	-0.672	-0.365	0.652	-0.089
RAI Shared rule	-0.278	-0.321	0.388	0.087
Brookings 2014 GDP Est. (Million $)	0.552	0.580	-0.483	-0.179

Table 51: Correlation Matrix

	Weighted CV SID	RAI Self-rule	RAI Shared rule	Brookings 2014 GDP Est. (Million $)
SID Sum	-0.288	-0.418	-0.172	0.486
SID Min	-0.296	-0.101	-0.243	0.377
SID Max	0.195	-0.342	-0.302	0.096
SID Mean	-0.520	-0.372	-0.266	0.428
SID SD	0.160	-0.276	-0.199	0.232
National Population (thousands)	-0.406	-0.672	-0.278	0.552
City Population (thousands)	-0.593	-0.365	-0.321	0.580
V-DEM Liberal Democracy	0.492	0.652	0.388	-0.483
Weighted SUM SID	0.558	-0.089	0.087	-0.179
Weighted CV SID	1	0.407	0.311	-0.531
RAI Self-rule	0.407	1	0.683	-0.424
RAI Shared rule	0.311	0.683	1	-0.322
Brookings 2014 GDP Est. (Million $)	-0.531	-0.424	-0.322	1

E6. Model Results

Table 52: Estimating intraregional inequality in metropolitan areas

	Dependent variable:			
	Weighted CV (Williamson)			
	(1)	(2)	(3)	(4)
Regional Authority Index	−0.020 (0.024)			
Self-rule		−0.002 (0.050)	0.0005 (0.052)	−0.074 (0.051)
Shared Rule		−0.019 (0.052)	−0.024 (0.052)	−0.005 (0.050)
Self-rule * Economic Dev. per capita				−0.274*** (0.033)
Population		0.681*** (0.071)	0.589*** (0.086)	0.684*** (0.082)
Liberal Democracy		−0.376 (0.345)	−0.298 (0.304)	−0.112 (0.328)
Econ Dev. per capita		0.614*** (0.179)	0.605*** (0.181)	4.080*** (0.378)
Left-wing City Government			−0.151 (0.108)	−0.110 (0.102)
Intercept	1.348*** (0.304)	−4.182*** (0.362)	−2.551*** (0.299)	−2.762*** (0.369)
N Cities	30	30	30	30
SD Cities	1.461	1.142	1.124	1.043
Observations	141	141	141	141
Log Likelihood	−282.489	−276.077	−275.705	−274.774
Akaike Inf. Crit.	572.977	568.154	569.411	569.548
Bayesian Inf. Crit.	584.772	591.744	595.949	599.035

Note: Presented are beta coefficients estimated in a multi-level negative binomial model, with city-level random intercepts. Standard Errors are in parentheses. p<.10+, p<.05*, p<.01**, p<.001***

E7. Model Results with City Area

Table 53: Predicting intraregional inequality in metropolitan areas

	Dependent variable:
	Weighted CV (Williamson)
Self-rule	0.040 (0.045)
Shared Rule	−0.019 (0.037)
Econ. Dev. per capita	1.237*** (0.293)
Self-rule * Econ. Dev. per capita	−0.085*** (0.024)
Log Population	0.224** (0.075)
V-DEM Liberal Democracy Index	0.453+ (0.238)
City Gov. Left-wing Ideology	−0.169* (0.076)
City Size	0.022*** (0.003)
Intercept	−0.894* (0.414)
N Cities	30
SD Cities	0.427
Observations	141
Log Likelihood	−263.471
Akaike Inf. Crit.	548.941
Bayesian Inf. Crit.	581.378

Note: Presented are estimated beta coefficients. Robust Standard Errors are in parentheses. p<.10+, p<.05*, p<.01**, p<.001***

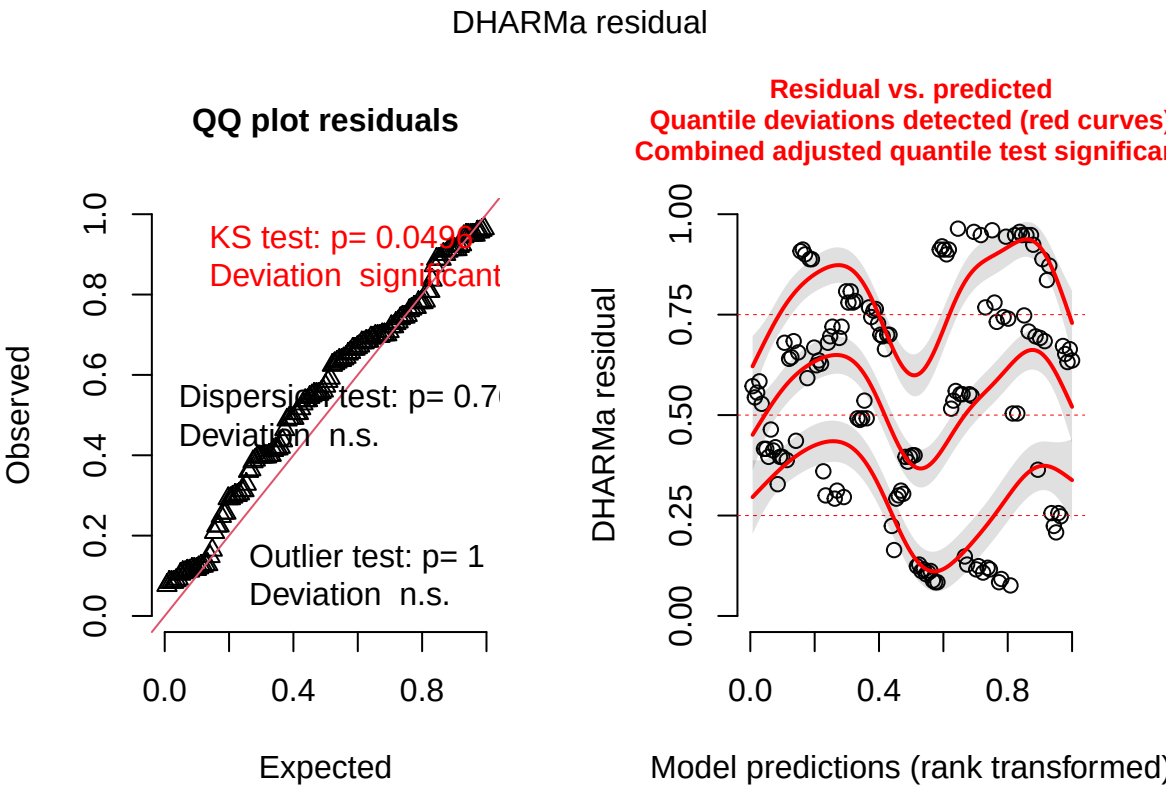
E8. Model Results with Year Random Intercept

Table 54: Predicting intraregional inequality in metropolitan areas

	Dependent variable:
	Weighted CV (Williamson)
Log Population	0.684*** (0.078)
V-DEM Liberal Democracy Index	−0.112 (0.206)
City Gov. Left-wing Ideology	−0.110 (0.099)
Mean Econ. Dev.	2.894*** (0.227)
Self-rule	−0.044 (0.050)
Shared Rule	−0.005 (0.050)
Self-rule * Mean Econ. Dev.	−0.194*** (0.021)
Intercept	−3.207*** (0.256)
N Cities	30
SD Cities	1.088
N Year	5
SD Year	0
Observations	141
Log Likelihood	−274.774
Akaike Inf. Crit.	571.548
Bayesian Inf. Crit.	603.984
Note:	Presented are estimated beta coefficients. Robust Standard Errors are in parentheses. p<.10+, p<.05*, p<.01**, p<.001***

E9. Model Diagnostics

Testing the assumption of linearity in residuals



The plot above reports the residual analysis results using simulation-baserd scaled (quantile) residuals with the `DHARMa` package in `R`. The left panel reports on the quantile-to-quantile (QQ) analysis of these residuals, and the right panel plots the predicted values against the simulated residuals. I used model 4 in the paper to conduct these analyses.

The left panel shows no signs of deviation from the theoretical normal distribution. The residuals all fall nicely on the diagonal line which indicates no deviation from the normal distribution. There is no evidence that shows the residuals are not normally distributed.

The right panel highlights some potential problems with large residuals. Some of the residuals deviate significantly from the 25-th and 75-th percentile of the residual distribution, thus the software flagged a potential problem in the model. However, looking at the trend line, although not strictly linear, the line regresses and forms a horizontal line. Therefore, the residuals do not seem to be related to the predicted values in a deterministic way.

E10. Modeling results excluding city government ideology

List of cities in Dataset

	Country	City Name
1	Australia	Canberra
2	Austria	Wien (Vienna)
3	Bangladesh	Dhaka
4	Belgium	Bruxelles-Brussel
5	Brazil	São Paulo
6	Canada	Montréal
7	Canada	Toronto
8	China	Beijing
9	China	Shanghai
10	Colombia	Bogotá
11	Croatia	Zagreb
12	Ecuador	Quito
13	El Salvador	San Salvador
14	France	Lyon
15	France	Paris
16	France	Toulouse
17	Germany	Berlin
18	Germany	Bremen
19	Germany	Hamburg
20	Hungary	Budapest
21	India	Hyderabad (India)
22	India	Mumbai (Bombay)
23	Ireland	Dublin
24	Japan	Kinki M.M.A. (Osaka)
25	Japan	Chukyo M.M.A. (Nagoya)
26	Netherlands	s-Gravenhage (The Hague)
27	Norway	Oslo
28	Pakistan	Karachi
29	Peru	Lima
30	Portugal	Lisboa (Lisbon)
31	Romania	Bucuresti (Bucharest)
32	Russian Federation	Moskva (Moscow)
33	Russian Federation	Sevastopol
34	Russian Federation	Sankt Peterburg (Saint Petersburg)
35	Spain	Barcelona
36	Spain	Zaragoza
37	Vietnam	Hà Noi
38	Vietnam	Thành Pho Ho Chí Minh (Ho Chi Minh City)

Table 55: List of Cities in Dataset

Model results

In this iteration, we see that the interaction of self rule and economic development remains in the expected negative direction, but has lost significance. Given the difference in N is only 35 rows, it appears that the inclusion of the city government ideology is quite crucial to the recovery of a significant self-rule * economic development effect. There could be a three-way interaction effect between self rule, economic development and city government ideology that could be at play here. Appendix A11 shows a variation of the model including such a three-way interaction. It appears the three-way interaction effect per se is not significance and close to zero, but the self-rule * economic development effect remains a significant and negative effect. In

Table 56: Estimating intraregional inequality in metropolitan areas

	Dependent variable:		
	Weighted CV (Williamson)		
	(1)	(2)	(3)
Regional Authority Index	−0.027 (0.032)		
Self-rule		0.029 (0.066)	−0.023 (0.083)
Shared Rule		−0.053 (0.055)	−0.037 (0.055)
Self-rule * Economic Dev. per capita			−0.204 (0.190)
Population		0.660*** (0.186)	0.722*** (0.187)
Liberal Democracy		−0.319 (0.616)	−0.121 (0.631)
Econ Dev. per capita		0.662** (0.202)	3.247 (2.416)
Intercept	1.487** (0.463)	−4.234* (1.798)	−4.215* (1.721)
N Cities	38	38	38
SD Cities	1.351	1.087	1.024
Observations	178	178	178
Log Likelihood	−417.353	−408.787	−408.263
Akaike Inf. Crit.	842.706	833.574	834.525
Bayesian Inf. Crit.	855.433	859.028	863.161
Note:	Presented are beta coefficients estimated in a multi-level negative binomial model, with city-level random intercepts. Standard Errors are in parentheses. p<.10+, p<.05*, p<.01**, p<.001***		

fact, the effect magnitude is even larger than the 2-way interaction effect model reported in the main text. However, that model failed to converge, possibly due to a smaller N, so the results should be taken with a grain of salt.

E11. Modeling results with a three-way interaction effect

Modeling results

Table 57: Estimating intraregional inequality in metropolitan areas

	Dependent variable:				
	Weighted CV (Williamson)				
	(1)	(2)	(3)	(4)	(5)
Regional Authority Index	−0.020 (0.024)				
Self-rule		−0.002 (0.050)	0.0005 (0.052)	−0.074 (0.051)	-1.097^{***} (0.149)
Shared Rule		−0.019 (0.052)	−0.024 (0.052)	−0.005 (0.050)	−0.058 (0.047)
Self-rule * Economic Dev. per capita				-0.274^{***} (0.033)	-0.580^{**} (0.216)
Left-wing * Self-rule					0.164^{***} (0.023)
Left-wing * Economic Dev. per capita					0.493^{+} (0.282)
Left-wing * Self-rule * Econ Dev.					0.013 (0.033)
Population		0.681^{***} (0.071)	0.589^{***} (0.086)	0.684^{***} (0.082)	0.498^{***} (0.124)
Liberal Democracy		−0.376 (0.345)	−0.298 (0.304)	−0.112 (0.328)	−0.295 (0.341)
Econ Dev. per capita		0.614^{***} (0.179)	0.605^{***} (0.181)	4.080^{***} (0.378)	3.249^{***} (0.577)
Left-wing City Government			−0.151 (0.108)	−0.110 (0.102)	-1.726^{***} (0.191)
Intercept	1.348^{***} (0.304)	-4.182^{***} (0.362)	-2.551^{***} (0.299)	-2.762^{***} (0.369)	8.976^{***} (0.374)
N Cities	30	30	30	30	30
SD Cities	1.461	1.142	1.124	1.043	0.889
Observations	141	141	141	141	141
Log Likelihood	−282.489	−276.077	−275.705	−274.774	−270.257
Akaike Inf. Crit.	572.977	568.154	569.411	569.548	566.514
Bayesian Inf. Crit.	584.772	591.744	595.949	599.035	604.848

Note: Presented are beta coefficients estimated in a multi-level negative binomial model, with city-level random intercepts. Standard Errors are in parentheses. Model 5 has not converged, results must be taken with a grain of salt. p<.10+, p<.05*, p<.01**, p<.001***

Self-rule * Economic Development Effect plot

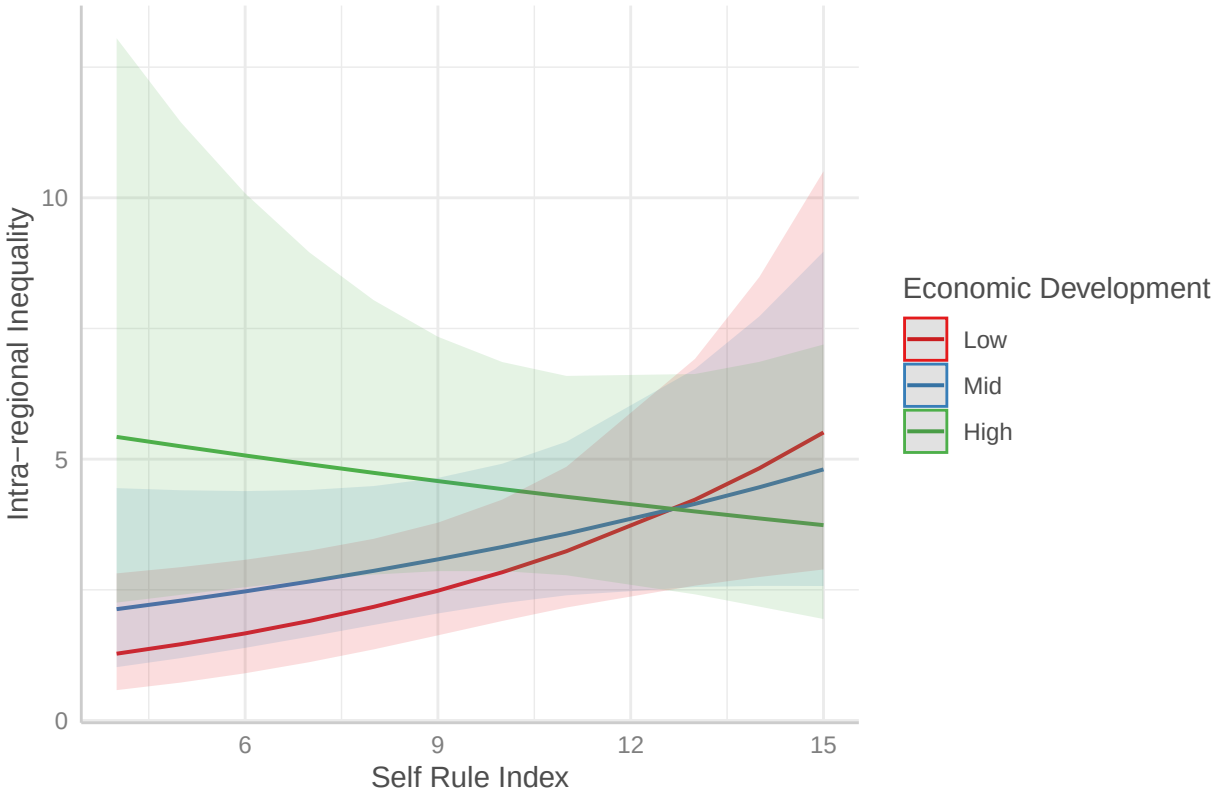


Figure 18: Effects of Self Rule on Spatial Inequality conditional on Economic Development per capita