Inefficiency and Self-Determination: Simulation-based evidence from Meiji Japan

Weese, Eric
Hayashi, Masayoshi
Nishikawa, Masashi

(Citation)
神戸大学経済学研究科 Discussion Paper,1627

(Issue Date)
2016

(Resource Type)
technical report

(Version)
Version of Record

(URL)
https://hdl.handle.net/20.500.14094/81009588

Inefficiency and Self-Determination: Simulation-based evidence from Meiji Japan

Eric Weese
Masayoshi Hayashi
Masashi Nishikawa

February 2017

Discussion Paper No.1627

GRADUATE SCHOOL OF ECONOMICS

KOBE UNIVERSITY

ROKKO, KOBE, JAPAN

Inefficiency and Self-Determination: Simulation-based evidence from Meiji Japan*

Eric Weese† Masayoshi Hayashi‡ Masashi Nishikawa§

February 2017

Abstract

We consider a model in which the arrangement of political boundaries involves a tradeoff between efficiencies of scale and geographic heterogeneity. If jurisdiction formation is decentralized, the model corresponds to a fractional hedonic game. We show how mixed integer programming can be used to calculate core partitions for fractional hedonic games via a sequence of myopic deviations. Using historical data from Japan regarding a set of centralized boundary changes, we estimate parameters using moment inequalities and find that core partitions always exist. In a counterfactual world in which there are no between-village income differences, these core partitions are extremely close to the partition that would be chosen by a utilitarian central planner. When actual cross-village income differences are used, however, sorting on income results in mergers that are both smaller and geographically bizarre.

*Portions of this paper were originally presented as "An Errors-in-Variables Model for Graph Outcome Data" at the Econometric Society Far East meeting. In addition, some ideas were present in the job market paper version of Weese [2015], but were removed during the publication process. We thank Steve Berry, Raquel Fernandez, Jeremy Fox, Matias Iaryczower, Hide Ichimura, Yuichi Kitamura, John Londregan, Tsunetoshi Mizoguchi, Masaki Nakabayashi, Kei Okunuki, Larry Samuelson, Motohiro Sato, Junichi Suzuki, Shlomo Weber, Noam Yuchtman, and seminar participants at various seminars for helpful comments. Julien Clancy provided excellent research assistance with an earlier version of the model. Portions of this research were conducted at Osaka University, the University of Tokyo, and the National Graduate Institute for Policy Studies. Funding was provided by the Japan Society for the Promotion of Science. Computation was performed using the FAS High Performance Computing system at Yale.

†Corresponding author. Kobe University (weese@econ.kobe-u.ac.jp). This research was conducted while at Yale University.

‡University of Tokyo

§Aoyama Gakuin University

Does exercise of the right to self-determination result in an efficient arrangement of political boundaries? There is substantial theoretical interest in this issue both inside and outside of economics. Policy relevance is obvious given recent events in the UK. Empirical results regarding the efficiency of jurisdiction formation, however, are very limited.

This paper considers a historical set of municipal mergers in Gifu, Japan, that were decided by a central planner in the late 19th century. We show that the observed pattern of new municipal boundaries corresponds reasonably well to that of a social planner maximizing a sum of utilities of individuals in an Alesina and Spolaore [1997] type model: there is a tradeoff between efficiencies of scale in the provision of public goods, and geographic heterogeneity in the jurisdiction in which the public goods are provided. The parameter governing this tradeoff is estimated using a "measurement error only" model of the form suggested in Pakes [2010], and a parameter describing the efficiencies of scale is calibrated based on official government reports and observed spending.

A counterfactual case is then considered, where pre-defined subunits corresponding to feudal villages were allowed to choose how to arrange themselves into jurisdictions in a coalition formation game without transfers. The core is used as the solution concept in this decentralized jurisdiction formation game, and results are obtained via simulation. The model used corresponds to an Aziz, Brandt, and Harrenstein [2014] fractional hedonic game, and core partitions are automatically Pareto optimal. Payoffs for players, however, are quasi-linear with respect to money, and we consider inefficiency from a utilitarian perspective.[1] We perform simulations with the observed data, as well as considering setups with changed village characteristics or the addition of inter-governmental subsidies.

Our simulations show that the decentralized outcome is very close to the social planner's optimal partition in the case where the players do not differ in per capita tax base. In this setup, a computationally constrained social planner could actually achieve better results by allowing a decentralized jurisdiction formation game to occur, rather than attempting to impose their own (imperfectly computed) solution.[2] The situation here is reminiscent of arguments regarding centrally planned economies: the central planner faces a variety of difficulties in computing an appropriate allocation, whereas if decentralized agents acting in their own best interest naturally lead to efficient production and consumption decisions.

The decentralized outcome in our case, however, results in substantial inefficiency when

[1]The utilitarian perspective is of interest because it formalizes an intuitive notion of "good" and "bad" coalition structures. An example of this presented later in the paper is Figure 4: this coalition structure is likely Pareto optimal, but is regarded by disinterested Japanese observers as an undesirable outcome.

[2]Similarly, a central planner facing asymmetric information problems could benefit from decentralization. We do not consider asymmetric information explicitly in this paper because this formed the core of previous work in Weese [2015], but from a qualitative perspective the argument would be the same.

the actual data regarding per capita tax base is used. Thus, although from a theoretical perspective inefficiency could arise from a variety of sources, our simulations suggest that the empirically important source of inefficiency is the sorting of Farrell and Scotchmer [1988]: each player in the coalition formation game would prefer to merge with others that are richer than themselves, while avoiding poorer players. Stratification on income leads to a shortage of mutually acceptable partners, resulting in coalitions that are geographically questionable and substantially smaller than those in the social planner's optimal partition. Depending on the exact scenario, back of the envelope calculations suggest that inefficiency could be equivalent to several percent of GDP.

From an econometric perspective, we consider standard moment inequality estimators following Pakes [2010], as well as some estimators based on stronger distributional assumptions. These additional estimators allow us to consider alternative specifications containing additional covariates. The results from these specifications suggest that geographic heterogeneity was indeed far more important in determining the political boundaries chosen than religious, agricultural, historical, or other sorts of heterogeneity. The additional estimators thus provide justification for the preferred moment inequalities specification.

The main methodological contribution of this paper is to present a method of computing core partitions in fractional hedonic games. Our overall approach follows a method used in the "roommates problem" by Chung [2000], where successive myopic deviations eventually lead to a stable partition. A major issue is that the coalition formation game in Gifu consists of approximately 1000 players, and unlike a standard (pairwise) roommates problem, enumeration of potential coalitions is computationally infeasible. To avoid having to enumerate all potential coalitions, we express each myopic deviation as the solution to a mixed integer program. Using this technique, we are able to compute core partitions in a few hours using standard equipment.

Finding core partitions of fractional hedonic games is known to be an NP-hard problem in general [Brandl, Brandt, and Strobel 2015]. To our knowledge, our results are the first to show numerical solutions for large instances of these games. Although fractional hedonic games have attracted theoretical interest in economics, to date they have not been used in applied research. Our results suggest that many real world instances of fractional hedonic games may be much more easily solvable than theoretical worst case instances.

Using our myopic deviation algorithm we find that the core of our coalition formation game is non-empty, given the actual data and our parameter estimates. Thus, despite potential theoretical difficulties with the "right to self-determination" as operationalized in this paper,[3] empirically there are always outcomes that satisfy the relevant conditions.[4] The ongoing legal and philosophical debates regarding self-determination are thus relevant, as the existence of such a right would not result in instability and endless cycling, but would instead lead to stable partitions. Our results further suggest that empirical techniques could be brought to bear on questions that previously seemed amenable only to theoretical analysis. For example, is there a quantitative justification for the assertion that because Londoners are not a "people", London and other such urban agglomerations should not possess a right to self-determination?

An obvious objection to our approach is that we obtain parameter estimates by assuming that a national government acted as a benevolent social planner. If this assumption is incorrect, then the portions of this paper that serve as a program evaluation of a particular set of municipal mergers in 19th century Japan are invalid.[5] The main objective of our analysis, however, is more general: we show that there is an (approximate) "invisible hand" type result for decentralized jurisdiction formation when players differ only in "horizontal" characteristics, but not when they also differ in "vertical" characteristics. Simulations are required to reach these conclusions because the models we are most interested in have no closed form solutions [Gregorini 2009]. To perform these simulations we must somehow choose plausible parameter values. We base our parameters on a particular instance of boundary changes in Japan because the institutional setup there appears to match a fractional hedonic model and we can thus make it computationally tractable. We investigate which parameter values matter for our results (the congestability of public goods) and which do not (the precise tradeoff between heterogeneity and efficiencies of scale). If we have dramatically misunderstood the actual process of mergers in our Japanese data, the general results from our simulations still hold for a hypothetical environment in which there is substantial congestability of public goods as well as some sort of tradeoff between heterogeneity and efficiencies of scale. We believe that this is an environment of interest because it corresponds to how public goods appear to be provided in many situations.

[3] Well-known simple examples, such as Gale and Shapley [1962], show that the core can be empty in a one-sided matching game of the sort we consider.

[4] Follow-up research [Weese 2016] finds stable partitions when considering European geography and historical European national boundaries: this suggests that our Gifu dataset is not a "lucky draw" but is rather indicative of broad patterns of stability for fractional hedonic games based on actual data, despite theoretical counterexamples.

[5] The "obvious" reduced-form approach to our question quickly encounters a similar problem: if the southern half of a country is allowed to change boundaries in a decentralized way, and changes in the northern half are mandated centrally, is any observed difference in boundary patterns due to inefficiency in the decentralized approach or political biases in central decision-making?

1.1 Related Literature

This paper is inspired by Desmet et al. [2011], who consider European national boundaries as a coalition formation game. Desmet et al. use exhaustive enumeration for their simulations, and are forced to cut their dataset in half (from 24 down to 11 players) in order to make this computationally feasible. A number of other papers consider similar political coalition formation games. These include Brasington [1999], Gordon and Knight [2009], and Weese [2015]. These papers do not focus on simulating the outcome of the coalition formation game that they study, and the simulations that are performed do not face computational constraints because the object of interest is pairwise mergers.

Integer programming has been used extensively in the two-sided matching literature for finding chains of kidney donors [Roth, Sönmez, and Ünver 2007]. Our application of integer programming techniques is to a matching game where there is only one type of player: both our algorithm and the underlying theory differ substantially from the two-sided case.[6] The previous literature on integer programming in political economy appears limited to Serafini [2012], who considers a seat allocation problem in the EU parliament. Previous uses in other fields of economics include Gomory [1994] and Pinar and Camci [2012], as well as Elomri et al. [2013] in supply chain management.

This paper appears to be the first quantitative study of municipal mergers in Meiji Japan. Previous work on more recent Japanese municipal mergers includes Hirota and Yunoue [2014], Miyazaki [2014], and Weese [2015]. The techniques used and results obtained in these papers differ substantially from those presented below.[7]

From a broader perspective, this paper presents a sorting model based on a "strong Tiebout equilibrium" [Greenberg and Weber 1986], one where players arrange themselves into core-stable coalitions based on their income as well as other characteristics.[8] Many Tiebout models involve each player caring about the "average" type of player in their coalition, and a fractional hedonic game provides a natural way of modelling this "average" based payoff.

[6]For example, stability properties in two-sided models guarantee the existence of stable partitions, and algorithms such as the deferred acceptance algorithm allow for easy computation of these partitions in many cases [Roth 2008].

[7]Hirota and Yunoue [2014] uses a logit framework to look at political determinants of mergers. Miyazaki [2014] uses data on municipal referenda. Weese [2015] considers recent Japanese data where the central government provides equalization payments to municipalities. The observed equalization payments in this recent data are extremely large (up to 25% of GDP per capita for the smallest municipalities), and counterfactuals where there are no such payments are thus so far out of sample that there would be computational difficulties with any such simulation, as well as theoretical difficulties in interpreting the results.

[8]The main differences between our model and the canonical Tiebout [1956] model are that efficiencies of scale are never completely exhausted, the number of communities is (locally) small, and individual players are each of a distinct type. In the taxonomy offered by Scotchmer [2002], our model is one of a "spatial club" good, related to work such as Hochman, Pines, and Thisse [1995].

We provide an algorithm to compute the solution to large fractional hedonic games, and we show that empirically this solution exists. Although the precise model we consider is much simpler than those generally used in the Tiebout literature,[9] our algorithm would also apply to fractional hedonic games where the payoff for players depended on many more variables. It thus may be empirically possible to use strong Tiebout equilibrium models to analyze problems related to public schooling or other local public goods.

The remainder of this paper has the following structure: Section 2 presents the theoretical model, Section 3 describes the econometric model, Section 4 introduces the data used, Section 5 discusses the estimation results, Section 6 covers the counterfactual simulations performed, and Section 7 concludes.

2 Model

We consider a modification of the Alesina and Spolaore [1997] model of political jurisdiction formation, using a functional form for distance costs taken from Desmet et al. [2011]. Let there be N players, each of whom needs to receive local government services. Player i has income y_i and an inelastic demand for p_i units of services.[10] A coalition m of players will provide $P_m = \sum_{i \in m} p_i$ units of municipal services to themselves at a cost of

$$c(P_m) = \gamma_1 + \gamma_2 P_m. \tag{1}$$

The interesting case is the one where $\gamma_1 > 0$, as then the average cost per unit of service declines as more players are added to a coalition. The situation is that of a club good, where $\gamma_2 > 0$ corresponds to the case with congestability.

There is no quality dimension to the services provided, and the cost of providing them must be paid via proportional taxation. The budget constraint for coalition m is

$$\gamma_1 + \gamma_2 P_m = \tau_m Y_m \tag{2}$$

where $Y_m = \sum_{i \in m} y_i$. Other than the proportional taxation at τ_m, there is no redistribution or other transfers within a coalition. For a given municipality m, there is no choice regarding the tax rate τ_m as it is determined by the budget constraint.

In addition to the amount of taxes paid, players care about the identity of their coalition

[9] For example, our model does not include a real estate market, and there is no variation in public good quality or demand for the public good.

[10] In the empirical application below, a player will correspond to a feudal village, and p will be taken to be the population of the village.

partners. This setup corresponds to a hedonic coalition formation game as described in Bogomolnaia and Jackson [2002].[11] Specifically, the utility of player i in coalition m is given by

$$u_{im} = \beta_1 L(i,m) y_i + \beta_2 \tau_m y_i \tag{3}$$

where $L(i,m)$ is the heterogeneity that i experiences as a member of coalition m. We would expect that $\beta_1 < 0$ and $\beta_2 < 0$, as both heterogeneity and taxation are undesirable. Heterogeneity will be assumed to take the form

$$L(i,m) = \frac{\sum_{i' \in m} \ell_{ii'} y_{i'}}{Y_m} \tag{4}$$

where $\ell_{ii'}$ is the distance between i and i'. This specification for heterogeneity follows Desmet et al. [2011]: players experience disutility proportional to the average distance between them and their coalition partners.[12] A slightly unusual feature of the specification in Equation 3 is that richer players suffer greater disutility from distance. If the distances in question are geographic, then this could be due to a greater time cost of travel for those with higher incomes.[13] For the model in this section, and for the counterfactual simulations later on, distance will be taken to be geographic distance. However, when estimating parameters, we will also consider more complicated specifications where other sorts of distances are also included.[14]

The major advantage of using Equation 4 as the functional form for heterogeneity is that the payoffs in Equation 3 now have the form of a weighted fractional hedonic game. Aziz, Brandt, and Harrenstein [2014] introduce fractional hedonic games: they are a hedonic game where the payoff for player i of belonging to coalition m is determined by averaging some values $v_i(i')$ of all players i' in this coalition m.[15] That is,

[11] This is the hedonic game originally considered in Dreze and Greenberg [1980], except without transfers of any sort.

[12] This form of L is based on Greenberg [1956], as extended by Lieberson [1964]. It differs from the "distance to policy" heterogeneity cost used in Alesina and Spolaore [1997] and subsequent papers. Earlier work includes Greenberg and Weber [1986]. A literature review is provided in Donder, Breton, and Peluso [2012].

[13] This specification makes computation of core partitions substantially easier, and will also better match the observed coalitions in the data used. A further advantage is that empirically the players will correspond to feudal villages, containing multiple households with different levels of y. The preferences described in Equation 3 lead to all of these households having the same preferences over mergers: to see this, divide the equation by y. Thus, the specific form chosen allows us to ignore within-village heterogeneity in income.

[14] In this case, β_1 and L become vectors, and each distance would be calculated following Equation 4, using $\ell^{\mathrm{a}}_{ii'}$, $\ell^{\mathrm{b}}_{ii'}$, and so forth. These distances then enter additively in the utility function in Equation 3.

[15] In the coalition formation literature, coalitions are generally denoted by S. In this paper we use m instead because the coalitions in question correspond to municipalities.

$$u_{im} = \frac{\sum_{i' \in m} v_i(i')}{|m|} \tag{5}$$

We define a weighted version of this setup. In our particular case, we are interested in using tax bases as the weights, and thus player i will have a weight of y_i. Let the payoff for player i in a weighted fractional hedonic game be

$$u_{im} = \frac{\sum_{i' \in m} y_{i'} v_i(i')}{\sum_{i' \in m} y_{i'}}. \tag{6}$$

To see that the payoffs in Equation 3 have the form of a weighted fractional hedonic game, let

$$v_i(i) = \beta_2(\gamma_1 + \gamma_2 p_i), \tag{7}$$

$$v_i(i') = \beta_1 y_i \ell_{ii'} + \beta_2 \frac{y_i}{y_{i'}} \gamma_2 p_{i'} \qquad \text{for } i' \neq i. \tag{8}$$

The intuition here is that if player i is by themselves, then they must pay the entire cost of providing services, but they experience no distance cost. If player i forms a coalition with i', then there is a distance cost, but this is potentially offset by savings in the cost of providing services. Player i will now be able to share the fixed cost γ_1 with player i', as well as the variable cost of providing their own p_i units of demand for the good. On the other hand, however, they must now help provide the $p_{i'}$ units of the good that player i' needs. The degree to which player i will end up paying the variable cost for the goods going to player i' depends on the relative tax bases of the two players: this is why a $y_i/y_{i'}$ term appears at the end of Equation 8. If $y_i/p_i = y_{i'}/p_{i'}$, meaning that the tax base per unit demand of i and i' is the same, then $(p_i + p_{i'})/(y_i + y_{i'}) = p_i/y_i$ and the terms involving γ_2 in Equations 7 and 8 can be ignored entirely. If the per unit tax bases of i and i' are not the same, however, then the “richer” player will be providing a subsidy to the “poorer” player, and γ_2 becomes potentially important.

Let $\pi \in \Pi$ be a partition of players into coalitions, where Π is the set of all possible partitions. A Benthamite social planner would choose the partition

$$\begin{aligned} \pi^{\text{FB}} &= \operatorname*{argmax}_{\pi \in \Pi} \sum_i u_{i\pi} \\ &= \operatorname*{argmax}_{\pi \in \Pi} \beta_1 \sum_{m \in \pi} \frac{1}{Y_m} \sum_{i \in m} \sum_{i' \in m} \ell_{ii'} y_i y_{i'} + \beta_2 \gamma_1 |\pi| \end{aligned} \tag{9}$$

where $u_{i\pi}$ indicates the utility that player i receives from whatever coalition it belongs to in partition π. In Appendix A we show that Equation 9 is equivalent to a weighted Herfindahl index in the case where there are discrete types of players.

The intuition for the social planner's problem is clearly visible in Equation 9: the tradeoff facing the planner is between the first term (heterogeneity within each municipality m), and the second term (the fixed cost of running $|\pi|$ municipalities). The variable cost γ_2 does not appear in Equation 9. This is because there are always $\sum_{i=1}^{N} p_i$ units of municipal service demanded, regardless of the partition chosen.

This optimal partition π^{FB} is generically unique. A well-known special case is where the ℓ are given by euclidean distances, determined by players' locations on some plane. In the limiting case, where the players are tiny, uniformly distributed on the plane, and otherwise identical, the optimal partition is given by a regular hexagonal tiling. This was first discussed in the "central place theory" of Christaller [1933].[16] In general, however, there is no closed-form solution for the optimal partition of a fractional hedonic game [Aziz, Gaspers, et al. 2015] and it must be computed via some combinatorial optimization technique.

Our interest is in comparing π^{FB} with partitions that would form in the case of a decentralized coalition formation game. It is not theoretically obvious what the result will be here. One potential argument is that partitions resulting from a decentralized process should be distorted relative to those selected by the social planner because of a "fiscal externality" type result [Flatters, Henderson, and Mieszkowski 1974]: players at the "edge" of a coalition are being charged a tax rate τ determined by the total cost of providing services, rather than the marginal cost of their own demand for services. Another potential distortion is that small players have greater interest in merging than large players, because they face the same (total) distance cost but the smaller player will have greater savings from efficiencies of scale. It will turn out empirically that neither of these effects are important, and that the terms involving γ_2 in Equations 7 and 8 appear to be responsible for almost all inefficiency when there is decentralized jurisdiction formation.

In order to compare the decentralized case with the centralized case, we first need to formalize the concept of a "right to self-determination". This appears to be well represented by the core. In the coalition formation game without transfers considered in this paper, the core is

$$\Pi^* = \{\pi | \forall S' \notin \pi, \exists i \in S' \text{ s.t. } u_{i\pi} \geq u_{iS'}\}. \tag{10}$$

There is the possibility that Π^* is empty, and a substantial amount of work has been devoted

[16] Drèze et al. [2008] provides extensive citations regarding hexagonal tiling results. The efficient partition will be stable in this case because any deviation to a larger hexagon would be opposed by those at the edge of the deviation, and any deviation to a smaller hexagon would be opposed by those at the center of the hexagons in the efficient partition. However, the core is very large here, and thus depending on how it is determined which partition from the core actually occurs, substantial inefficiency could result.

to finding conditions under which the non-emptiness of Π^* is guaranteed.[17] In general, the results in this literature have been mostly negative: it is difficult to find conditions under which the core is guaranteed to be non-empty, and even more difficult to define these conditions in such a way that they can be easily checked. Brandl, Brandt, and Strobel [2015] discuss how fractional hedonic games also suffer from this problem.

In this paper we will mostly ignore this issue, and instead show below that core partitions exist given our data and parameter estimates. A potential criticism here is that this "works for me" attitude does not tell us anything about whether core partitions generally exist in fractional hedonic games.[18]

As a simple attempt to better understand why we observe a non-empty core in our data, we examined core emptiness for random coalition formation games in a simple euclidean environment. We considered a six player fractional hedonic game following Equations 7 and 8, where players differed in their location on a plane but had identical values $y_i = y$ and $p_i = p$. We normalized $\beta_1 y = 1$, and then calculated a value for $\beta_2\gamma_1$ as well as each player's location on the plane, with the objective of matching as closely as possible payoffs given in the Brandl, Brandt, and Strobel [2015] six player example.[19] We verified that this "euclidean" version of their example still had an empty core, and then considered random games where players were distributed uniformly within the bounding box of the original player locations. We generated 10 million of these random games: none of them had an empty core.[20]

The payoffs from the Brandl, Brandt, and Strobel [2015] example require players to be located on the vertices of a set of (nearly) equilateral triangles. We can only suppose that the tolerances required to generate a preference cycle are extremely narrow. The lack of this sort of special configuration in real world data sets would thus provide a natural explanation for why we find core partitions in our Japanese data, and more generally suggests that almost all non-artificial data sets would similarly have a non-empty core for the particular type of fractional hedonic game we consider.

[17]These conditions include "consecutiveness" [Greenberg and Weber 1986], "intermediate preferences" [Demange 1994], and the "top coalition property" [Banerjee, Konishi, and Sönmez 2001], among many others. Banerjee, Konishi, and Sönmez [2001] provides a detailed literature review.

[18]On the other hand, in the two-sided matching literature in certain cases empirical results regarding existence of stable matchings predated theoretical results explaining why this occurred.

[19]The value of $\gamma_2 p$ does not matter in this setup, as discussed above.

[20]Drèze et al. [2008] consider a coalition formation game with transfers, and show theoretically that the core is "almost" non-empty. This matches with the empirical finding here that the core is non-empty in the case without transfers.

3 Estimation Strategy

Estimation of the parameters of a structural model where the outcome takes a partition form presents substantial difficulties. We will avoid several of these difficulties by using a "measurement error only" model, where there are no payoff-relevant idiosyncratic shocks: for further discussion, see Appendix B. Models of this sort have a long history in econometrics [Morgan 1990], and have seen recent application in moment-inequality models [Pakes et al. 2015]. Motivated by the data available, we assume that most covariates are potentially measured with error. "Standard" instruments do not appear to be of much use: we provide further discussion of this point in Appendix C.

The observed outcome is a partition of N players into coalitions, chosen by a central planner. There is also a set of covariates X that describe the characteristics of this partition and other potential partitions. We assume that the central planner is utilitarian. We simplify notation by defining $u_m = \sum_{i \in m} u_{im}$ to be the total payoff for players participating in merger m, and $u_\pi = \sum_{m \in \pi} u_m$ to be the total payoff of partition π for all players.

Let X^*_π be the covariates describing this partition π. As the model presented in Section 2 presents a tradeoff between heterogeneity and efficiencies of scale, the simplest useful description of the characteristics of a partition π would have one variable that describes the total heterogeneity experienced in the partition, and another that describes the total cost of providing public services. We will use the first variable in X^*_π to describe the (distance) heterogeneity experienced in partition π. Label this entry in X^*_π as $X^*_{\pi\mathrm{D}}$. We calculate this by looking at the first term in Equation 9, and considering the portion following the coefficient β_1. This gives us

$$X^*_{\pi\mathrm{D}} = \sum_{m \in \pi} \frac{1}{Y_m} \sum_{i \in m} \sum_{i' \in m} \ell_{ii'} y_i y_{i'} \tag{11}$$

We now consider the cost of providing public services. Label the next entry in X^*_π as $X^*_{\pi\mathrm{FC}}$, and let it equal the second term in Equation 9, after removing the coefficient β_2. Thus, $X^*_{\pi\mathrm{FC}} = \gamma_1 |\pi|$, which is the fixed cost of running the $|\pi|$ municipalities present in partition π, where each municipality costs γ_1 to run. As discussed in Section 2, the variable cost does not depend on the partition π. There is thus no need for X^*_π to contain a $X^*_{\pi\mathrm{VC}}$ entry, as it would be identical for all partitions.

The value of the social planner's objective for partition π, given in Equation 9, can now be rewritten as

$$u_\pi = X^*_\pi \beta^0. \tag{12}$$

where β^0 is the true value of $\beta = (\beta_1, \beta_2)^{\mathrm{T}}$, and $X^*_\pi = (X^*_{\pi\mathrm{D}}, X^*_{\pi\mathrm{FC}})$. We assume a standard measurement error setup: the econometrician does not observe the true value of the covariate

X^*_π, but instead sees

$$X_\pi = X^*_\pi + \eta_\pi, \tag{13}$$

where $\eta_\pi = (\eta_{\pi\mathrm{D}}, \eta_{\pi\mathrm{FC}})$ is measurement error.[21]

Estimation will be based on comparing the characteristics of the observed partition, X_{π^0}, to the characteristics of another partition, $X_{\pi'}$, for many possible alternative partitions π'. As we are interested in the differences in characteristics between partitions π' and π^0, let

$$\tilde{X}_{\pi'} = X_{\pi'} - X_{\pi^0} \tag{14}$$

denote this difference, with $\tilde{X}^*_{\pi'}$ and $\tilde{\eta}^*_{\pi'}$ defined similarly. The central planner chose π^0 optimally based on Equation 9, and thus any other partition must have been worse from the central planner's perspective. Thus,

$$u_{\pi'} - u_{\pi^0} = \tilde{X}^*_{\pi'}\beta^0 \leq 0 \tag{15}$$

must hold for all $\pi' \in \Pi$.

In the model presented in Section 2, β_1 and β_2 were both scalars. It is easy to extend this theoretical model, however, to the case where there are several different types of heterogeneity, and β_1 is a vector describing the relative importance of these different types. If β_1 has even moderate length, and each of these types of heterogeneity are assumed to be measured with error, then a standard moment inequalities approach will not result in acceptably narrow confidence sets for β.

On the one hand, the best estimation strategy is one based on minimal assumptions. On the other hand, as will become clear in the following sections, minimal assumptions do not really allow for models to be estimated with more than two or three covariates. Based on a preliminary examination of our data as well as a review of the domestic qualitative literature, we believe that a very simple model based on geography will actually match the observed data fairly well.[22] To verify this, however, we would have to estimate a model containing geography as well as many other covariates, and show that these other covariates are not nearly as important.

[21] This matches the form of the payoffs given in Equation 3 if population (which determines τ_m) and tax bases y_{im} are measured without error, and X^* is interpreted to be data giving the distances $L(i,m)$. The model thus assumes that the *distances* are measured with error, not whatever underlying variables generate the distances. If the latter were the case, additional work would be required to explain the distributional assumption that will introduced shortly: under certain circumstances the error term could still be normally distributed (or at least mean zero), but the model in general becomes more complex.

[22] A model where geography is the only source of heterogeneity has a particular advantage given our model in Section 2, as we could ignore any potential political decision-making process within each individual feudal village: we will discuss this more at the beginning of Section 6.

The approach we will take is the following: we begin by presenting a strong set of assumptions, ones that will allow for estimation of models with many covariates. We then gradually relax these assumptions and show similar results, albeit with smaller sets of covariates. Finally, we consider the standard moment inequality estimator, which uses minimal assumptions and will give us parameter estimates for a model involving only geography.

We begin with some particularly implausible assumptions:

Assumption 1.

a) $\tilde{X}^*_{\pi'}$ *has an (improper) uniform distribution on the half-space satisfying Inequality 15.*

b) $\tilde{\eta}_{\pi'} \sim N(0, \sigma^2 I)$*, i.i.d.*

Appendix E shows that these assumptions result in an estimator that has the form of a probit. The probit has been used extensively, with assorted variations, in the empirical literature examining political jurisdiction formation: Brasington [1999] is an early example. We consider this model both because it provides a link with the existing empirical literature, and because, despite requiring assumptions that strain credulity, the estimates produced turn out to be surprisingly similar to those from the models making weaker assumptions.[23]

Now consider instead the following assumptions:

Assumption 2.

a) $\tilde{X}^*_{\pi'}$ *is distributed on a bounded region satisfying Inequality 15.*

b) $\tilde{\eta}_{\pi'} \sim N(0, \sigma^2 I)$*, i.i.d.*

Here the assumption regarding the distribution of $\tilde{X}^*$ is more pleasant, but the uncomfortable assumption regarding the distribution of $\tilde{\eta}$ remains. The assumption regarding $\tilde{\eta}_{\pi'}$ is the same as in the total least squares literature, and is undesirable because estimates will depend on the units in which the data is expressed.[24]

These assumptions lead to a deconvolution estimator that can be implemented computationally in small samples as a smoothed maximum score estimator. We present the details in Appendix F. A problem with this estimator is that the simple computational implementation makes sense only when the sample is "small", and thus asymptotics cannot be discussed. The

[23] Often empirical papers provide OLS estimates, even though OLS appears clearly inappropriate. We offer probit estimates in a similar spirit.

[24] A variety of solutions have been proposed, including Samuelson [1942]. Markovsky and Van Huffel [2007] provides a recent overview of the literature.

main advantage of this estimator is that – like the probit discussed above – it is commonly used in empirical work, and is thus useful as a well-known reference.[25]

We might thus be interested in an estimator that has standard asymptotic properties, particularly if it avoids the uncomfortable total least squares assumption required above. For this, consider a standard deconvolution approach. The assumptions needed in this case are

Assumption 3.

a) $\tilde{X}^*_{\pi'}$ *is distributed on a bounded region satisfying Inequality 15.*

b) $\tilde{\eta}_{\pi'} \sim N(0, \Sigma)$, *i.i.d.*

We provide details in Appendix G.

Finally, and as our main specification, we consider the case where only the standard assumptions required for a moment inequality approach are imposed:

Assumption 4.

a) $\tilde{X}^*_{\pi'}$ *is distributed on a bounded region satisfying Inequality 15.*

b) $\tilde{\eta}_{\pi'}$ *is distributed with mean zero conditional on the instruments* Z.

These assumptions lead to an estimator that is set identified.[26] The instruments we will use are based mainly on population p and tax base y.[27] We use moments that correspond to subsets of the data: these are discussed in Appendix H and shown in Appendix Table 9. We consider moments based on the restriction

$$\begin{aligned} E[\tilde{X}\beta^0|Z] =& E[\tilde{X}^*\beta^0 + \tilde{\eta}\beta^0|Z] \\ =& E[\tilde{X}^*\beta^0|Z] + 0 \\ \leq& 0 \end{aligned} \tag{16}$$

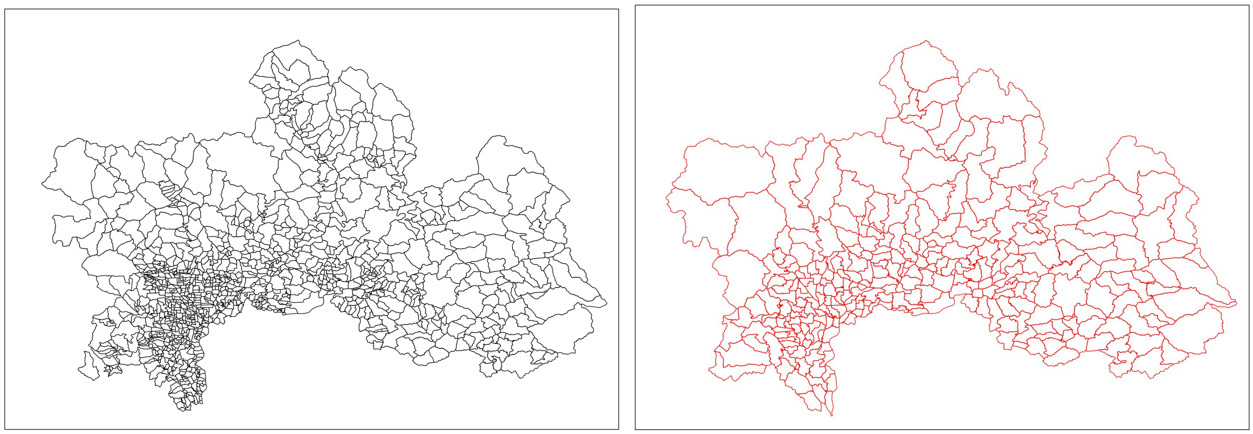
which follows from Assumption 4.[28]

[25]The argument in Appendix F is of course very different than the standard setup for a smoothed maximum score estimator. Our point is that computationally the estimator corresponds to this standard estimator, and thus it is easier to understand the estimates when they are presented below.

[26]Empirically, we will see below that we obtain set estimates rather than a point estimate. Theoretically, whether the estimator should converge to a point estimate depends on the data generating process for X. For example, if feudal villages only come in certain discrete populations and distances from one another, then the tradeoff between distance and efficiencies of scale would remain set identified asymptotically.

[27]The definition of $\tilde{\eta}_{\pi'}$ includes π^0, and thus π^0 is also implicitly being used as an instrument here. This is

Figure 1: Mergers in Gifu Prefecture



(a) Feudal villages, 1881

(b) Municipalities, 1897

4 Data

We use data from Gifu Prefecture in Japan. During the Meiji period, a set of municipal mergers (the *Meiji Daigappei*) were mandated by the central government as part of its modernization policies: prefectural and national officials acted as a central planner for these mergers. Mergers occurred across the country, mainly in the 1880s and 90s, and are described in more detail in the introduction to Appendix N. We concentrate on Gifu because high quality data on covariates is only available for that prefecture. The main advantage of historical data is that it better matches the simple theoretical model presented in Section 2.[29] In fact, the document responsible for the mergers (Interior Ministry Order 352) states in fairly explicit terms that the mergers are to involve a tradeoff between efficiencies of scale and geographic distance.[30] We thus have primary source support for a model that

valid because there is no payoff relevant idiosyncratic shock in the model, and measurement error η is mean zero even after conditioning on the partition chosen by the central planner.

[28]Empirically, some scaling of $\tilde{X}$ is necessary. We choose to scale the columns of $\tilde{X}$ so that their mean absolute values are equal.

[29]Modern data for Japan (and most other countries) would feature municipalities receiving some sort of transfers from a higher level of government. These systems usually exist due to some desire for redistribution. In the presence of such a transfer system, centrally planned mergers becomes a complicated tradeoff between redistribution through this transfer system, and redistribution by forcing rich and poor municipalities to merge together. Using data from a period when there was almost no redistribution avoids these issues.

[30]"... for the purpose of creating independent municipalities, in each municipality an appropriate amount of financial resources are required ... when merging do not make area excessively large and do not disturb convenience of access." It is true that the words "efficiencies of scale" do not appear in the order, but the tax base of each village is fixed, and thus the obvious way a municipality with "appropriate" financial resources could be created out of villages without "appropriate" financial resources would be if the per capita cost of providing services is decreasing with scale. A potential counterargument would be that the order is not referring to efficiencies of scale, but is instead asking for poorer areas to be deliberately merged with

can conveniently be written in the form of a fractional hedonic game. The same source also states that the planner is to “give consideration to the wishes of the villages, and not be antagonistic to the sentiment of the people.” The mergers are to be consultative but not democratic, with the planner responsible for considering local opinions before deciding on the final set of jurisdiction boundaries.

The main dataset for covariates is the *Gifu-ken Chouson Ryakushi* (GKCR) of 1881 and related documents. This covers the southern portion of Gifu, describing 1111 feudal villages that were combined to form 286 western-style municipalities. The initial boundaries of these villages from the GKCR are shown in Figure 1a, and the boundaries after the mergers are shown in Figure 1b.[31]

To match the model to the data, let the players be feudal villages. Let the inelastic demand for services be given by population, as reported in the GKCR.[32] For tax base, we use the *koku* ratings reported in the GKCR. This is historical land tax data, and, although denominated in rice, covers all sorts of production. As discussed in Appendix N, land tax was the most important source of revenue during this period, and thus use of the *koku* ratings seems appropriate.

The boundaries shown in Figure 1a describe each feudal village as a polygon. However, in most cases, the villages in the GKCR correspond to one or more clusters of houses, surrounded by the land worked by these households. Although a household level map is not available for Gifu, the *Jinsoku Chizu* of 1880 shows the precise location of households for part of eastern Japan. Appendix Figure 6 shows a representative rural area: the households are clearly clustered, and the location of households could be reasonably accurately described using only a small number of points. We take advantage of this feature of the population distribution of this period, and create a new dataset based on points rather than polygons. In most cases only one point is required: this means that there is basically no within-village

richer areas, thereby creating municipalities with closer-to-average (and thus “appropriate”) resources. This alternative interpretation is not consistent with the portion of the order that reads “existing villages that ... have sufficient resources should not be merged or split”, because if the objective was to redistribute resources then the richer villages are precisely the ones that should be targeted for merging.

[31] In terms of economic theory, the observed pattern of municipal boundaries is consistent with the model presented above, in which there is a tradeoff between efficiencies of scale and geographic heterogeneity. In Appendix D we present a brief qualitative discussion of why a model based instead on the internalization of externalities appears to be inappropriate in this particular case.

[32] Appendix Figure 13 shows the population density of feudal villages. Villages with higher population density have municipalities with smaller surface area, while those areas with lower population density have jurisdictions with larger area. This pattern follows the “size density hypothesis” of Stephan [1977], which has been subjected to considerable study outside of economics. In Gifu, the pattern continues to hold for the post-merger municipalities. The pattern also holds across a wide selection of countries, and varieties of jurisdictions [Stephan 1984]. Suzuki [1999] provides additional citations along with an application to Japanese data. The pattern does not appear to be due to measurement error: this possibility was discussed in Vining, Yang, and Yeh [1979] and Stephan [1979].

Table 1: Cost of providing local government services

	population	cost
"large"	3165	$c_1 + c_2$
"medium"	$\frac{3165}{2}$	$\frac{2}{3}c_1 + \frac{c_2}{2}$
"small"	$\frac{3165}{4}$	$\frac{1}{2}c_1 + \frac{c_2}{4}$

Source: government document reproduced in *Niigata-ken Shichouson Gappei Shi*.

heterogeneity in terms of geography, and will allow for us to ignore potential within-village politics when we perform counterfactual simulations in Section 6.

For distance ℓ, we begin by calculating a straight-line distance and a walking distance, based on the point data just discussed. Details regarding these calculations are provided in Appendix K.2. We also calculate distances for other sorts of heterogeneity: Table 2 gives the complete list of covariates used. Details regarding these covariates and their calculation are given in Appendix K.3.

With the theoretical model described in Section 2 and the estimation strategy described in Section 3, the importance of the fixed cost γ_1 is identified relative to the cost of heterogeneity. It is not possible, however, to say anything about the importance of the variable cost γ_2 using data on the partition chosen by the central planner. This is because γ_2 does not enter into the optimization problem in Equation 9. For counterfactual simulations, however, the value of γ_2 may be important, as it affects the tax rate τ_m, which in turn affects the individual payoffs given in Equation 3. A value for γ_2 thus needs to be chosen, and this choice requires the use of some sort of auxiliary data.

During the merger period, government bureaucrats produced a document describing the cost of providing public services for municipalities of three sizes: these costs are shown in Table 1.[33] Here $c_1 = ¥545.668$ was a constant that corresponded to administrative costs that exhibited efficiencies of scale, and $c_2 = ¥1467.931$ was a constant corresponding to costs that did not exhibit efficiencies of scale. At the three points provided, the costs correspond exactly to a cost function of the form used in Equation 1, with a fixed cost $\gamma_1 = c_1/3$, and a variable cost $\gamma_2 = \frac{2c_1/3+c_2}{3165}$, despite the fact that statistically there is an extra degree of freedom. There is no explanation offered of how the government arrived at these estimates, and thus it is unclear whether they believed that a cost function with only a fixed cost and a variable cost was particularly appropriate, or whether at the sizes that they chose to examine

[33] A population of 3165 appears to have been used as the base because it corresponded to the average population served by an administrative office under the briefly-used "ward" system, described in Appendix N.1.

the efficiencies of scale happened to fit this pattern.

While there is no documentation available describing how these numbers were arrived at, verification of other sorts is available. Data on actual municipal expenditures is available for 1881, before the implementation of the new municipal system. This is shown in Appendix Figure 22, along with the cost function based on Table 1. Reiter and Weichenrieder [1997] survey the existing literature and conclude that there has been limited success in using actual expenditure data to estimate efficiencies of scale. For comparison purposes, however, a bivariate regression is provided in the figure.

The strongest confirmation for the validity of the numbers in Table 1 comes from much later sources. In 1950, when roughly the same municipal structure was still in place, a government document describing the efficiencies of scale in the provision of public services was produced.[34] This document provides a detailed breakdown of efficiencies of scale by service, for 20 public services, with the cost of each service described by a spline function with 6 knots. Despite the gap of 60 years and a substantial expansion in the number of public services provided, the estimates match the 1890 figures very closely, as shown in Figure 22.[35] We thus use values of γ_1 and γ_2 corresponding to Table 1.

Using the values of p, y, ℓ, and γ just discussed, we create $\tilde{X}$ matrices with which to use the estimators discussed in Section 3. A major advantage of the "measurement error" type of model is that our choice of alternate partitions to consider can depend on the partition π^0 that actually occurred. We consider a total of 3990 alternate partitions, created by considering three types of modifications to π^0: "switches", where two neighbouring feudal villages that are in two different mergers in π^0 are swapped, "splits", where a merger in π^0 is broken into two separate groups of feudal villages, and "mergers", where one further merger is conducted between two adjacent municipalities. Further details regarding how each row of $\tilde{X}$ is constructed given an alternative partition π' are provided in Appendix L. Summary statistics regarding the data matrices are provided in Table 2.[36]

[34] This is the *kijun zaisei juyou gaku* portion of the *heikou koufukin*.

[35] An additional difference is that the 1890 figures appear to have been produced to describe the appropriate size for municipalities during the reorganization, while the 1950 figures were for use in an equalization transfer program. The different purpose suggest that any political biases in the reported figures would also be quite different.

[36] Additional results in Appendix E suggest that similar results are obtained when only "switches" or only "splits" and "mergers" are considered.

Table 2: Summary Statistics (for $\tilde{X}$)

	I	II	III	Units	Description (of underlying variable X)	Source
FIXED.COST	0	-0.05	-0.02	¥	Fixed cost of providing public services	NSGS
	(0)	(0.13)	(0.09)			
DIST.WALKING	1.92	0.49	1.30	1000 sec.	Distance in terms of walking time	CIAS,
	(2.84)	(1.94)	(2.59)			GIAJ
DIST.STRAIGHT	1.97	0.47	1.33	km	Straight line distance	CIAS
	(2.99)	(2.06)	(2.73)			
RELIGION	0.02	-0.03	0.002	Herfindahl	Differences in religious sect identities	GKCR
	(0.17)	(0.13)	(0.15)			
PRODUCTION	0.05	0.01	0.03	Herfindahl	Differences in (agricultural) products	GKCR
	(0.36)	(0.13)	(0.29)			
PROPERTY	0.02	0.0004	0.01	Herfindahl	Differences in types of property	GKCR
	(0.11)	(0.05)	(0.09)			
LORD	0.28	0.05	0.18	Herfindahl	Differences in identity of feudal lord	GKCR
	(0.74)	(0.35)	(0.61)			
FISH	0.03	0.02	0.03	100*Herf.	Differences in fishing activity	GKCR
	(0.49)	(0.26)	(0.41)			
WEALTH	0.01	-0.001	0.003	Herfindahl	Differences in land holding distribution	GKCR
	(0.04)	(0.02)	(0.037)			
HH300	0.17			Indicator	Are there more than 300 households?	GKCR
	(0.55)					
HH500	0.04			Indicator	Are there fewer than 500 households?	GKCR
	(0.55)					
N	2257	1733	3990			

Statistics given in Columns I-III are for $\tilde{X}$: as described in Equation 14, this is the difference between the characteristics X of the partition actually observed, and an alternative partition. The "Description" column provides a very brief description of each underlying characteristic this is used in computing the differences. For a more detailed description of the characteristics and the method used, see Appendix K.

Column I: "Switches" (swap two adjacent villages in different mergers)

Column II: "Mergers/Splits" (split an actual merger in half, or put two actual mergers together)

Column III: I and II together. See Appendix H for further details.

Data source abbreviations:

NSGS: *Niigata-ken Shichouson Gappei Shi*

CIAS: Center for Integrated Area Studies, Kyoto Univ.

GIAJ: Geospatial Information Authority of Japan

GKCR: *Gifu-ken Chouson Ryakushi*

5 Parameter Estimates

We are interested in what the observed data can tell us about the tradeoff between efficiencies of scale and heterogeneity. In most cases, we will normalize results so that fixed cost always has a coefficient of -1.[37] The units for fixed cost are yen, and this normalization thus provides a natural numeraire for coefficient estimates. A wide variety of variables describing heterogeneity are available in the data, but casual inspection of Figure 1 suggests that geography is by far the most important. We will first confirm this impression by considering specifications based on Assumptions 1-3. After this, we will calculate estimates using Assumption 4 for a model based only on geography, and use this model as the basis for our counterfactual simulations.

A particular concern that arises at this point is that of standard errors. With the exception of the moment inequalities estimator, the estimators described in Section 3 make an assumption that observations – that is, alternative partitions that the social planner could have chosen but did not – are i.i.d. at least in the error structure. Suppose that in the actually observed partition π^0 we see a coalition consisting of ten players: $\{1, 2, 3...10\}$. We could consider an alternative partition that instead includes two coalitions: $\{1, 2, 3, 4, 5\}$ and $\{6, 7, 8, 9, 10\}$. However, we could also consider an alternative partition that includes the two coalitions $\{1, 2, 3, 4, 6\}$ and $\{5, 7, 8, 9, 10\}$. In this case, there are many very similar alternative partitions, and the i.i.d assumption appears to be violated.

We attempt to avoid this problem by careful choice of the set of alternative partitions that we consider, so that multiple "similar" alternative partitions are not used.[38] Appendix H provides further information regarding the particular alternative partitions we consider, and summary statistics are shown in Table 2.

Table 3 gives the results from the "probit" model based on Assumption 1. The parameter β_2, describing the importance of the fixed cost, is not identified if all the alternative partitions have the same number of (post-merger) municipalities as the actually observed partition π^0.[39] We first consider a set of alternative partitions that has this characteristic, in order to be able to ignore the cost of providing services, and instead focus purely on the tradeoffs the central planner appears to have made between different sorts of heterogeneity.

[37] The exception is the probit estimates, because some of the estimates we present are for models that do not involve a fixed cost term.

[38] A major advantage of the "measurement error only" type model is that we are generally allowed to choose a subset of alternative partitions to consider. Most models with payoff relevant idiosyncratic shocks (other than the logit) do not allow this, and thus would be computationally infeasible.

[39] This is because regardless of the partition chosen, there will be $\gamma_1|\pi'| = \gamma_1|\pi^0|$ paid in fixed cost, as all partitions considered have the same number of municipalities.

Table 3: Parameter Estimates (Probit)

	I	II	III	IV	V	VI
FIXED.COST					-0.99^{***}	-0.88^{***}
					(0.05)	(0.03)
DIST.WALKING	-0.05^{***}	-0.05^{***}		-0.07^{***}	-0.06^{***}	-0.05^{***}
	(0.002)	(0.002)		(0.01)	(0.003)	(0.002)
DIST.STRAIGHT			-0.04^{***}	0.02		
			(0.002)	(0.01)		
RELIGION	-0.04	-0.03	-0.05	-0.04	0.03	-0.00
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
PRODUCTION	-0.02	-0.02^{*}	-0.02^{*}	-0.02	-0.11^{***}	-0.03^{**}
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
PROPERTY	-0.12^{***}	-0.12^{***}	-0.12^{***}	-0.12^{***}	-0.02	-0.10^{***}
	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)	(0.03)
LORD	-0.05^{***}	-0.05^{***}	-0.05^{***}	-0.05^{***}	-0.06^{***}	-0.05^{***}
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.004)
FISH	-0.13^{*}	-0.13^{**}	-0.10^{*}	-0.13^{*}	-0.10^{***}	-0.11^{***}
	(0.05)	(0.05)	(0.04)	(0.05)	(0.02)	(0.02)
WEALTH	-0.17	-0.16	-0.17^{*}	-0.17	-0.32^{*}	-0.21^{**}
	(0.09)	(0.09)	(0.08)	(0.09)	(0.14)	(0.07)
HH300		0.03^{***}				
		(0.01)				
HH500		0.01				
		(0.01)				
Num. obs.	2257	2248	2257	2257	1733	3990

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Note: for ease of interpretation, variance of the error term is set to $\sigma^2 = 10$, which makes FIXED.COST coefficient close to -1. Tradeoffs in table are thus (close to) interpretable in terms of yen.

Columns I-IV show results using Π'_1, a set of 2257 alternative partitions created by moving player i from municipality m_1 to m_2, such that alternative partition π' contains $m'_1 = m_1 \setminus i$ and $m'_2 = m_2 \cup i$, instead of m_1 and m_2. This is done for all i, m_1, and m_2, such that m_1 contains at least two players, and i is geographically adjacent to m_2. This produces a total of 2257 moves. This corresponds to Column I in Table 2.

Column V is based on the data described in Column II of Table 2.

Column VI is based on the data described in Column III of Table 2.

Column I provides estimates of the tradeoff between seven types of heterogeneity: geographic distance, as expressed in minutes of walking time, and six other variables. Comparing the coefficient estimates in Column I with the standard deviations in Table 2, we see that geographic distance appears to be the most important determinant of the boundaries of political jurisdictions: the standardized coefficient is four times higher than that of any of the other variables.[40] Perhaps not coincidentally, geography is the only type of heterogeneity explicitly mentioned in Interior Ministry Order 352.

We might wonder whether there is any evidence that the central planner actually chose boundaries following the sort of model outlined in Section 2. One alternative hypothesis is that the planner simply followed a set of instructions it was given. The instructions in Interior Ministry Order 352 stated that municipalities should have between 300 and 500 households. In Column II, we include two additional variables to take into account these instructions.[41] The first variable is statistically significant and the second is not, but the inclusion of these variables does not have a substantial effect on the other coefficient estimates, and given the 0-1 nature of these variables at the estimated coefficients they are not economically important regardless of their statistical significance.[42] It thus appears that the central planner may have been paying attention to the lower limit of 300 households, but was also clearly considering other factors when deciding the pattern of mergers.[43] The raw data shows that the upper limit appears to have been less respected than the lower: Appendix Figure 14 shows that a substantial number of mergers resulted in municipalities of more than 500 households.

We also might wonder whether there is any evidence in the data that the central planner actually considered walking distances, rather than simply looking at straight line distance, as

[40] The coefficient on fishing appears anomalously large, and is much larger than will be estimated later in Table 4 and 5. Most of the villages in the dataset have few if any fishermen, while a few are very dependent on fish. This covariate more clearly violates the uniformity in Assumption 1.a than other covariates, which may explain why it is the only one to have an order of magnitude difference in the estimates.

[41] The construction of these variables is given in Appendix K.3.

[42] There are 9 fewer observations in Column II because data on the number of households was not available.

[43] Matsuzawa [2013] presents at least one case where they argue that central planners attempted to force a village to merge with specific reference to the lower population limit. The point of our analysis here is not to argue that Matsuzawa [2013] is incorrect: our point is that from a *quantitative* perspective, factors such as efficiencies of scale and geographic heterogeneity do a relatively good job of explaining the observed pattern of mergers, and Column II shows that this is not due to colinearity between geographic distance within a merger and the 300/500 household thresholds. There is no substantial change in any of the coefficients in Column I when the household threshold variables are included. We do not conduct a more extensive analysis of a model based only on the household thresholds because the social planner's objective function in this model is difficult to write down. For example, if a -1 penalty were imposed for each merger violating the threshold, then merging all of Gifu together into a single municipality would result in only a single -1. Even if the penalty were assessed on a per capita basis, there would in general be an enormous number of partitions with exactly the same penalty: a swap of some municipalities between two mergers that violate the thresholds will not change the objective function so long as the municipalities continue to violate the thresholds after the swap.

the latter is easier seen on a map. Column III repeats Column I, except substituting straight line distance for walking distance. There is no substantial change in coefficients, other than the coefficient on distance being somewhat lower. This is not particularly surprising, because straight line distance and walking distance are highly correlated. Column IV includes both distances. Here we see that the coefficient on walking distance has the expected sign and if anything a slightly higher magnitude than Column I, whereas the coefficient on straight line distance is statistically insignificant and has the opposite sign. We thus conclude that the planner seems to have followed the Ministry instructions to consider the convenience of transportation, and did not take the dramatic shortcut assuming that Gifu was flat, and that all points that appeared to be equidistant on a map were in fact equally easy to reach.

Column V uses a different set of alternative partitions, created by considering either a partition where two adjacent municipalities were merged together, or a partition where one of the municipalities was split into two. With these alternatives, there are now a different number of municipalities in the alternative partition than in the actual partition π^0 (either one fewer or one more), and thus the importance of the fixed cost β_2 is now identified relative to the importance of the different sorts of heterogeneity. The only major difference in Column V is the coefficients on property and production, the former of which is smaller and the latter larger, compared to Columns I-IV. The types of land present in a municipality are closely related to the types of products produced, and the effect of these two covariates may thus be difficult to separate.

Column VI reports results using a combined dataset. The results are broadly similar to those reported in the preceding columns. Due to the assumptions required, the probit model reported in Table 3 is most useful for preliminary analysis and quickly checking multiple specifications. We thus continue with models based on more plausible assumptions.

Table 4 reports estimates from the "smoothed maximum score" estimator of Equation 24, based on Assumption 2. Columns I-VI show that, in addition to geographic distance, a variety of other variables are statistically significant when entered into the regression one at a time. Column VII, however, shows that most of these variables become statistically insignificant when entered together.

Table 5 reports estimates from the "minimum distance" estimator of Equation 26, based on Assumption 3. Results here are broadly the same as in Table 4, although statistical significance levels are lower. Unsurprisingly, statistical significance decreases as weaker assumptions are employed in estimation. We do not report results for a column with all variables included: all the coefficients except for distance become insignificant for most specifications beyond Column VII, and optimizing the objective function becomes increasingly difficult.

Table 4: Parameter Estimates (Smoothed Maximum Score)

	I	II	III	IV	V	VI	VII
FIXED.COST	-1.00^{***}	-1.00^{***}	-1.00^{***}	-1.00^{***}	-1.00^{***}	-1.00^{***}	-1.00^{***}
	(0.05)	(0.02)	(0.03)	(0.03)	(0.02)	(0.03)	(0.04)
DIST.WALKING	-0.08^{***}	-0.08^{***}	-0.08^{***}	-0.07^{***}	-0.08^{***}	-0.08^{***}	-0.06^{***}
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
RELIGION	-0.06						0.00
	(0.06)						(0.05)
PRODUCTION		-0.04^{**}					-0.02^{*}
		(0.01)					(0.01)
PROPERTY			-0.16^{***}				-0.06
			(0.04)				(0.05)
LORD				-0.06^{***}			-0.05^{***}
				(0.01)			(0.01)
FISH					-0.003^{*}		-0.001
					(0.001)		(0.001)
WEALTH						-0.54^{**}	-0.38^{**}
						(0.22)	(0.15)
Num. obs.	3990	3990	3990	3990	3990	3990	3990

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$. Standard errors are reported for fixed cost because it is is normalized to -1 after estimation.

Coefficient estimates for the importance of geographic distance are very similar in Tables 4 and 5: across 14 specifications, the coefficient on distance is always between -0.06 and -0.08. On the other hand, the situation becomes confused when considering other variables: religious heterogeneity is statistically significant in Table 5 but not 4, while heterogeneity in wealth is statistically significant in Table 4 but not 5. Unlike the estimates for the importance of geographic distance, coefficient estimates on these other variables vary widely depending on the exact specification used. In both Table 4 and 5, the coefficient on geographic distance is much larger relative to its standard deviation than any of the other variables. Given these results, for counterfactual simulations we will use a model that features only the trade-off between efficiencies of scale and geographic distance. A major advantage of choosing this specification is that it allows us to ignore potential political issues with within-village decision-making.[44] An additional justification for this specification is that geographic heterogeneity is the only sort of heterogeneity explicitly mentioned in Interior Ministry Order 352.

[44]See the discussion at the beginning of Section 6 for details. An ancillary benefit of this simple model is that simulation results can be displayed in two dimensions by plotting players according to latitude and longitude. Visualization becomes much more difficult as additional variables are added.

Table 5: Parameter Estimates (Minimum Distance)

	I	II	III	IV	V	VI	VII
FIXED.COST	-1.00^{***}	-1.00^{***}	-1.00^{***}	-1.00^{***}	-1.00^{***}	-1.00^{***}	-1.00^{***}
	(0.10)	(0.07)	(0.06)	(0.09)	(0.07)	(0.08)	(0.07)
DIST.WALKING	-0.07^{***}	-0.08^{***}	-0.07^{***}	-0.08^{***}	-0.08^{***}	-0.08^{***}	-0.06^{***}
	(0.01)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)
RELIGION	-0.35^{**}						-0.25^{**}
	(0.13)						(0.11)
PRODUCTION		-0.11^{*}					
		(0.05)					
PROPERTY			-0.33^{**}				-0.25
			(0.12)				(0.16)
LORD				-0.09^{*}			
				(0.04)			
FISH					-0.02^{*}		
					(0.01)		
WEALTH						-0.75	
						(0.60)	
Num. obs.	3990	3990	3990	3990	3990	3990	3990

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$. Standard errors are reported for fixed cost because it is normalized to -1 after estimation.

For appropriate parameter values to use, we turn to our final set of estimates. Table 6 reports estimates from the "moment inequalities" estimator of Equation 16, based on Assumption 4. With only distance included, the confidence set includes the coefficient estimates in Tables 4 and 5. Including other variables, however, causes problems: confidence sets for the distance coefficient become unbounded in two cases, and include zero in one other case. If it has already been decided that Column I is an appropriate specification, then the results in this table are useful. However, for exploratory analysis, Table 6 is basically useless: Column V, for example, shows that differences in the lord that ruled the villages during the feudal period is enough to satisfy all the moment inequalities generated from Equation 16, without resorting to geographic distance at all. In the absence of good instruments for all the covariates being considered, it is difficult to use moment inequalities to estimate more complicated specifications than the single covariate in Column I. The results in Column I, however, are useful, because they confirm that the estimates of the importance of walking distance relative to fixed cost obtained in Tables 4 and 5 are plausible. Column I also suggests that other reasonable values for the coefficient on distance would be ones that place relatively more importance on distance: previous estimates are near the upper end of the confidence set in Column I, and thus it might be useful to check values closer to the lower end as well. The upper endpoint of -0.06 corresponds to one hour of additional walking time being approximately equivalent to ¥0.2 ($\simeq 0.06/1000 * 60 * 60$), or about the cost of a gallon of rice.[45]

[45]To evaluate model fit, the optimal partition for the social planner can be calculated as described in the following section. Appendix Figures 23 and 24 show these results.

	I	II	III	IV	V	VI	VII
FIXED.COST	-1	-1	-1	-1	-1	-1	-1
DIST.WALKING	$[-0.12, -0.06]^*$	$[-\infty, -0.03]^*$	$[-0.12, -0.06]^*$	$[-.12, -0.06]^*$	$[-.20, 0.04]$	$[-0.12, 0.08]$	$[-0.12, -0.04]^*$
	$(-0.15, -0.05)$	$(-\infty, -0.001)$	$(-0.17, -0.04)$	$(-0.17, -0.04)$	$(-\infty, 0.34)$	$(-\infty, \infty)$	$(-0.19, -0.05)$
RELIGION		$[-0.70, \infty]$					
		$(-1.27, \infty)$					
PRODUCTION			$[-0.02, 0.02]$				
			$(-0.06, 0.07)$				
PROPERTY				$[-0.06, 0.10]$			
				$(-0.20, 0.29)$			
LORD					$[-0.72, 0.82]$		
					$(-2.96, \infty)$		
FISH						$[-0.14, 0.01]$	
						$(-\infty, \infty)$	
WEALTH							$[-6.05, 8.88]$
							$(-10.14, 26.30)$
Num. obs.	3990	3990	3990	3990	3990	3990	3990

$^*p < 0.05$. Reported confidence sets are [50%] and (95%). Confidence sets calculated following Andrews and Guggenberger [2009], using subsampling.

Table 6: Parameter Estimates (Moment Inequalities)

6 Counterfactual Simulations

Suppose that, instead of centralized mergers, individual feudal villages had been allowed to decide independently how to arrange themselves into municipalities. We then have approximately 1000 players involved in a fractional hedonic coalition formation game, with approximately 2^{1000} potential coalitions. It is not computationally feasible to enumerate all the coalitions that could potentially form. We present a method that relies on the payoff structure inherent in fractional hedonic games.

An advantage of the particular fractional hedonic game payoffs presented in Section 2 is that income heterogeneity *within* an individual feudal village does not matter: the preferences of an individual within a given village over potential merger partners do not depend on whether that individual is rich or poor.[46] Furthermore, in our data many feudal villages have everyone located (almost) at the same point geographically (see Appendix Figure 6).[47] Thus, so long as we stick to a specification where heterogeneity is based on geography, all individuals within a village will have the same preferences over all potential mergers, and we can thus avoid potential complications that would normally arise from within-village politics.

Any given partition π may have many blocking coalitions. Suppose that m' is a blocking coalition. Taking the payoffs defined in Equation 6 for a weighted fractional hedonic game, it must be the case that, for every player i in m',

$$u_{i\pi} < \frac{\sum_{i' \in m'} y_{i'} v_i(i')}{\sum_{i' \in m'} y_{i'}}. \tag{17}$$

The intuition behind our strategy is that multiplying both sides of this inequality by $\sum_{i' \in m'} y_{i'}$ creates inequalities that are linear in the membership of m', and the membership of m' can be described by a binary variable for each player indicating whether or not it is a member of m'. Details of this approach are provided in Appendix I. The problem of finding a blocking coalition can then be posed as a maximization problem based on mixed integer programming with linear constraints. Let w be a vector of weights, and let t be a slack variable. The program

$$\begin{aligned} &\operatorname*{argmax}_{m'} \max_{t>0} t \\ \text{s.t.} \quad \forall i \in m', \quad & w_i t < -u_{i\pi} \frac{\sum_{i' \in m'} y_{i'}}{y_i} + \beta_1 \sum_{i' \in m'} \ell_{ii'} y_{i'} + \beta_2 (\gamma_1 + \gamma_2 \sum_{i' \in m'} p_{i'}) \end{aligned} \tag{18}$$

[46] To see this, divide Equation 3 by y_i.

[47] For details regarding physical locations of villages, see Appendix K.1. Appendix Figure 5 shows that most villages are associated with only a single point.

Data: N, v, w, y
Result: A core partition π^* (or loop forever)
Arbitrarily assign players to a starting partition π_1;
Iteration count $j = 1$;
while *there is a blocking coalition m' for partition π_j* **do**
  Identify "affected" coalitions, $A = \{m | m \in \pi_j, \exists i \in m \text{ s.t. } i \in m'\}$;
  Identify "residual" players, $R = \{i | i \in m \in A, i \notin m'\}$;
  if $R \neq \emptyset$ **then**
    Recursion: find a core partition π^{R*} using only players R;
    $\pi_{j+1} = (\pi_j \setminus A) \cup \{m'\} \cup \pi^{R*}$;
  else $\pi_{j+1} = (\pi_j \setminus A) \cup \{m'\}$;
  $j = j + 1$;
end
$\pi^* = \pi_j$;

Algorithm 1: Core Partition via Myopic Deviations

will either return a blocking coalition m', or an infeasibility certificate with a numerical proof that no such coalition exists. We will call the m' that is returned by this optimization a "myopic deviation".

Algorithm 1 attempts to find a core partition by successively generating blocking coalitions. Nomenclature and some ideas regarding recursion are taken from Ray and Vohra [1997], while the use of myopic deviations comes from Roth and Vate [1990] and Chung [2000]. In this algorithm, the (mixed) binary program to find a blocking coalition given in (18) appears in the inner loop.

The coalition formation game considered in this paper contains "minimal inaccessible coalition configurations" as described in Papai [2003], and thus the no-cycle results from the two-sided matching literature do not apply. There is thus the possibility that Algorithm 1 will loop forever. Using our data and parameter estimates, however, the algorithm always terminates.[48] By using different weights w in (18) across runs of the algorithm, we pick out different paths of myopic deviations, and thus different core partitions. The partition π_1 used to initialize Algorithm 1 does not appear to matter: we obtain qualitatively similar results using the grand coalition, the all-singleton partition, or the social planner's preferred partition. We use the all-singleton partition as our starting partition for the results discussed below, because it is clear that any stable partition can be obtained via a sequence of myopic deviations starting from the all-singleton partition.[49]

[48] Computational difficulty results in Arkin et al. [2009] regarding the existence of polynomial time algorithms suggest a possible explanation for why the algorithm used is computationally feasible.

[49] Proof: one deviation for each coalition in π^*. Computation time is also much lower when starting from

Table 7: Simulation Results: Number of Municipalities

β_1	I (social planner)	II ("heuristic" planner)	III (equal tax base)	IV (actual tax base)	V (no variable cost)	VI (subsidized fixed cost)
0	1	1	1	60	1	99
-0.06	224	340	268.2	409.9	255.8	724.8
			(3.0)	(2.7)	(3.4)	(1.0)
-0.08	271	386	320.2	459.0	304.9	766.0
			(2.7)	(2.2)	(3.3)	(1.0)
-0.12	341	460	396.0	540.6	382.8	831.2
			(2.8)	(1.9)	(2.8)	(0.9)

Estimated standard deviations of partitions within solution set are given in parentheses were there are multiple solutions to the coalition formation game. The social planner's optimal partition is unique, as is the decentralized outcome where there is no distance cost.

We run Algorithm 1 based on parameters from Column I, Table 6 and the observed covariates in our dataset.[50] As we are dealing with set identification rather than point identification, we consider three values of distance cost β_1: -0.06, -0.08, and -0.12. We then run 100 counterfactual simulations using Algorithm 1 with each of these values of β, with randomized weights w drawn from a uniform distribution. We discuss an alternative algorithm in Appendix I.3, which yields similar results.

To compute the social planner's optimal partition, we use an approach based on Yigit, Aydin, and Turkbey [2006].[51] We then compare the partitions that are predicted to arise under a decentralized jurisdiction formation process to those that a central planner is predicted to select.

Results are shown in Tables 7 and 8. The rows of these tables show different values of β_1 used to perform the simulations. For reference, we include as the first row the case where there is no heterogeneity cost ($\beta_1 = 0$). This is a case discussed in Farrell and Scotchmer [1988]: from the social planner's perspective, the grand coalition is optimal, but differences

the all-singleton partition.

[50]The justification for using this column was discussed near the end of Section 5. Our use of the observed covariates is not obvious given the econometric model in Section 3: see Appendix I.4 for details.

[51]This algorithm uses simulated annealing as an inner optimization loop, and uses a genetic algorithm as an outer optimization loop for restarting the annealing algorithm at different initial points. The overall approach is thus that of annealing with multiple restarts, using a particular method of choosing the starting points. One advantage of this method is that the outer optimization loop is easily parallelizable. The optimization problem here is also of NP difficulty. Barros [1998] provides an introduction to these issues. Appendix Figures 23 and 24 show the results of this optimization approach.

Table 8: Simulation Results: Inefficiency (¥1000)

β_1	I (social planner)	II ("heuristic" planner)	III (equal tax base)	IV (actual tax base)	V (no variable cost)	VI (subsidized fixed cost)
0	0	0	0	10.9	0	18.0
-0.06	0	11.1	2.4	14.6	1.5	60.7
			(1.7)	(1.6)	(0.3)	(1.4)
-0.08	0	11.2	3.5	10.3	1.7	56.6
			(1.6)	(1.2)	(0.2)	(0.2)
-0.12	0	9.8	3.3	22.6	1.7	52.9
			(1.5)	(0.8)	(0.2)	(0.1)

Estimated standard deviations of partitions within solution set are given in parentheses were there are multiple solutions to the coalition formation game. The social planner's optimal partition is unique, as is the decentralized outcome where there is no distance cost.

in tax base will lead to partitions with multiple coalitions in the decentralized case.[52]

Column I in Table 7 shows the partition that would be chosen by the social planner. By definition, this partition is reported with an inefficiency of zero in Table 8. The remaining columns describe the results of a decentralized coalition formation process under various conditions.

To interpret the magnitude of the inefficiency present in decentralized partitions, we consider a comparison with a constrained social planner. Finding the optimal partition described in Column I is a challenging computational problem. Suppose that the planner does not have the resources to determine the optimal partition, and must use a simpler approach to deciding the pattern of mergers.[53] A variety of such approaches are available, and the simplest of these is arguably the "greedy" algorithm. With this algorithm, the planner creates the partition sequentially: out of all potential coalitions, the planner chooses the coalition m that provides the highest per capita utility for its participants, then reduces the set of potential coalitions by removing all the coalitions that involve players in m, and repeats the process to choose the next coalition. Column II shows the results of applying this simple algorithm: it results in about 50% more municipalities, and inefficiency of around ¥$10,000$ compared to the true optimal partition. This provides a baseline for comparison

[52] For this row, we find partitions based on the recursive algorithm provided by Farrell and Scotchmer [1988]. For all other rows, we use Algorithm 1.

[53] An alternative here would be to consider an asymmetric information problem following Weese [2015]. We do not do this because we do not have any information regarding how severe the asymmetric information problem would be in this case. We could use values estimated in Weese [2015], but Weese [2015] has already analyzed those particular values in detail in the case of 21st century mergers.

with decentralized outcomes, which we now consider.

Column III of Tables 7 and 8 shows the characteristics of partitions that arise if the per capita tax base, y/p, were set to be the same for all players in the game.[54] This is the case where there is "horizontal" (geographic) heterogeneity, but no "vertical" (tax base per capita) heterogeneity. We see that even in this case the partitions that arise as a result of the decentralized coalition formation process are not exactly the same as the one that would be chosen by the social planner. We also verify that the social planner's partition is not part of the core. However, Table 8 shows that these decentralized partitions look much better than the Column II results for the computationally constrained social planner. The first major conclusion of our simulations is thus that, in the case where there is no vertical heterogeneity, a decentralized coalition formation process results in partitions that are very close to what would have been selected by a utilitarian social planner.

Figure 2 shows one randomly selected core partition from the $\beta_1 = -0.06$ row of Column III.[55] From a qualitative point of view, the coalitions displayed in Figure 2 appear reasonable from the social planner's perspective: most coalitions are geographically convex, and the cases where this is not true can usually be explained by intervening mountains making the selected coalition structure more reasonable from the perspective of walking distance.[56]

In contrast, Figure 3 shows a random example of the coalition structure that arises in the decentralized coalition formation game in the case where the actual per capita tax base data is used. Statistics for 100 such random partitions are shown in Column IV of Tables 7 and 8. In the case where different players have different per capita tax bases, there are about 70% more coalitions than in the partition selected by the social planner. Furthermore, the coalitions that do form are not generally convex in a geographic sense, as those in Figure 2 were.

The differences between Figures 2 and 3 illustrate the differences between Columns III and IV in Tables 7 and 8. The geographic configurations in Figure 3 are sufficiently bizarre that it is unsurprising that the partitions in Column IV are worse than those chosen by a computationally constrained central planner using an extremely simple algorithm.[57]

---

[54]The number used for the per capita tax base in this case is $\sum_{i=1}^{N} y_i / \sum_{i=1}^{N} p_i$. As discussed in Appendix N, this is approximately 1.

[55]The lowest distance cost row is used for visualization because the coalitions that result are larger, and thus patterns are more readily apparent.

[56]The walking distance matrix is not isomorphic to a Euclidean distance matrix, and thus it is not possible to represent the walking distance for players in a figure such as Figure 2.

[57]One might wonder what sort of partitions would occur in cases where unilateral deviations are not allowed. A restriction on allowable deviations would only enlarge the set of stable partitions, as anything that was stable before would also be stable under the restriction. Thus, Figure 3 is also a stable partition

Figure 2: Decentralized mergers with equal per capita tax base

Edges indicate members of the same coalition. Colours are the same within each coalition, but random across coalitions. No players are missing ("off the page") on the left or right sides of the figure.

Figure 3: Decentralized mergers with actual per capita tax base

Edges indicate members of the same coalition. Colours are the same within each coalition, but random across coalitions. No players are missing ("off the page") on the left or right sides of the figure.

The second major conclusion from our simulations is thus that, based on the actual data and our parameter estimates, decentralized jurisdiction formation would have worked out poorly: it would have resulted in geographically questionable coalitions motivated only by zero-sum tax base concerns, leading to substantial inefficiency from a utilitarian perspective. The theory behind this result comes from Farrell and Scotchmer [1988]: in the case where players differ in a vertical characteristic their preferences regarding merger partners are determined (partly, in our case) by this vertical characteristic.[58] Players thus trade off heterogeneity in the horizontal characteristic in exchange for similarity in the vertical characteristic. In the model in Section 2, the same amount in total is being spent on providing services for any configuration involving the same number of coalitions. A willingness to accept coalition partners that are a worse match on the horizontal characteristic in exchange for being a better match on the vertical characteristic therefore creates inefficiency from a (utilitarian) social perspective.

Although the *potential* for this effect is clear from the model in Section 2 and the theoretical results in Farrell and Scotchmer [1988], it was not obvious (at least to us) that the effect would be empirically important until we actually performed the simulations.[59] Conversely, some alternative sources of inefficiency discussed in Section 2 turn out not to be important from a quantitative perspective.[60] As noted by Gregorini [2009], models of coalition formation with both horizontal and vertical heterogeneity do not have analytically tractable

under such a restriction. We do not study this set of partitions because it appears to be quite large.

[58]The $\beta_1 = 0$ row of Tables 7 and 8 shows results in exactly the model given by Farrell and Scotchmer [1988]: here there is only vertical (income) heterogeneity, and no horizontal (geographic) heterogeneity. The socially optimal result in this case is for the grand coalition to form, but the presence of the variable cost means that players will minimize their tax rate by avoiding forming coalitions with poorer players. Simulation results here give a total of 60 coalitions forming.

At first glance it actually appears that the inefficiency resulting from a "vertical heterogeneity only" model is about the same magnitude as our full model that also incorporates horizontal heterogeneity (at least for Columns III-V). Have we simply wasted a great deal of time worrying about unimportant horizontal heterogeneity? Consider what happens as the number of players is increased in our game. Suppose that we draw the y values for these new players from the same distribution as existing players. For the cost function we use in Section 2, the number of municipalities will increase at a slower rate than the number of players. That is, in a "vertical heterogeneity only" model, asymptotically the per capita inefficiency will fall to zero as the number of players becomes large. We get rid of this problem by adding horizontal heterogeneity, and having additional players added on the "edge" of the game. The game now expands across the plane while maintaining a constant density of players. In this case the level of inefficiency will not decrease as more players are added, as sorting on the vertical dimension will only happen "locally", and the local market for merger partners never increases in market thickness. As far as we can tell, the similarity of the magnitude reported in Column IV between the $\beta_1 = 0$ row and the other rows seems to be a chance occurrence.

[59]In fact, below we will discuss some alternative parameter values for which this effect is no longer empirically substantial.

[60]Specifically, a Flatters, Henderson, and Mieszkowski [1974] type fiscal externality would show up in Column III, but we see little evidence for such an effect. Similarly, there does not appear to be any problem arising from different incentives for smaller and larger players to merge.

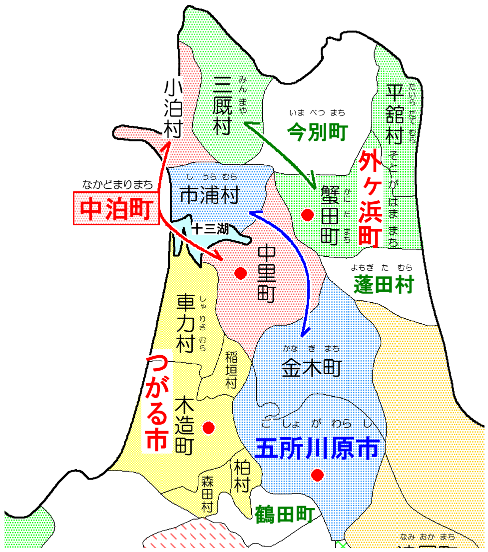


Figure 4: Actual decentralized merger outcome, Aomori Prefecture, c. 2006.

Map colours indicate members of the same coalition. Japanese text gives the names of pre-merger municipalities (in black) and post-merger municipalities (in colour). Arrows join members of non-contiguous coalitions.
Source: Geospatial Information Authority of Japan

solutions. Simulations are thus required to determine which effects that exist in theory are also important quantitatively, and which theoretical results turn out not to be important when considering actual data.

At this point, a potential objection is that the above discussion is based on the simulated mergers shown in Figure 3, but these mergers are unreasonable and in fact only serve to show that the model of Section 2 is an inappropriate model of municipal mergers. In particular, although geographic adjacency is not shown in Figure 3, it is clear that some of the mergers predicted are not geographically contiguous.[61] Should any realistic model of municipal mergers really be predicting these sorts of configurations?

Figure 4 shows a set of decentralized municipal mergers that actually occurred in Aomori Prefecture around 2006. These mergers were part of the *Heisei daigappei* set of municipal mergers. The figure shows three geographically discontiguous mergers, involving in total eight geographically contiguous municipalities. In the centralized mergers of the Meiji period, these sorts of arrangements are not observed in the data. Thus, bizarre configurations of the sort shown in Figure 3 can and do occur in reality, and they do so only during decentralized mergers (Heisei) and not centralized ones (Meiji). Furthermore, the qualitative explanation offered for the outcome shown in Figure 4 is also in line with the model in Section 2: the municipalities shown on the map differed substantially in levels of indebtedness and revenue sources, and the observed mergers were the result of an attempt to avoid matching with undesirable but neighbouring municipalities.

[61] This can be verified by looking at Figure 9 in Appendix N, which shows the geographic adjacencies of the players.

We now perform additional simulations to better understand the source of the inefficiency displayed in Figure 3. We first consider the case where $\gamma_2 = 0$. Column V of Table 7 shows that in this case the decentralized partitions are very close to the partition that would have been chosen by the social planner.

The intuition for this result is that, with only a fixed cost of providing services, adding any member to a coalition will decrease the tax rate that needs to be charged.[62] If there were no horizontal (geographic) differentiation, this case would correspond exactly to one considered in Farrell and Scotchmer [1988] where there is no inefficiency. The presence of geographic heterogeneity creates a theoretical potential for inefficiency, but empirically this turns out not to be important. Thus, in an environment in which public goods can be provided with only a fixed cost, it appears that decentralized mergers are unlikely to cause any particular problems. Congestability of the public good is key to our inefficiency results, further underscoring the importance of obtaining parameters based on data. A pure public good yields very different simulation results, and even the most casual empiricism suggests that the vast majority of government spending is not on pure public goods.

We chose to analyze data from the Meiji period in part because there was no transfer scheme from the national government to municipalities, and this lack of transfers allowed for a particularly simple model in Section 2. An intergovernmental transfer system was developed later, however, in the post-war period. At the risk of oversimplification, this scheme originated mainly as a subsidy on the variable cost of providing public services, reducing γ_2 from the perspective of municipalities. Over several decades, this scheme mutated into one that instead subsidized the *fixed* cost of providing public services, reducing γ_1 (instead of γ_2) from the perspective of municipalities. These two periods correspond with the two post-Meiji waves of municipal mergers in Japan: the "Showa" mergers occurred when variable cost was subsidized, and the "Heisei" mergers, fixed cost. The transfer situation in the Showa period corresponds roughly to the simulations shown in Column V. We perform a final set of simulations, shown in Column VI, to see how the change in subsidy scheme would have changed the pattern of decentralized mergers. The number of coalitions is far higher than in any of the other columns, and indeed reaches the resolution of the data, in the sense that most municipalities remain as singletons, with only the smallest participating in mergers at all.[63] Appendix O provides details about the transfer schemes during these

[62]In contrast, in the case with both a fixed cost (γ_1) and a marginal cost (γ_2), adding an additional player who is substantially poorer will increase the tax rate for members of a coalition. As discussed above, the decentralized process in this case results in jurisdictions that are substantially smaller than the social optimum. In Column III there is no variation in income, and thus tax per capita is equal to the variable cost plus the average fixed cost. In this scenario adding an additional member to a coalition always decreases the tax rate, the same as in Column V.

[63]It is still reasonable to compare these results to others: see Appendix J for details.

periods, and the simulations performed.

The intuition for the result shown in Column VI is straightforward: a transfer payment scheme equivalent to part of the fixed cost γ_1 reduces the incentive to merge from the perspective of the municipality. In contrast, a transfer payment scheme equivalent to part of the variable cost γ_2 reduces the importance of the differences in per capita tax base. Thus, the former case results in municipalities choosing a decentralized merger pattern that is even less desirable, from the perspective of the social planner, while the latter case results in mergers that are quite close to the social optimal. Qualitative evidence from the merger waves in question supports these results: In the official government evaluation of the Heisei mergers,[64] the reluctance of municipalities to merge is noted. In contrast, in the Showa mergers, the number of municipalities was reduced by 6152, very close to the targeted reduction of 6273 [Yoshitomi 1960].[65] It thus appears that, in contrast to the equalization payments offered during the Showa period, the type of subsidy provided during the Heisei period results in substantial problems when considering decentralized mergers.

A quantitative interpretation of the amount of inefficiency displayed in Table 8 is challenging, because local government during the Meiji period began as a very small portion of GDP but then grew quickly as Japan industrialized. Appendix Table 10 suggests that the units used in Table 8 correspond roughly to the annual salary of a senior government official. The total expenditure on police by Gifu prefecture (Appendix Table 14) is roughly equal to the inefficiency reported in Column VI of Table 8. Thus, the calculated amounts of inefficiency are important when considered in the context of the size of Meiji-era local governments, even though they are not large in absolute terms.

An alternative interpretation could be obtained by scaling up the inefficiency reported in Table 8 by the difference in expenditures on public services between the Meiji period and the present. The fixed costs γ_1 represent 12% of the estimated expenditures on public services in Gifu, and the inefficiency reported in Column V of Table 8 is equivalent to about a doubling of this component, or a little more than 10% of local government spending. Local government spending as a percentage of GDP is difficult to calculate due to the extremely large transfer system, but if it were in the range of 15-25% then inefficiency would represent 2-3% of GDP. Thus, the amount of inefficiency calculated may be large, but this depends on the method used to compare it to total output.

[64] *"Heisei no Gappei" no Hyouka-Kenshou-Bunseki.*

[65] This result also suggests why there it is still unresolved whether the Showa mergers were centralized or decentralized: it does not matter, because the outcome would have been the same. See Appendix O for discussion.

7 Conclusion

In this paper we showed that a decentralized process of jurisdiction formation results in a pattern of boundaries very similar to what would be chosen by a utilitarian social planner, so long as players differ only in “horizontal” characteristics. When players are also “vertically” differentiated, the decentralized outcome has smaller coalitions as well as bizarre matching on the horizontal characteristics. We obtained these results using historical data on Japanese municipal mergers, a model that allows the merger game to be expressed as a fractional hedonic game, and a new method that makes it possible to calculate solutions for large fractional hedonic games through mixed integer programming.

The external validity of simulations regarding 19th century Japanese farming villages is open to debate, and we did not attempt a formal extension of our results to the international arena. Consider very briefly, however, the stance of various countries regarding the existence of a “right to self-determination”. In the United Kingdom, it is generally accepted that Scotland can hold an independence referendum. In Canada, a supreme court decision and federal legislation has established that a successful Quebec independence referendum would force the rest of Canada to negotiate a separation agreement. On the other hand, the Spanish government denies the existence of any such rights for the autonomous communities of Spain. Perhaps not coincidentally, the potentially separatist regions of the United Kingdom and Canada are by most calculations not particularly rich, while the Basque Country and Catalonia are substantially better off than the remainder of Spain. Our results suggest that the positions regarding self-determination held by each of these countries may be welfare-maximizing: decentralized decision-making results in partitions that are very close to the social optimum when inequality between regions is low, but not when inter-regional inequality is high.

We believe that fractional hedonic games are an appropriate way of modelling mergers and splits of political jurisdictions. Fractional hedonic games have attracted interest both inside and outside of economics, but suffer from the potential non-existence of stable partitions in the same way as many other hedonic games. In this paper we considered a particular form of fractional hedonic game where there is a tradeoff between a fixed cost that can be shared between more players as coalition size increases, and a distance cost that generally increases with coalition size. With our data and estimated parameter values, we always find core partitions when we perform our simulations. Furthermore, no empty cores were observed in 10 million random games, even though the setup for these games was chosen to be favourable for non-existence. This suggests that the particular type of fractional hedonic game that we are considering, while still theoretically at risk of having an empty core, has a stable partition with probability very close to one.

This finding is potentially important because, in addition to political jurisdictions, other phenomena could also be analyzed using the fractional hedonic model of this paper. Ethnic or linguistic groups, for example, could be considered in this framework, and have recently received extensive theoretical analysis (e.g. Ginsburgh and Weber [2011]). Empirical analysis of choice of language or ethnicity has often focussed on individual decisions,[66] but reduced-form results such as those in Michalopoulos [2012] suggest that analysis of identity formation at the group level might also be informative. Weese [2016] provides an early attempt at this sort of analysis.

Even further afield, fractional hedonic games might also be used to model the formation of students into schools or classes, workers into unions, or public employees into different pension funds. In these cases substantial changes to the model presented in this paper would likely be required, but the basic approach presented should still be applicable.

References

Alesina, Alberto and Enrico Spolaore (1997). “On the Number and Size of Nations”. *Q. J. Econ.* 112 (4):1027–1056.

Andrews, Donald W. K. and Patrik Guggenberger (2009). “Validity Of Subsampling And “Plug-In Asymptotic” Inference For Parameters Defined By Moment Inequalities”. *Econom. Theory* 25:669–709 (03).

Arkin, Esther M. et al. (2009). “Geometric Stable Roommates”. *Information Processing Letters* 109 (4):219–224.

Aziz, Haris, Felix Brandt, and Paul Harrenstein (2014). “Fractional Hedonic Games”. *Proceedings of the 13th International Conference on Autonomous Agents and Multiagent Systems*. International Foundation for Autonomous Agents and Multiagent Systems. Paris.

Aziz, Haris, Serge Gaspers, et al. (2015). “Welfare Maximization in Fractional Hedonic Games”. *Twenty-Fourth International Joint Conference on Artificial Intelligence*. Twenty-Fourth International Joint Conference on Artificial Intelligence.

Banerjee, Suryapratim, Hideo Konishi, and Tayfun Sönmez (2001). “Core in a Simple Coalition Formation Game”. *Soc. Choice Welf.* 18 (1):135–153.

Barros, Ana Isabel (1998). *Discrete and Fractional Programming Techniques for Location Models*. Dordrecht; Boston: Kluwer Academic Publishers.

Bogomolnaia, Anna and Matthew O. Jackson (2002). “The Stability of Hedonic Coalition Structures”. *Games Econ. Behav.* 38 (2):201–230.

Brandl, Florian, Felix Brandt, and Martin Strobel (2015). “Fractional Hedonic Games: Individual and Group Stability”. *Proceedings of the 2015 International Conference on Autonomous Agents and Multiagent Systems*. AAMAS ’15. Richland, SC: International Foundation for Autonomous Agents and Multiagent Systems, pp. 1219–1227.

[66] See Clingingsmith [2014] for example, or Jia and Persson [2015] and the references therein.

Brasington, David M. (1999). “Joint Provision of Public Goods: The Consolidation of School Districts”. *J. Public Econ.* 73 (3):373–393.

Christaller, Walter (1933). *Die zentralen Orte in Süddeutschland: eine ökonomisch-geographische Untersuchung über die Gesetzmässigkeit der Verbreitung und Entwicklung der Siedlungen mit städtischen Funktionen*. Wissenschaftliche Buchgesellschaft. 352 pp.

Chung, Kim-Sau (2000). “On the Existence of Stable Roommate Matchings”. *Games and Economic Behavior* 33 (2):206–230.

Clingingsmith, David (2014). “Industrialization and Bilingualism in India”. *J. Human Resources* 49 (1):73–109.

Demange, Gabrielle (1994). “Intermediate Preferences and Stable Coalition Structures”. *J. Math. Econ.* 23 (1):45–58.

Desmet, Klaus et al. (2011). “The Stability and Breakup of Nations: A Quantitative Analysis”. *J Econ Growth* 16 (3):183–213.

Donder, Philippe De, Michel Le Breton, and Eugenio Peluso (2012). “On the (Sequential) Majority Choice of Public Good Size and Location”. *Soc Choice Welf* 39:457–489 (2-3).

Dreze, J. H. and J. Greenberg (1980). “Hedonic Coalitions: Optimality and Stability”. *Econometrica* 48 (4):987–1003.

Drèze, Jacques et al. (2008). ““Almost” Subsidy-Free Spatial Pricing in a Multi-Dimensional Setting”. *Journal of Economic Theory* 143 (1):275–291.

Elomri, A. et al. (2013). “Stability of Hedonic Coalition Structures: Application to a Supply Chain Game”. *Applications of Multi-Criteria and Game Theory Approaches: Manufacturing and Logistics*. Ed. by Lyes Benyoucef, Jean-Claude Hennet, and Manoj Kumar Tiwari. Springer Science & Business Media, pp. 337–364.

Farrell, Joseph and Suzanne Scotchmer (1988). “Partnerships”. *Q. J. Econ.* 103 (2):279–297.

Flatters, Frank, Vernon Henderson, and Peter Mieszkowski (1974). “Public Goods, Efficiency, and Regional Fiscal Equalization”. *J. Public Econ.* 3 (2):99–112.

Gale, D. and L. S. Shapley (1962). “College Admissions and the Stability of Marriage”. *Am. Math. Mon.* 69 (1):9–15.

Ginsburgh, Victor and Shlomo Weber (2011). *How Many Languages Do We Need?: The Economics of Linguistic Diversity*. Princeton: Princeton University Press. 232 pp.

Gomory, Ralph E. (1994). “A Ricardo Model with Economies of Scale”. *Journal of Economic Theory* 62 (2):394–419.

Gordon, Nora and Brian Knight (2009). “A Spatial Merger Estimator with an Application to School District Consolidation”. *J. Public Econ.* 93:752–765 (5-6).

Greenberg, Joseph H. (1956). “The Measurement of Linguistic Diversity”. *Language* 32 (1):109–115.

Greenberg, Joseph and Shlomo Weber (1986). “Strong Tiebout Equilibrium under Restricted Preferences Domain”. *Journal of Economic Theory* 38 (1):101–117.

Gregorini, Filippo (2009). *Political Geography and Income Inequalities*. Working Paper 152. University of Milano-Bicocca, Department of Economics.

Hirota, Haruaki and Hideo Yunoue (2014). “Municipal Mergers and Special Provisions of Local Council Members in Japan”. *The Japanese Political Economy* 40:96–116 (3-4).

Hochman, Oded, David Pines, and Jacques-François Thisse (1995). “On the Optimal Structure of Local Governments”. *The American Economic Review* 85 (5):1224–1240.

Jia, Ruixue and Torsten Persson (2015). *Individual vs. Social Motives in Identity Choice: Theory and Evidence from China.*

Lieberson, Stanley (1964). "An Extension of Greenberg's Linguistic Diversity Measures". *Language* 40 (4):526–531.

Markovsky, Ivan and Sabine Van Huffel (2007). "Overview of Total Least-Squares Methods". *Signal Processing*. Special Section: Total Least Squares and Errors-in-Variables Modeling 87 (10):2283–2302.

Matsuzawa, Yūsaku (2013). *Chōson gappei kara umareta Nihon kindai : Meiji no keiken.* Kōdansha sensho mechie 563. Tōkyō: Kabushiki Kaisha Kōdansha.

Michalopoulos, Stelios (2012). "The Origins of Ethnolinguistic Diversity". *Am. Econ. Rev.* 102 (4):1508–39.

Miyazaki, Takeshi (2014). "Municipal Consolidation and Local Government Behavior: Evidence from Japanese Voting Data on Merger Referenda". *Econ Gov* 15 (4):387–410.

Morgan, Mary S (1990). *The History of Econometric Ideas*. Cambridge [England]; New York: Cambridge University Press.

Pakes, A. (2010). "Alternative Models for Moment Inequalities". *Econometrica* 78 (6):1783–1822.

Pakes, A. et al. (2015). "Moment Inequalities and Their Application". *Econometrica* 83 (1):315–334.

Papai, Szilvia (2003). *Random Paths to Stability in Hedonic Coalition Formation*. University of Notre Dame.

Pinar, M. C. and A. Camci (2012). "An Integer Programming Model for Pricing American Contingent Claims under Transaction Costs". *Computational Economics* 39 (1):1–12.

Ray, Debraj and Rajiv Vohra (1997). "Equilibrium Binding Agreements," *J. Econ. Theory* 73 (1):30–78.

Reiter, Michael and Alfons Weichenrieder (1997). "Are Public Goods Public? A Critical Survey of the Demand Estimates for Local Public Services". *Finanz. Public Finance Anal.* 54 (3):374–408.

Roth, Alvin (2008). "Deferred Acceptance Algorithms: History, Theory, Practice, and Open Questions". *Int. J. Game Theory* 36 (3):537–569.

Roth, Alvin E., Tayfun Sönmez, and M. Utku Ünver (2007). "Efficient Kidney Exchange: Coincidence of Wants in Markets with Compatibility-Based Preferences". *Am. Econ. Rev.* 97 (3):828–851.

Roth, Alvin E. and John H. Vande Vate (1990). "Random Paths to Stability in Two-Sided Matching". *Econometrica* 58 (6):1475–1480.

Samuelson, Paul A. (1942). "A Note on Alternative Regressions". *Econometrica* 10 (1):80–83.

Scotchmer, Suzanne (2002). "Local Public Goods and Clubs". *Handbook of Public Economics*. 4 vols. Elsevier, pp. 1997–2042.

Serafini, Paolo (2012). "Allocation of the EU Parliament Seats via Integer Linear Programming and Revised Quotas". *Mathematical Social Sciences* 63 (2):107–113.

Stephan, G. Edward (1977). "Territorial Division: The Least-Time Constraint Behind the Formation of Subnational Boundaries". *Science* 196 (4289):523–524.

— (1979). "Political Subdivision and Population Density". *Science* 205 (4402):219–220.

— (1984). "Territorial Subdivision". *Social Forces* 63 (1):145–159.

Suzuki, Tsutomu (1999). *Size-Density Hypothesis in P-Median Problems*. no. 836. Institute of Policy and Planning Sciences discussion paper series.

Tiebout, Charles M. (1956). "A Pure Theory of Local Expenditures". *J. Polit. Econ.* 64 (5):416–424.

Vining, Daniel R., Chung-Hsin Yang, and Shi-Tao Yeh (1979). "Political Subdivision and Population Density". *Science* 205 (4402):219–219.

Weese, Eric (2015). "Political Mergers as Coalition Formation: An Analysis of the Heisei Municipal Amalgamations". *Quantitative Economics* 6 (2):257–307.

— (2016). *European Political Boundaries as the Outcome of a Self-Organizing Process*. Discussion Paper 1629. Graduate School of Economics, Kobe University.

Yigit, Vecihi, M. Emin Aydin, and Orhan Turkbey (2006). "Solving Large-Scale Uncapacitated Facility Location Problems with Evolutionary Simulated Annealing". *Int. J. Prod. Res.* 44 (22):4773–4791.

Yoshitomi, Shigeo (1960). *Chihō jichi : jittai to tenbō*. Tōkyō: Keisō Shobō.

A Herfindahl/Fragmentation Index

For this discussion we need only consider one (amalgamated) municipality. We will thus suppress m subscripts throughout this section and take all sums over only the players in the municipality being considered. Suppose that players can be divided into discrete types, with distance $\ell_{ii'}$ being 1 if i and i' are the same types and 0 if they are different. Index types by t, and let $t(i)$ denote the type of player i. Let s_t be the share of players in municipality m that are type t, weighted by income:

$$s_t = \frac{\sum_i y_i \delta_{t(i),t}}{Y_m}.$$

Here $\delta_{t(i),t(i')}$ is the Kronecker delta, equal to 1 if i and i' are the same type, and 0 otherwise. With this notation, the relationship between δ and ℓ is $\delta_{t(i),t(i')} = 1 - \ell_{ii'}$.[67] Let H denote the Herfindahl index of municipality m with respect to types, weighted by income, and Y the total income of municipality m. Then

$$\begin{aligned} H = \sum_t s_t^2 = \sum_i \frac{y_i}{Y} s_{t(i)} &= \sum_i \frac{y_i}{Y} \sum_{i'} \frac{y_{i'} \delta_{t(i),t(i')}}{Y} \\ &= \sum_i \sum_{i'} \frac{(1 - \ell_{ii'}) y_i y_{i'}}{Y^2} \\ &= \sum_i \frac{y_i}{Y} - \sum_i \sum_{i'} \frac{\ell_{ii'} y_i y_{i'}}{Y^2} \\ &= 1 - \sum_i \sum_{i'} \frac{\ell_{ii'} y_i y_{i'}}{Y^2}. \end{aligned} \tag{19}$$

Multiply this by Y, and the second term is equal to the inner portion of the first term in Equation 9. The outer summation in Equation 9 takes an average of heterogeneity over municipalities, weighted by income.[68] With discrete types, the average distance considered is thus equal to one minus the average Herfindahl index. This is the fragmentation index generally used in work on ethnic or linguistic fragmentation.

[67] This notation is helpful for intuition, because δ can be thought of as describing an N by N matrix with entries of 0 or 1. Rearranging rows and columns of this matrix would yield a block diagonal matrix, with each block corresponding to a type. The fraction of entries that are in block t is s_t^2, and thus the average entry is $\sum_t s_t^2$.

[68] This weighting accounts for why the (1/Y) in Equation 9 is not squared. The total income of all municipalities together is constant regardless of partition, and is thus absorbed into β_1.

B "Standard" Discrete Choice Models

As any structural model proposed is extremely unlikely to explain the observed outcome perfectly, an error term of some sort needs to be included as part of the data generating process. In our situation, however, the number of possible coalitions is very large: with N players, there are $2^N - 1$ potential coalitions.[69]

A model that includes an idiosyncratic term for each of these possible mergers will lead to some potential mergers having extremely positive idiosyncratic shocks. This causes problems similar to those discussed in Berry and Pakes [2007], where an increasing number of products results in consumer utility increasing without bound if there is an idiosyncratic shock representing "taste for products". The situation here, however, has an additional feature that makes a "taste for products" approach particularly unattractive: the number of potential coalitions is a function of the size of the coalition: there are N coalitions of size 1, $N(N-1)$ coalitions of size 2, and $\binom{N}{k}$ coalitions of size k. The total number of coalitions is thus non-monotonic in k.[70] To simplify discussion, consider the case where coalitions are generally smaller than $N/2$. In this region, the total number of coalitions of size k is increasing in k. If idiosyncratic shocks are uncorrelated, generally some of the larger coalitions will then have positive shocks much larger than those of any of the smaller coalitions.

If the correlation structure of the error term were misspecified such that the true correlation were underestimated, estimates for other parameters from this specification would generally be biased such that only the smallest mergers appeared attractive from a structural perspective, and the explanation for larger observed configurations would be that these were mergers with very positive idiosyncratic shocks. Conversely, if the model of the correlation structure were incorrect such that the correlation in the idiosyncratic term between partitions were overestimated, then the opposite bias in estimates of other parameters would occur: parameter estimates would suggest that larger mergers were very desirable, and that the smaller mergers that were observed occurred because of very positive idiosyncratic shocks.

From a theoretical perspective, a correctly specified correlation structure for the idiosyncratic shocks would eliminate the problem just discussed, and any standard estimation technique could be employed. From a practical perspective, even if it were possible to model the correlation structure of the idiosyncratic shocks correctly, estimators of this sort tend to involve high dimensional integrals and are not computationally feasible.[71]

[69]The total number of possible partitions of players into coalitions is given by the Bell numbers, and grows superexponentially in N.

[70]There are only N coalitions of size 1, only N coalitions of size $N-1$, and only one coalition of size N, but there are many coalitions of an intermediate size.

[71]There are a few specific forms for the idiosyncratic shock that might make estimation feasible, but these forms appear unlikely to match whatever shocks are actually present in the data. Logit models, which are

C "Standard" Instruments

Moment inequality models make minimal distributional assumptions regarding the idiosyncratic shock, and thus rely heavily on instruments in order to obtain an acceptably small identified set. Many of the types of instruments generally used, however, appear inapplicable to the data used in this paper. The implausibility of these instruments is not a special feature of the particular data used, but rather appears to be a general characteristic of political jurisdiction formation data.

Specifically, "lagged variable" instruments are implausible because recent innovations are not of particular interest: political boundaries are changed rarely, and any lagged measurement will include a correlated error of exactly the sort that needs to be avoided. "Neighbouring market" instruments turn out to be extremely weak, because even when clearly defined "markets" for mergers do exist, most variation is within market, as each merger market generally includes both a central city and its rural hinterland.[72] Finally, geographic or climatic variables are non-excludable. In the dataset considered, the central planner was explicitly directed to consider geographic distance, and casual inspection of any random selection of maps suggests that the importance of geography in Gifu is not an unusual feature in the design of political boundaries.

A potential objection here is that the difficulty in finding instruments means that researchers in this area simply need to work harder in order to find a dataset that does have appropriate instrumental variables. The problem is that both the number and size of datasets concerning political jurisdictions is sharply limited. Even large countries sometimes only have a few thousand jurisdictions at the lowest level, and there are simply not that many large countries in the world. Randomized experiments are basically unheard of, and quasi-experimental variation is difficult to find because the policy decisions made often result in precisely the sort of endogeneity that needs to be avoided. It is important to develop econometric approaches suitable for the type of data actually available.

D Externalities

The observed pattern of mergers shown in Figure 1b is difficult to explain using a model where the benefit of a larger jurisdictions is the internalization of externalities. Externalities are

valid even when considering only a subset of the choices, do not appear to be appropriate because of a violation of the IIA assumption: idiosyncratic payoffs for the $\{1, 2, 3, 4, 5\}$ coalition should be correlated with those for the $\{1, 2, 3, 4, 6\}$ coalition.

[72] This phenomenon is illustrated in Table 1 of Weese [2015], where a division of prefectures into "rural", "mixed", and "metropolitan" results in just over 75% of prefectures being classified as "mixed".

generally treated as having increasing marginal damage, or equivalently, decreasing marginal benefit. Plausible externalities, such as pollution, traffic, or the exhaustion of common pool resources, would generally be observed at higher levels in areas with higher population density. Thus, the benefit of internalization should be higher in areas with higher population density, and larger jurisdictions should thus be observed in these areas. On the other hand, in areas with lower population density, the damage from these externalities is more limited, and thus there is not the same need for large jurisdictions.

The observed pattern of jurisdictions in Figure 1b is the opposite of what would be expected based on the externality model just described, as jurisdictions have the smallest area in those regions with the highest population density. Furthermore, Japan was overwhelmingly rural during this period: while population density varies substantially depending on terrain, there are only two locations in Gifu that could reasonably be considered to be cities, consisting of less than 10% of the population. The lack of large urban agglomerations further reduces the number of potential externalities that need to be considered. In rural areas, the only plausible spillovers between municipalities are related to public works: irrigation that uses scarce water, levees to protect against flooding, or roads. We observe, however, that jurisdictions have *smaller* smaller surface area in the densely populated areas, and cover *larger* areas in the mountainous rural regions. A model based on externalities thus appears inappropriate both because of a lack of plausible externalities, and because the major prediction of such a model does not appear to be present in the partition that was actually chosen by the Meiji central government.

E Probit model

Normalize $||\beta||^2\sigma^2 = 1$. Consider the likelihood of seeing an observation $\tilde{X}_{\pi'}$. Conditional on a value of $\tilde{X}^*$, the likelihood of seeing $\tilde{X}_{\pi'}$ is $f(\frac{(\tilde{X}^* - \tilde{X}_{\pi'})}{\sigma})$, where f is the multivariate standard normal given in assumption (b) above. We now need to integrate over the distribution of $\tilde{X}^*$. The easiest way to do this is to work with hyperplanes parallel to that described by Inequality 15: first, consider all values of $\tilde{X}^*$ such that $\tilde{X}^*\beta = k$ for some given $k < 0$. Conditional on a value of k, the likelihood of seeing $\tilde{X}_{\pi'}$ is proportional to $\phi(\frac{k - \tilde{X}_{\pi'}\beta}{||\beta||\sigma})$, where ϕ is the standard (univariate) normal distribution.[73] We then integrate over all values of $k < 0$. The likelihood of seeing $\tilde{X}_{\pi'}$ is thus proportional to

[73]To see this, rotate the coordinate system using $\beta/||\beta||$ as a basis vector. The distribution of η is unchanged by such a rotation, but integration conditional on k is now trivial.

$$
\begin{aligned}
&\int_{-\infty}^{0} \phi(\frac{k-\tilde{X}_{\pi'}\beta}{||\beta||\sigma})dk \\
=&||\beta||\sigma \int_{-\infty}^{\frac{-\tilde{X}_{\pi'}\beta}{||\beta||\sigma}} \phi(y)dy \\
=&||\beta||\sigma\Phi(\frac{-\tilde{X}_{\pi'}\beta}{||\beta||\sigma})
\end{aligned}
$$

where Φ is the (univariate) standard normal CDF. Given our assumption that $||\beta||\sigma = 1$, the above is equal to $\Phi(-\tilde{X}_{\pi'}\beta)$. We can thus use the following maximum likelihood estimator:

$$
\hat{\beta} = \underset{\beta}{\operatorname{argmax}} \sum_{\pi' \in \Pi'} \log \Phi(-\tilde{X}_{\pi'}\beta). \tag{20}
$$

This is the same as the likelihood in a standard probit model if there is an observation with covariates $\tilde{X}_{\pi'}$ that resulted in a "failure" ($Y = 0$). The intuition here is that $\tilde{X}_{\pi'}$ describes the characteristics of the partition π' relative to the partition π^0: π' was *not* selected by the planner, which is why $\tilde{X}_{\pi'}$ describes an observation that would correspond to a "failure" in a probit model.[74]

F Deconvolution / Smoothed Maximum Score Estimator

Let the distribution of $\tilde{X}^*_{\pi'}\beta^0$ be $F_{\tilde{X}^*\beta^0}$. Then by Assumption 2,

$$
\tilde{X}_{\pi'}\beta^0 = \tilde{X}^*_{\pi'}\beta^0 + \tilde{\eta}_{\pi'}\beta^0 \tag{21}
$$

has a distribution that is a convolution of $F_{\tilde{X}^*\beta^0}$ and a $N(0, \sigma^2||\beta^0||^2)$ distribution. Write this as

$$
F_{\tilde{X}\beta^0} = F_{\tilde{X}^*\beta^0} * N(0, \sigma^2||\beta^0||^2) \tag{22}
$$

[74]Our variables $\tilde{X}$ do not include any "constant" variable, and thus the MLE estimator is equivalent to a probit model run using variables $\tilde{X}_{\pi'}$ that do not include an intercept term. Why is there no intercept? Each alternative partition π' could have been selected, but was not, and each row of $\tilde{X}$ gives the characteristics $\tilde{X}_{\pi'}$ comparing that partition to π^0. If there were a π' that appeared to have identical characteristics to π^0, then this partition must have $\tilde{X}_{\pi'} = \mathbf{0}$. There thus should not be an intercept term. If there *were* a variable that had the same value in every row of $\tilde{X}$, then this means that π^0 differs from all the alternative partitions in Π' in the same way with respect to this variable. The data in this case would exhibit complete separation.

where $*$ is the convolution operator. This suggests an estimator that uses the empirical distribution $\bar{F}_{\tilde{X}\beta}$ to calculate via deconvolution an estimated distribution $\hat{F}_{\tilde{X}^*\beta}$, and then checks the degree to which this estimated distribution satisfies Assumption 2.a.

Deconvolution is a challenging problem, particularly when the errors are "supersmooth", which is the case for normally distributed errors.[75] A direct approach via inverting the characteristic function runs into severe difficulties. We first consider an approach based on a deconvoluting kernel estimator.

Fan [1992] proposes an estimator for the deconvolution problem with normal noise, based on kernel density estimation using a normal kernel. Kernel density estimation involves a convolution of the kernel with a sample from the distribution of interest. Fan notes that deconvolution and convolution are inverse operations. If the bandwidth used for kernel density estimation is sufficiently large, then the deconvolution is entirely cancelled out. In this special case, a deconvoluting kernel has the same form as the normal kernel used for density estimation, albeit with a bandwidth calculated very differently. Starting with a standard normal kernel, Fan [1992] shows that the corresponding deconvoluting kernel is

$$K_n(x) = \frac{h_n}{\sqrt{2\pi(h_n^2 - \sigma_0^2)}} \exp\left(-\frac{h_n^2 x^2}{2(h_n^2 - \sigma_0^2)}\right). \tag{23}$$

where h_n is the deconvolution bandwidth, and σ_0^2 is the variance of the error. In our case, $\sigma_0^2 = \sigma^2 ||\beta||^2$.

This deconvoluting kernel is only appropriate in the case where the errors are "small", and Fan [1992] defines "small" in a way that shrinks with the sample size, meaning that at some sufficiently large sample size the errors will cease to be "small". A discussion of asymptotic properties is thus not really appropriate.[76]

In the deconvolution literature, estimators that are not consistent are often considered because they appear to have better finite sample properties than those that are consistent [Carroll and Hall 2004]. The Fan [1992] estimator is of particular interest because from the perspective of implementation it turns out to be very close to the Manski [1975] maximum score estimator.

Specifically, the deconvoluting kernel in Equation 23 can be used to produce an estimate $\hat{F}_{\tilde{X}^*\beta}$ for any β. The restriction in Assumption 2.a implies that $F_{\tilde{X}^*\beta^0}(0) = 1$, and estimation

[75] See Fan [1991] and references therein for a detailed discussion of the distinction between "supersmooth" and "ordinary smooth".

[76] It might be possible to construct a sequence of estimators that uses the deconvoluting kernel in Equation 23 initially before switching to another approach, such as the deconvolution that follows Assumption 3, but we do not pursue this argument.

can be performed using the sample analog:

$$\hat{\beta} = \underset{\beta}{\operatorname{argmax}} \hat{F}_{\tilde{X}^*\beta}(0) \tag{24}$$

The condition for identification is quite natural: any hyperplane other than that described by β^0 must have some of the support of $\tilde{X}^*$ on both sides of the hyperplane.[77] For computation, note that the kernel in Equation 23 corresponds to a normal kernel with bandwidth of $\tilde{h} = \sqrt{\frac{h_n^2 - \sigma_0^2}{h_n^2}}$. For a given $\tilde{h}$, the estimate $\hat{F}_{\tilde{X}^*\beta}(0)$ takes a form equivalent to that of the smoothed score considered in Horowitz [1992]:

$$\hat{F}_{\tilde{X}^*\beta}(0) = \sum_{\pi' \in \Pi'} \Phi(-\frac{\tilde{X}_{\pi'}\beta}{\tilde{h}}). \tag{25}$$

An obvious problem here is that σ_0^2 is unknown; however, any choice for $\tilde{h}$ corresponds to some choice of deconvolution bandwidth h_n, given the actual σ_0^2. Thus, choosing $\tilde{h}$ arbitrarily gives a deconvolution estimator of the form of Equation 23, albeit with a suboptimal choice of h_n. The resulting estimator is extremely close in terms of implementation to a smoothed maximum score estimator, although the interpretation of the smoothing is very different.[78] An estimate of σ_0^2 is not obtained, and a normalization of β is required.[79]

G Deconvolution / Minimum Distance Estimator

Use the same notation for distributions F given at the beginning of Appendix F. Consider a sieve estimation approach [Grenander 1981] for producing an estimate of the univariate distribution $\hat{F}_{\tilde{X}^*\beta^0}$. This is slightly non-standard, but will lead to a minimum-distance style estimator, and is substantially easier than estimating the multidimensional distribution $\hat{F}_{\tilde{X}^*}$. As with the maximum score style estimator of Equation 24, $F_{\tilde{X}^*\beta^0}(0) = 1$.

The simplest sieve estimator for $F_{\tilde{X}^*\beta^0}$ is a step function with J steps, where J would grow with the sample size. Let this estimator be $\hat{F^q}_{\tilde{X}^*\beta^0}$, where q is a length J vector of quantiles

[77] This would be satisfied, for example, if the support of $\tilde{X}^*$ includes a half-sphere around the origin. Intuitively, the support needs to include points where the central planner is almost indifferent between choosing π' and π^0.

[78] Within the discrete choice literature, Fox [2010] considers the "rank order property", which if satisfied would allow for parameter estimation in discrete choice models using only a subset of the choices, via maximum score estimation. One of the estimators considered in this paper is in fact implemented as a smoothed maximum score estimator, although the assumptions differ from the estimator proposed by Fox.

[79] Assumption 2.b suggests the normalization $||\beta||^2 = 1$, but we find that $\sum_i |\beta_i| = 1$ gives better results, and thus use that normalization instead.

that fully specifies the step function. The corresponding minimum distance estimator is then

$$\hat{\beta} = \underset{\beta}{\operatorname{argmin}} \min_{q,\sigma^2} Q(F_{\tilde{X}\beta}, \hat{F}^q_{\tilde{X}^*\beta} * N(0,\sigma^2)) \tag{26}$$

where $\sigma^2 = \beta^{\mathrm{T}}\Sigma\beta$, and Q is some minimum distance statistic.[80] This is easily computable once the normalization $||\beta||^2 = 1$ is imposed.[81]

H Alternate Partitions and Moments Used

We will consider three types of alternate partitions π'. First, there are "mergers":

$$\pi' = \{(\pi^0 \setminus \{m_1, m_2\}) \cup \{m_1'\}\}, \text{ with } m_1, m_2 \in \pi^0, m_1' = m_1 \cup m_2.$$

Here two coalitions have been combined into one, decreasing the total number of coalitions by one. In this case, the coalitions in the alternative partition are larger than the coalitions in the actually observed partition.[82]

Second, there are "splits":

$$\pi' = \{(\pi^0 \setminus \{m_1\}) \cup \{m_1', m_2'\}\}, \text{ with } m_1 \in \pi^0, m_1 = m_1' \cup m_2'.$$

Here one merger has been split into two, increasing the total number of coalitions by one. In this case, the coalitions in the alternative partition are smaller than the coalitions in the actually observed partition.

Finally, there are "switches":

$$\begin{aligned}&\pi' = \{(\pi^0 \setminus \{m_1, m_2\}) \cup \{m_1', m_2'\}\}, \text{ with } m_1' = (m_1 \setminus i) \cup j, m_2' = (m_2 \setminus j) \cup i,\\ &m_1, m_2 \in \pi^0, \quad i \in m_1, j \in m_2\end{aligned}$$

[80] We use the Anderson-Darling test statistic.

[81] Kneip, Simar, and Van Keilegom [2015] provide a method for problems of this type, but unfortunately it does not appear to be applicable in this case because the "boundary" in our case is at $X^*\beta = 0$, whereas in Kneip, Simar, and Van Keilegom [2015] it is positive.

[82] More generally, one could consider "extensions":

$$\begin{aligned}\pi' =& \{(\pi^0 \setminus \{m_1, m_2, m_3 ...\}) \cup \{m_2', m_3' ...\}\}, \text{ with } m_1, m_2, m_3 ... \in \pi^0,\\ & m_2' \supseteq m_2, m_3' \supseteq m_3 ...,\\ & m_1 = (m_2' \setminus m_2) \cup (m_3' \setminus m_3) ...\end{aligned}$$

Here one coalition has been eliminated, and other existing coalitions extended to include its former members. In previous versions of this paper we used alternative partitions of this type, and obtained similar results.

"Mergers"	"Splits"	"Switches"
Smaller pop. < 400	Total pop. < 1600	(not subdivided)
Smaller pop. 400 - 800	Total pop. 1600 - 2400	
Smaller pop. 800 - 1600	Total pop. > 2400	
Smaller pop. > 1600		
Smaller pop. > 1600 and smaller *koku* > 1000		
"very rural" and smaller *koku* > 1000		

Table 9: Moments Used

Here two players are swapped between mergers. This does not change the number of coalitions in the partition, but does result in players with different characteristics being grouped together.

For the set of "mergers", we create one alternative partition for each pair of adjacent coalitions in π^0.

For the set of "splits", we create alternative partitions for each non-singleton coalition in π^0 via the following method. Begin by choosing a player $i \in m_1$. Assign this player to the new coalition m_2', and make everyone else who was in m_1 a member of m_1'. Now, check the geographic adjacencies of players in m_1'. Find the player $j \in m_1'$ that has the greatest percentage of edges touching players in the new coalition m_2'. Move this player j from m_1' to m_2'. Continue moving players in this fashion until the total population of m_2' is at least as large as that of m_1'.[83]

For the set of "switches", we create one alternative partition for each pair of adjacent players i and j, where i is in a different coalition than j.

We base our moment inequalities estimator on Inequality 16. This inequality should hold for the dataset as a whole, as well as for subsets of the data. Given the way we created our set of alternative partitions, we already have three obvious subsets: "mergers", "splits", and "switches".

Within "mergers", it makes sense to differentiate between the case where one of the coalitions being merged was small, and the case where both coalitions had large populations. Of particular interest is the case of coalitions with a relatively large tax base, as our model suggests that these will be less likely to be merged even if they are located reasonably close to each other. In our model we have assumed that distance is potentially measured with error, and thus we do not use it as an instrument. However, areas that are mountainous

[83]We do not look at geographic distance in this algorithm because in our model we are assuming that distance is measured with error.

or otherwise particularly rural generally contain mergers with villages that are further away (particularly in terms of walking time). Thus, we make a final distinction, considering a subset of "very rural" locations, where less than 2% of the land is occupied by the village. These subsets are summarized in Table 9.

Within "splits", there is similarly an advantage in differentiating between cases where a relatively small coalition is being broken up, and where a relatively large coalition is being broken up. We did not find any advantage to considering other categories. In the case of "switches", there does not appear to be any further breakdown that is useful for the purpose of identification.

Identification does not improve if further moments based on smaller subsets are used: there appears to be no easy fix for the unbounded confidence sets shown in Table 6. At first glance, it is not obvious why there would be such a difficulty with these confidence sets. For example, in Column II it seems that all that would be necessary to prevent unboundedness would be four appropriate sample moments. The first sample moment would involve alternative partitions where $\tilde{X}_{\pi' \mathrm{FC}}$ was on average negative, $\tilde{X}_{\pi' \mathrm{D}}$ was positive, and there was on average no change in religious heterogeneity $\tilde{X}_{\pi' \mathrm{R}}$: this would establish an upper bound for β_1/β_2, the importance of distance relative to the cost of providing public services. The second sample moment would involve alternative partitions where $\tilde{X}_{\pi' \mathrm{FC}}$ was on average positive, $\tilde{X}_{\pi' \mathrm{D}}$ was on average negative, and there was on average no change in religious heterogeneity. This moment would establish a lower bound for β_1/β_2. The third and fourth moments would be the same as the first and second, except with changes in $\tilde{X}_{\pi' \mathrm{R}}$ instead of $\tilde{X}_{\pi' \mathrm{D}}$: these would establish lower and upper bounds for the importance of religious heterogeneity relative to the cost of public good provision.

The problem that arises is that any selection of "mergers" results in an increase in all sorts of heterogeneity relative to the actual partition: both geographic heterogeneity and religious heterogeneity increase. Similarly, any selection of "splits" results in a decrease in all sorts of heterogeneity. This colinearity tends to expand confidence sets, as one type of heterogeneity can be traded off with another. Infinite confidence sets occasionally result, when large coefficients cannot be rejected because these coefficients generate correspondingly large estimates for the variance of the underlying measurement error.

With very strong instruments, it would be possible to use some of the "switches" as cases where there was a direct tradeoff between geographic heterogeneity and religious heterogeneity. However, the number of feudal villages that are not in the coalition that is geographically closest is very small, and there is no instrument available to pick these out. One potential solution would be to simply assume that the available set of instruments is much larger: for example, all variables except distance are measured without error. Assumptions of this sort, however, lead to empty identified sets and thus do not appear appropriate.

I Simulation Details

I.1 Derivation of Equation 18

For coalition m' to be a blocking coalition for the partition π, it must be the case that $u_{i\pi} < u_{im'}$ for all i in m'. For a given π, we are interested in finding such an m', or proving that none exists and thus π is in the core. Rearranging Equation 2 and substituting it into Equation 3, we obtain

$$u_{im'} = \beta_1 \frac{\sum_{i' \in m'} \ell_{ii'} y_{i'} y_i}{\sum_{i' \in m'} y_{i'}} + \beta_2 \frac{y_i(\gamma_1 + \gamma_2 \sum_{i' \in m'} p_{i'})}{\sum_{i' \in m'} y_{i'}}. \tag{27}$$

Multiplying both sides by $\frac{1}{y_i} \sum_{i' \in m'} y_{i'}$, we express the constraint $u_{i\pi} < u_{im'}$ as

$$u_{i\pi} \frac{\sum_{i' \in m'} y_{i'}}{y_i} < \beta_1 \sum_{i' \in m'} \ell_{ii'} y_{i'} + \beta_2 (\gamma_1 + \gamma_2 \sum_{i' \in m'} p_{i'}). \tag{28}$$

Now let z be a vector of binary variables of length N, with $z_i = 1$ if $i \in m'$, and zero otherwise. In Inequality 28, the expression $\sum_{i' \in m'} y_{i'}$ can then be rewritten as $\sum_{i'} z_{i'} y_{i'}$. The only variable in Inequality 28 that is not known is z, and the inequality is linear in z. Consider the following set of (pairs of) disjunctive constraints:

$$\forall i \text{ either Inequality 28 holds or } z_i = 0. \tag{29}$$

This is one pair of constraints per player, for a total of N pairs of constraints.

The problem of finding a coalition m' that is a blocking coalition for the partition π is thus equivalent to the problem of finding a vector z that satisfies the restriction given in (29). By adding a slack variable t to Inequality 28 and maximizing the slack, we turn the problem of finding a blocking coalition into an optimization problem. The addition of a weight variable w_i allows for different blocking coalitions to be selected: if w_i is relatively high, the selected blocking coalition will increase i's payoff by more.

I.2 Computation Notes

A problem of the form just discussed can be solved by commercial solvers. Although in theory the problem has NP complexity, in practice, and with the actual data, solutions can be obtained rapidly even with approximately 1000 players. We use CPLEX, which considers this problem to be a binary program with "indicator constraints". From a computational perspective, presolving the problem with about 1000 players is computationally costly. We thus first check sub-problems for each county in Gifu. Only if none of these have a blocking coalition do we check the whole problem. This reduces dramatically the amount of time spent in presolve.

A further reduction in time required can be obtained by stopping the optimization problem at the first solution. Fully solving the optimization problem dramatically lengthens the time required to find the next blocking coalition, and does not appear to improve the time required to find a core partition. Stopping upon finding the first (integer feasible) solution results in different runs of the algorithm producing solutions, as desired. A major advantage of this approach is that for some values of the weights the algorithm terminates quickly, while for others it does not terminate within the maximum allowable job time of the computer system used. It is thus possible to obtain core partitions quickly by running many instances of the algorithm in parallel, with different weights.

A final speedup in computation is obtained by collapsing the smallest feudal villages into other nearby villages that ended up in the same merger. Thus, instead of 1099 players, computations are actually performed using 910 players. It is unclear why this 20% decrease in the number of players results in a dramatic speedup in computation times. One potential explanation is that the presence of particularly small players prevents certain otherwise useful heuristics from being applied successfully in the mixed integer program.

The generalizability of the computational approach employed might appear limited because of the specific form required. The use of linear inequalities, however, is not as restrictive as it may first appear. Barros [1998] and others describe methods for expressing more complex restrictions in linear form by generating additional variables. Although using this approach may currently be computationally challenging, mixed integer programming algorithms have seen enormous improvements in speed in recent years [Bixby 2012]. Combined with improvements in hardware performance, simulation of at least approximate versions of models with non-linear payoff structures may soon become feasible. The easiest of these would likely be a model involving, for example, quadratic distance costs.[84]

One might wonder what the "best" partitions look like in Columns III-VI of Tables 7 and 8. Unfortunately, it is difficult to modify Algorithm 1 to produce partitions that are desirable from a social perspective, because choosing the "best" myopic deviation in this case

[84] Early results using a dataset based on the Heisei municipal mergers suggest that games of up to 100 players can be simulated using quadratically constrained mixed integer programs. Although the increased numerical difficulty of the quadratic model reduces the number of players by an order of magnitude, 100 players is still sufficient for many applied models.

involves a non-linear objective and is thus computationally costly. Using the Dinkelbach [1967] approach is possible, but it appears that the increase in computation time is not rewarded by partitions that are particularly good from the social planner's perspective. This provides suggestive evidence that there may be no partitions that are anomalously good.

I.3 Alternative Computational Method

An alternative method finding core partitions relies on the exhaustive enumeration of potential coalitions. In this case, restrictions need to be imposed so that this enumeration is computationally feasible. Specifically, consider only coalitions that are geographically contiguous, and consist of 11 players or less. This covers the vast majority of actual mergers. As an additional modification for computational simplicity, eliminate the smallest players: iteratively merge those *shizen son* with very low population with the neighbouring *shizen son* that has the closest koku rating per capita. This reduces the number of players to about 1080, but more importantly reduces the number of mergers with a large number of players, such that considering mergers with up to 11 players covers virtually all of the potentially stable coalitions.

Furthermore, rather than considering the coalition formation game as a whole, with about a thousand players, break the game into geographically contiguous units with about 40 players each. This corresponds to the standard IO setup of considering geographic "markets" for goods. To ensure that these restrictions themselves do not bias the results, the socially optimal partition will be computed using this same restricted set of coalitions.

To compute the core of each coalition formation game, the same approach based on random myopic deviations will be used. As the number of potential partitions is finite, a properly randomized approach will eventually find all partitions in the core. Ensuring reasonable performance is difficult, however, because of the possibility of cycles of myopic deviations. A brute force approach to avoid cycles is thus used, following Algorithm 1, but using exhaustive enumeration rather than mixed integer programming to find blocking coalitions. The core of the decentralized coalition formation game that results is never empty, and while occasionally a singleton, it generally consists of a number of partitions, all corresponding to roughly the same level of social welfare. The difference between the best and worst element of the core is minimal, corresponding to less than the fixed cost of one additional municipality, in games where twenty municipalities are forming on average.

I.4 Data for Counterfactual Simulations

The counterfactual simulations are performed using the observed data, from the GKCR and other sources. However, according to the econometric model presented in Section 3, this data is measured with error. Thus according to the model, the counterfactual simulations are being performed on a counterfactual Gifu prefecture, that has characteristics that are slightly noisier than the real Gifu prefecture. There is one case where the counterfactual simulation is correct, at least asymptotically: if the distribution of characteristics of players is a maximum entropy distribution, then adding measurement error does not change this distribution. In this case, then, simulations based on the observed characteristics of the players return (asymptotically) the same results as simulations based on the true characteristics of the players. The most relevant maximum entropy distribution is the following: players are uniformly distributed on the surface of a sphere. Here as the number of players becomes large, isotropic noise will not change the distribution. The players in Gifu prefecture are somewhat close to uniformly distributed, and we ignore the fact that they are distributed on only one small part of a sphere.

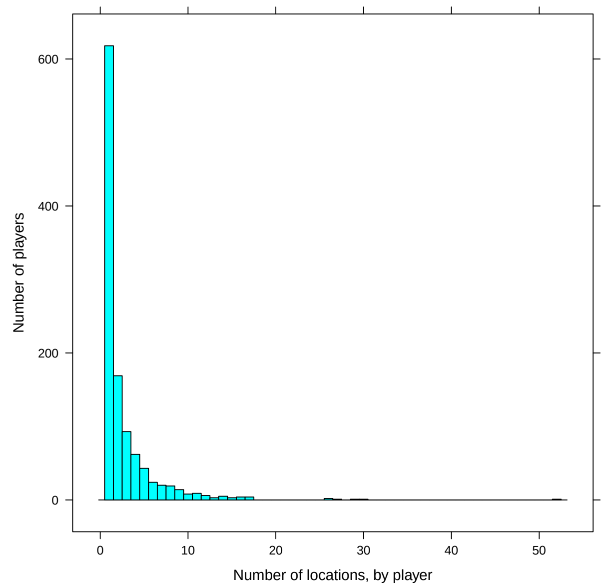
J Smaller Players

One might wonder whether this means that the actual inefficiency would be even higher, if only the size of the players were smaller, and thus it were possible for an even finer partition to emerge. It turns out that this appears to not be the case.

Suppose that we wished to consider the "same" coalition formation game, except with smaller players. One way to do this, albeit in only an approximate sense, would be to start by halving the distance cost (e.g. $\beta_1 = -0.03$ instead of $\beta_1 = -0.06$), which is equivalent to halving all the distances ℓ. Then, in order to retain population density at its original value, we reduce all the populations (and koku ratings) of players by $(1/2)^2 = 1/4$. This produces a "zoomed in" version of the original configuration.

If the number of players is large, and their distribution fractal, then this "zoomed in" configuration has the same distribution as the original configuration. The resulting number of coalitions in core partitions should thus be the same, except in the case where the core partitions in the initial game were anomalously large because the initial player sizes were too big. We find, however, that this effect is in fact not particularly important: "zoomed in" core partitions with $\beta_1 = -0.03$ have 210% more coalitions than the social optimum, compared to the corresponding initial case of $\beta_1 = -0.06$ with 180% more coalitions. Thus, it appears that with the initial data we are calculating roughly the right amount of inefficiency.

Figure 5: Points per Feudal Village



K Data Construction

This appendix describes the exact method used to construct each of the variables listed in Table 2. The main data source is the *Gifu-ken Chouson Ryakushi*. The GKCR was originally digitized by Skinner [1988], but he does not appear to have used it in published work. The GKCR version used is courtesy of Tsunetoshi Mizoguchi and Kei Okunuki, based on an original version at the Skinner Data Archive. A bilingual codebook is available in Mizoguchi [2004].

The GKCR describes the feudal villages (*shizen son*) present in Minou province, which contains most of the population of Gifu. It omits villages in Hida province, further to the north. There is a lengthy debate in the domestic Japanese literature regarding the exact definition of a *shizen son*: Yamaoka [1977] provides detailed examples. We do not participate in this debate, as our definition of a *shizen son* is imposed on us by the data source. Each line in the GKCR becomes one player in our coalition formation game. This decision is defensible because the GKCR was collected for administrative purposes, and data is available for the units in question only because they were administratively important: the line items in the GKCR were the base level at which taxes were collected during the feudal period.

Municipal mergers are not recorded directly in the GKCR. Our post-merger boundaries are based on official 1919 municipal boundaries provided by the Ministry of Land, Infrastructure, Transport, and Tourism. Two mergers and one split that occurred in 1903-05 were reversed (the next boundary change did not occur until 1921). The boundaries shown in Figure 1b are thus those of 1897, except for one minor boundary adjustment that does not affect any calculations.[85]

K.1 Points

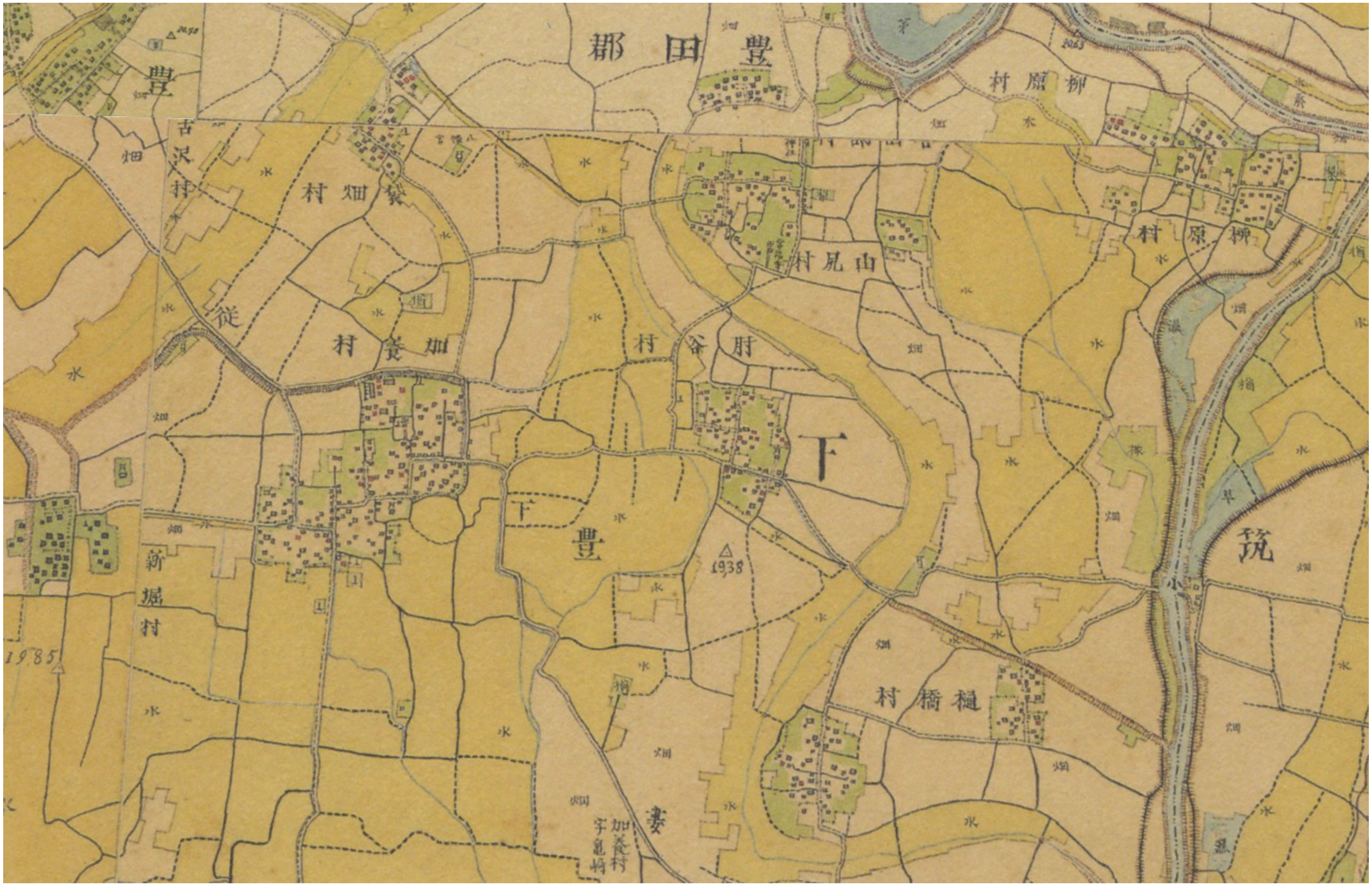
We use geocoded gazetteer data on Meiji locations, courtesy of the Center for Integrated Area Studies at Kyoto University. This data is based on the 1891 and subsequent official maps of Gifu Prefecture. The relevant subset of this data is shown in Appendix Figure 7: the gazetteer classifies points into types, and the most important for our purposes are "place" points. About half of the feudal village polygons have exactly one "place" within their boundaries. For these villages, we use this point as their geographic location. If a feudal village has more than one "place", then we keep track of all of these points, and will use them all (with equal weighting) for distance calculations.

If a village has no "place" points within its boundaries, then we use the location of a train station, in the very small number of cases that one exists.[86] If a village still has no points, we continue with gazetteer points related to municipality names, which are less attractive because the geocoding for these do not appear to be as accurate as for the "place" points. We continue in the same fashion for schools, companies, structures, and plains. In all cases, the first item shown in the "order of use" legend in Figure 7 to have any points inside the feudal village boundaries is used as the location of that village. If this item has multiple points within the feudal village boundaries, then we keep track of all of these.

[85]The most comprehensive list of municipal changes appears to be that maintained by M. Higashide at http://uub.jp/. For Gifu, we cross-checked these with the *Gifu-ken Chouson Gappeishi* and verified that they were correct.

[86]These are less desirable, because were generally built after the municipal merger period, and only show up in the gazetteer because some of the maps on which it is based come from the early 20th century. There are only 9 train stations in the gazetteer.

Figure 6: Toyota County, Ibaraki Prefecture



There are 59 feudal villages for which no points are found via this method. After manual inspection, 29 of these are cases where an appropriately named point is located just outside of the village polygon: we assign these points to the appropriate village. In the remaining 30 cases, we use the geographic centroid of the polygon for the location.

Figure 5 shows a histogram of the number of points per feudal village. For a majority of feudal villages, we have exactly one point associated with the village. In a small number of cases, there are a dozen or more points associated with a single feudal village. Appendix Figure 8 shows the points that are used.

For reporting simulation results graphically, we will display each feudal village as a single point, with a location equal to the mean latitude and longitude for the points associated with that feudal village. These "display points" are shown in Appendix Figure 9. This is purely for ease of presentation, however, and all calculations described subsequently are done over multiple points for the feudal villages that have them.

K.2 Distance

Straight-line distance is calculated using the great-circle distance formula, assuming that the earth is a sphere. For feudal villages represented by more than one point, this distance is calculated as the average distance across all relevant points. That is, if J_i is the set of points associated with feudal village i, and $J_{i'}$ the set of points associated with feudal village i', then the straight-line distance $\ell_{ii'}^{\mathrm{D.S}}$ is calculated as

$$\ell_{ii'}^{\mathrm{D.S}} = \frac{1}{|J_i||J_{i'}|} \sum_{j \in J_i} \sum_{j' \in J_{i'}} \ell_{jj'}^{\mathrm{D.S}} \tag{30}$$

where, with some abuse of notation, $\ell_{jj'}^{\mathrm{D.S}}$ is the straight line distance between point j and point j'. The result of repeated application of Equation 30 is a distance matrix $\ell^{\mathrm{D.S}}$ containing a straight line distance $\ell_{ii'}$ for each pair of feudal villages i and i'. To create $X_{\cdot\mathrm{D.S}}$, we then use Equation 11, with distances $\ell_{ii'}$ taken from the matrix $\ell^{\mathrm{D.S}}$.

For expositional purposes, we calculate a histogram of the straight line distances between adjacent feudal villages: these are $\ell_{ii'}^{\mathrm{D.S}}$, with the (i, i') pairs used corresponding to the edges shown in Figure 9. Figure 10 reports these distances, with the modal distance being a bit less than 2km, and some distances being substantially longer.

Straight line distance is likely inappropriate in the case of Gifu, however, because much of the prefecture is mountainous, and thus the actual path used to travel between two villages would not be a straight line, but rather a more complicated route that minimizes elevation changes. For these calculations, we do not consider data on the road network in place during this period: this network was relatively primitive, and we assume that there are walking tracks located wherever our algorithm calculates that people will be travelling. Although trains were being introduced during this period, they were used for longer distance journeys, and are not relevant for distance calculations between a feudal village and its neighbour, or the next village over. Thus, we consider walking as the only mode of transport.

Figure 7: Gazetteer Point Data

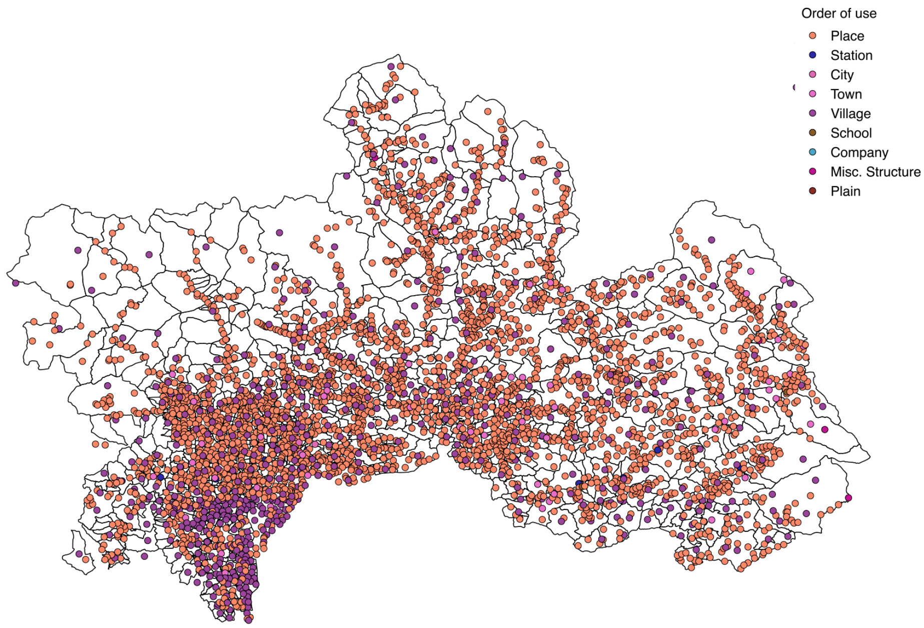
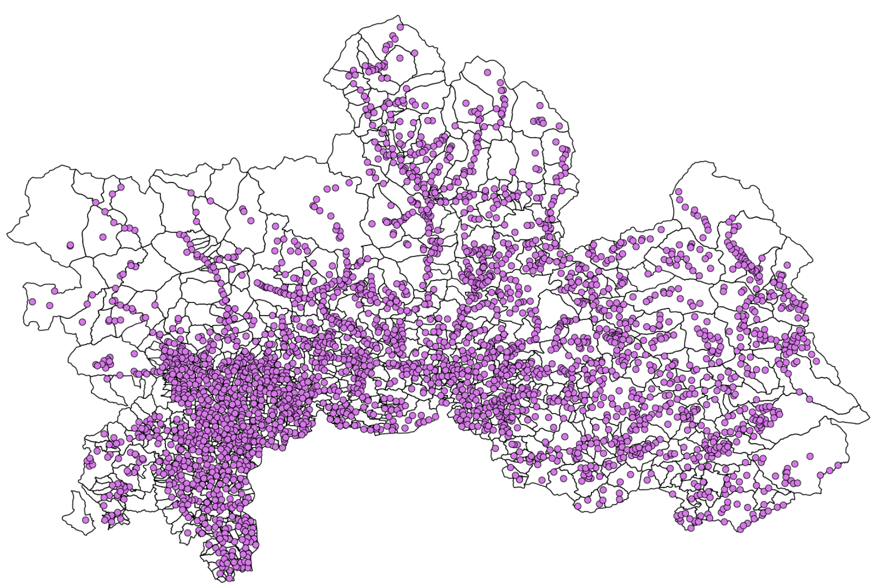


Figure 8: Points Used from Gazetteer



Given the mountainous nature of the prefecture, we assume that the major determinant of walking time is elevation change.[87] We use digital elevation data from the Geospatial Information Authority of Japan, at 10 meter grid square resolution. Figure 12 shows this elevation data.

To calculate walking time between two points based on this elevation data, we use the Fontanari [2000] implementation of Dijkstra's shortest-path algorithm, applied to a raster version of the elevation data.[88] The walking time returned is anisotropic: the cost of walking uphill is not simply equal to the benefit of walking downhill. Thus, the shortest path to a destination may be different from the shortest path returning from it. We use the roundtrip distance, following both of these paths, divided by two.[89] In the case where feudal villages are associated with multiple points, the approach in Equation 30 is used.

Figure 11 reports the walking distances for adjacent feudal villages. The units used here are 1000s of seconds, because walking speed is approximately 1km per 1000sec, and thus with these units coefficient estimates will be of roughly comparable magnitudes when using the straight line distance data and the walking distance data. According to the figure, the modal walking time to an adjacent village is a bit less than two hours.

[87]Rivers in Gifu are often seasonal, and generally small. A qualitative inspection of boundaries shows that they do not appear to follow rivers in a systematic way, and a preliminary quantitative analysis using GMM and the actual location of the boundary between two adjacent municipalities appeared to confirm this. We do not report these results because the standard errors were very high, and the econometric model used differs substantially from that presented in Section 3.

[88]This is the "walking distance" function `r.walk` in the GRASS GIS package. Parameters are left at their default values, which correspond to the Aitken [1977] and Langmuir [1984] adjustments to the Naismith [1892] walking time function.

[89]One is reminded of hiking trails that split at certain points, offering both a steeper and a gentler route.

Figure 9: Players and Adjacencies

Each vertex is a player, and edges indicate geographic adjacency.

Figure 10: Straight-line Distance

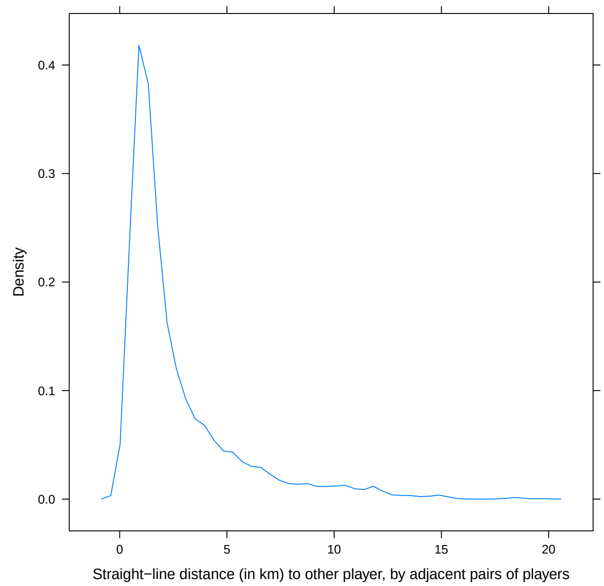


Figure 11: Walking Distance

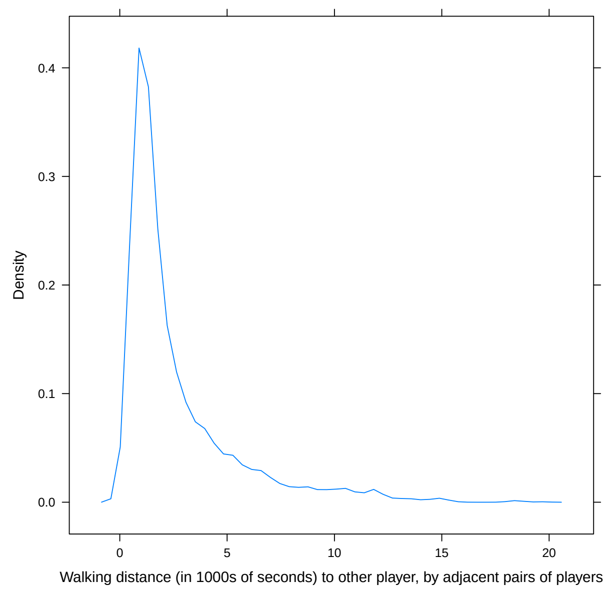
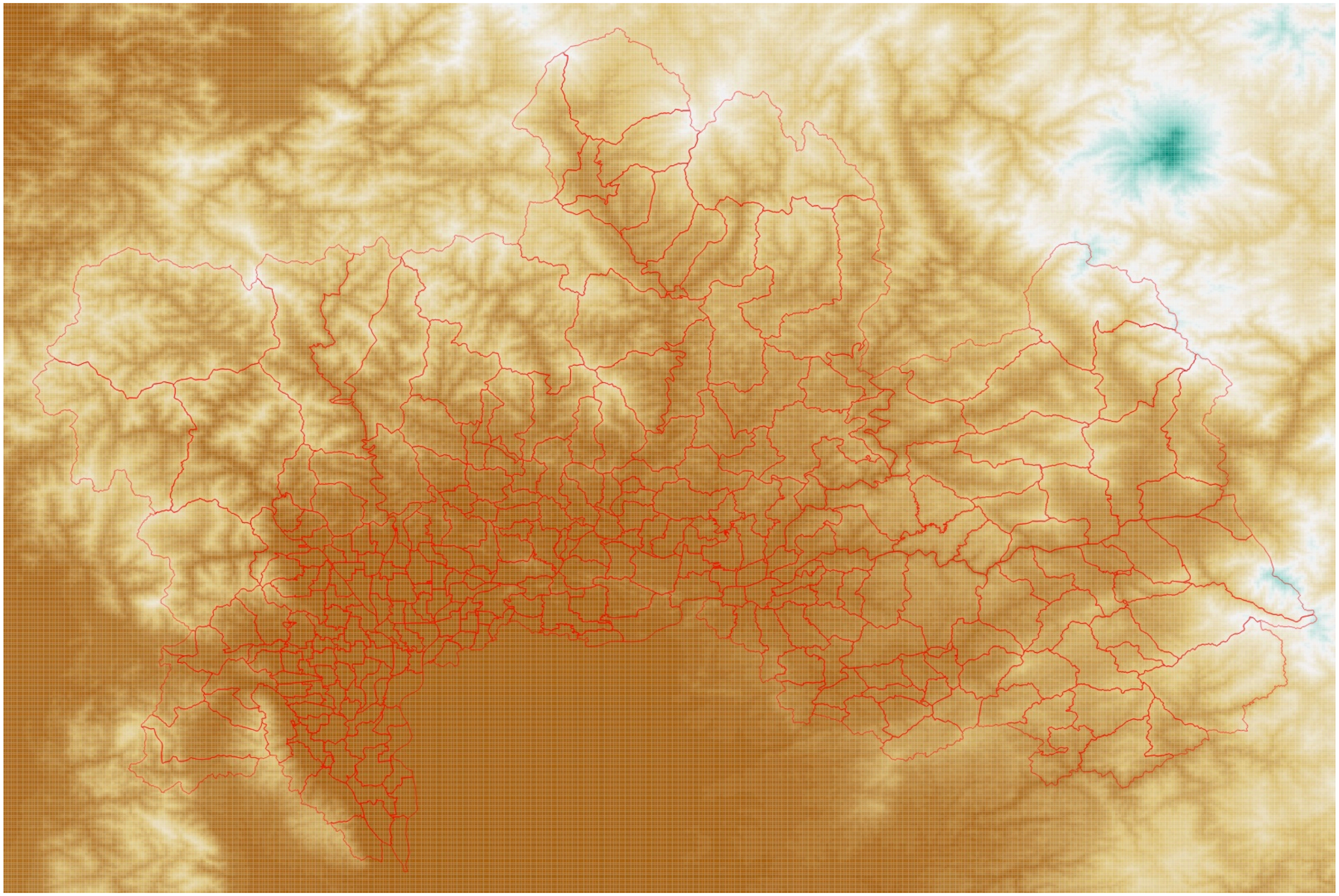


Figure 12: Elevation



Dark brown indicates low elevation, white higher elevations, and green highest. In mountainous regions, low elevations tend to correspond to river valleys.

K.3 Other Covariates

Figure 15 shows the most important product in each feudal village by value, with the legend including data on the total share of each item. To calculate a distance with this data, we use a discrete version of Equation 30. As discussed in Appendix A, this distance corresponds to commonly used measures of fragmentation.

Instead of points located geographically, let j now index types of products, and let J be the set of all products.[90] The distance between feudal villages i and i' in terms of production is then

$$\ell_{ii'}^{\text{prod}} = \sum_{j \in J} s_{ij}^{\text{prod}} s_{i'j}^{\text{prod}} \tag{31}$$

where s_{ij}^{prod} is the share of the j product in feudal village i's production.

To create $X_{\cdot\text{prod}}$, we use a slight modification of Equation 11:

$$X_{\pi,\text{prod}} = \sum_{m \in \pi} \frac{1}{\text{Prod}_m} \sum_{i \in m} \sum_{i' \in m} \ell_{ii'}^{\text{prod}} \text{prod}_i \text{prod}_{i'} \tag{32}$$

where prod_i is total production in feudal village i, and Prod_m is total production in coalition m.

We use a similar method to calculate distances regarding the types of land present in each feudal village, the identity of the lord of the village during the feudal period, the identity of religious sects in the villages, and the distribution of land among landlords. Figures 16 - 19 provide a summary of these data.

In addition to agriculture, some areas of Gifu engaged in fishing. This was mainly along the banks of rivers, although some ponds and lakes appear to also have been used. Figure 20 shows the distribution of fishermen in Gifu.

The official orders that resulted in the Meiji municipal mergers occurring explicitly mentioned a target size for amalgamated municipalities: they were supposed to be between 300 and 500 households. Let $\texttt{HH}_m$ be the number of households in municipality m. Then

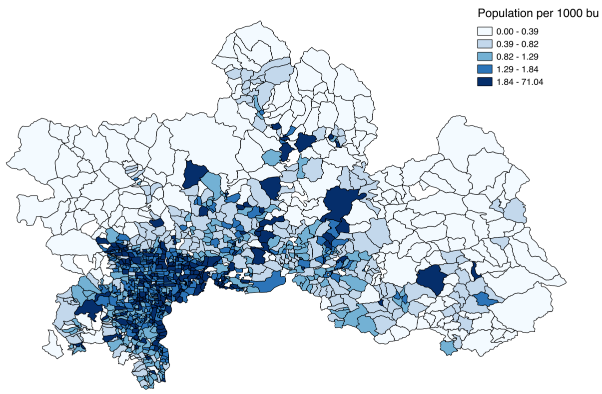
$$X_{\pi,\texttt{HH300}} = \sum_{m \in \pi} 1(\texttt{HH}_m > 300) X_{\pi,\texttt{HH500}} = \sum_{m \in \pi} 1(\texttt{HH}_m < 500). \tag{33}$$

This definition only makes sense if all the partitions considered contain the same number of municipalities.[91] This variable is thus only used in Column II, Table 3. This variable is

[90] |J|=37 in the GKCR data, but even approximate price data only appears to be available for 21 of these, and thus only 21 products are used. All of these 21 are agricultural, although some of the omitted 16 products are not.

[91] It might be possible to rewrite the equations so that they are an average rather than a sum. We do not

Figure 13: Population Density



presented in Figure 14.

A final variable of interest is income, y, which we treat as equivalent to tax base per capita. In our data, tax base is measured in *koku*: Figure 21 shows the distribution of *koku* per capita in the data. The modal *koku* rating is close to 1 *koku* per capita. This is a plausible value, as the *koku* unit of measure was originally defined as the amount of rice required to feed a man for one year, and production in rural Japan during this period was close to subsistence levels. Gifu, like most of Japan during this period, was predominantly rural and agricultural.

Expenditure data on public goods do not enter directly into our analysis, but is used indirectly as part of the calibration exercise for the parameters γ_1 and γ_2 describing the cost of public goods. Figure 22 shows GKCR data on expenditures as blue data points and a red (OLS) regression line.

The GKCR contains many other variables that we do not use in the analysis. Most of these are ignored because they appear to be at best only tangentially related to municipal mergers: for example, there are very detailed reports of the calendar day when each of

pursue this, and it is not obvious that it would lead to reasonable results.

Figure 14: Households (post-merger)

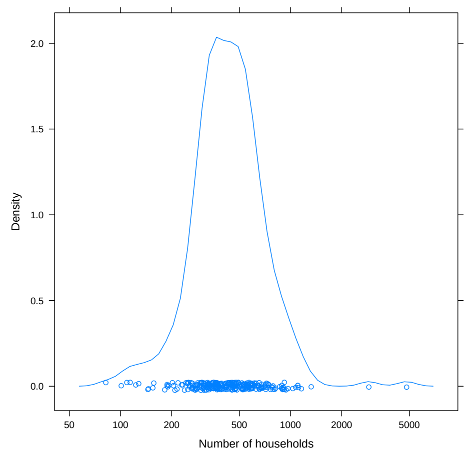
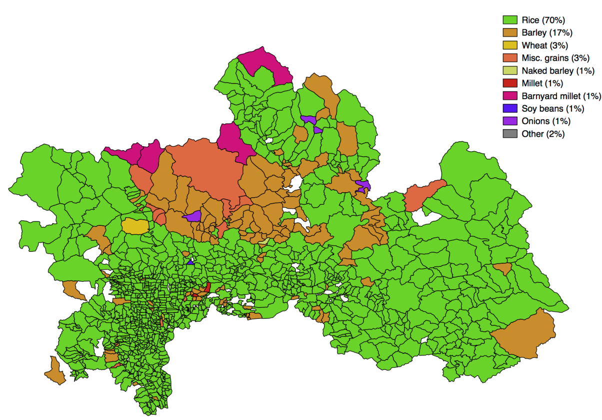
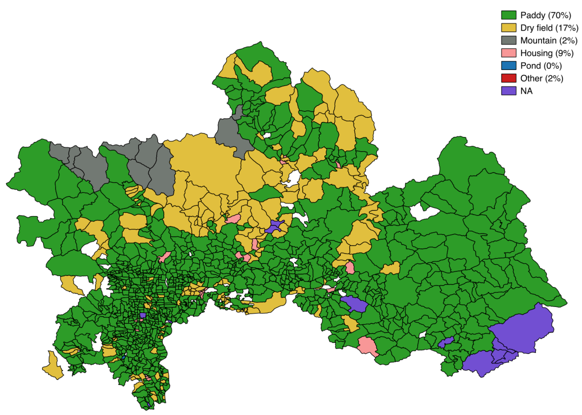


Figure 15: Most important product (by value)



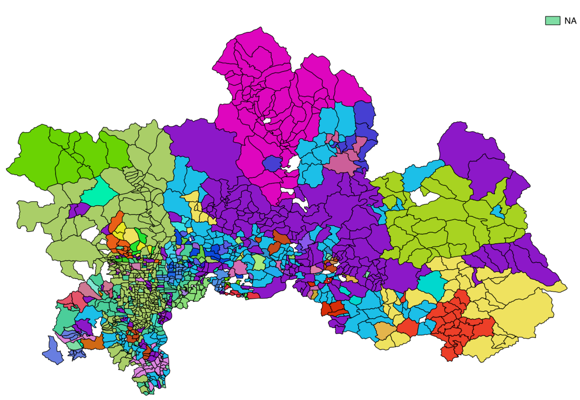
Production information on quantities from the GKCR is multiplied by price.

Figure 16: Most important land type (by value)



Land value information from GKCR

Figure 17: Most important feudal lord



Feudal lords (*ryoushu*) were a basic part of the tax collection and administration system during the feudal period. The lords are reported in the GKCR as historical data: they were removed early in the Meiji restoration, and thus cannot have any direct effect on municipalities during the Meiji period. Their historical legacy, however, could plausibly include cultural differences across feudal villages controlled by different lords.

Figure 18: Religious sects

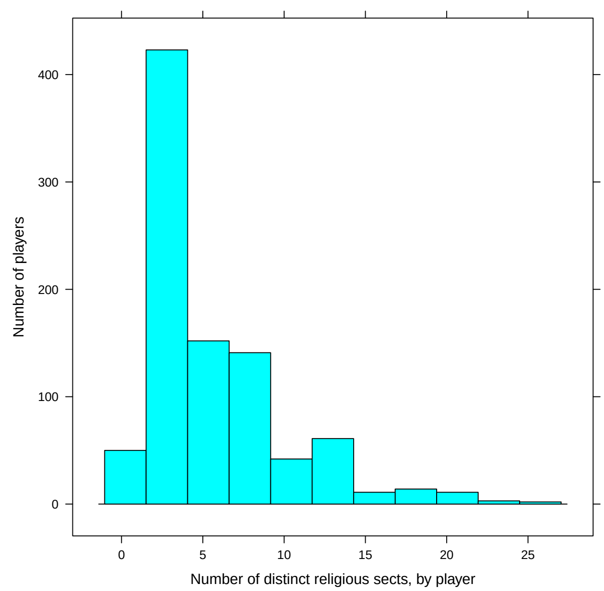
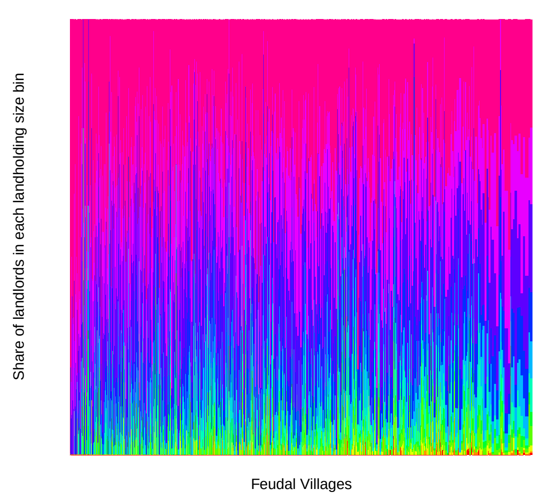
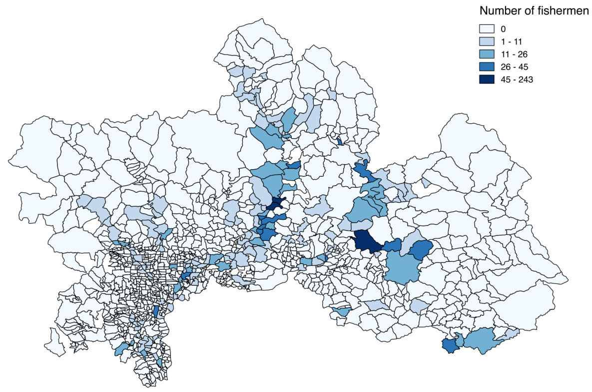


Figure 19: Landlord size



Landlords in each village are counted by size of landholdings: greater than ¥100, 200, 300, 500, 700, 1000, 1500, 2000, 5000, 10000, and 20000. Violet corresponds to small landlords, and red to large landlords. Villages are sorted by amount of total holdings. Because of data quality issues, no "less than ¥100" category is used.

Figure 20: Fishing



many crops are traditionally planted and harvested in each village. One additional variable that is of interest is that dealing with migration. In the GKCR, only 0.8% of individuals were classified as migrants. This classification is based on *honseki*, which should capture all individuals that migrated, and possibly also children of migrants. Thus, migration does not appear to have been that substantial in Gifu during the period in question, although substantial urbanization was occurring elsewhere in Japan. This justifies the omission of migration in our model.

L Construction of X

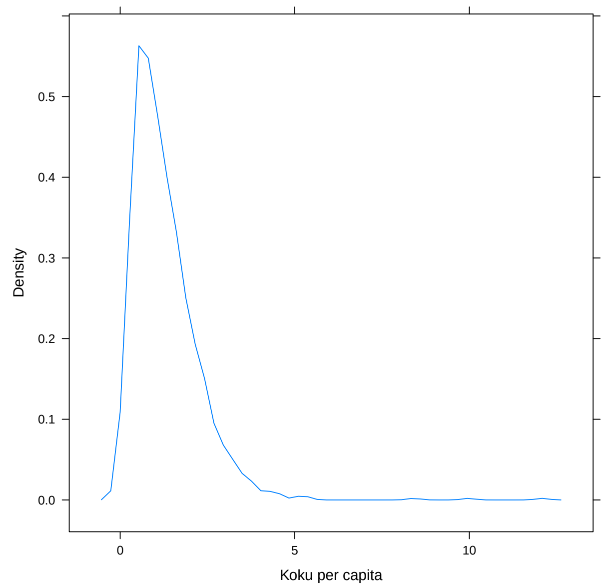
The alternative partitions considered consist either of moving a single municipality from one merger to another (Π_1'), or performing one additional merger or one fewer merger than actually occurred (Π_2'), or both. The precise construction of $\tilde{X}$ is strongly influenced by a desire to keep all entries of this data matrix at roughly the same order of magnitude, as this substantially reduces computational difficulties.

Consider first Π_1', where a single feudal village i is reassigned. Treat the other portion of municipality m_1 as a single player, labelled m_1' below. The difference in the heterogeneity cost between π' and π^0 will be

$$r_{m_1'}(L(m_1', m_1') - L(m_1', m_1' \cup i)) + r_i(L(i, m_2 \cup i) - L(i, m_1' \cup i)) + r_{m_2}(L(m_2, m_2 \cup i) - L(m_2, m_2)) \tag{34}$$

where L is defined as in Equation 4, except weighted by the relevant variable r rather than y. Suppose that the measurement error in the $L(m_1', m_1')$ and $L(m_2, m_2)$ terms is zero. Then

Figure 21: Koku per capita, by Feudal Village



there are four terms with measurement error, all related to moving player i.

Now consider the case of a merger. Here the heterogeneity cost will be

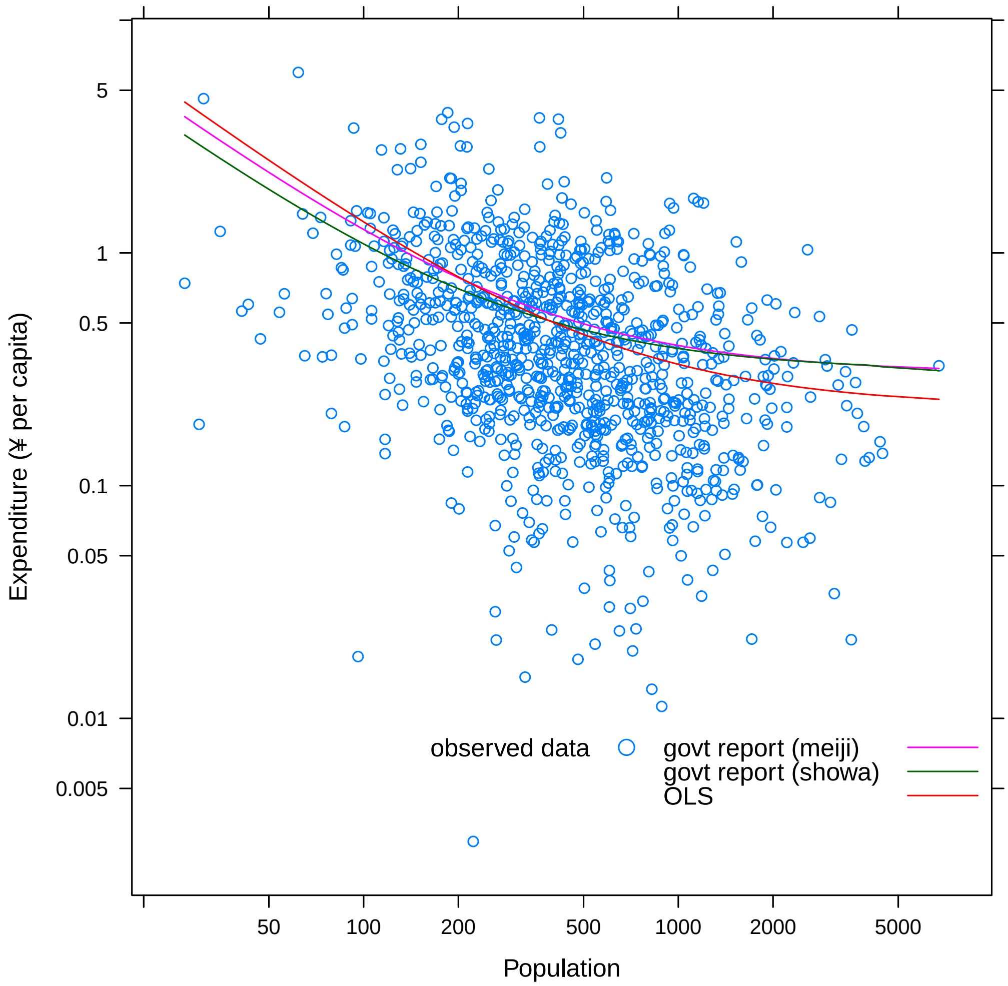
$$r_{m_1}(L(m_1, m_1 \cup m_2) - L(m_1, m_1)) + r_{m_2}(L(m_2, m_1 \cup m_2) - L(m_2, m_2)) \tag{35}$$

Here similarly suppose that the measurement error in the $L(m_1, m_1)$ and $L(m_2, m_2)$ terms is zero. Then there are two terms with measurement error, both related to the $m_1 \cup m_2$ merger.

Suppose that we wish to make each term equally important, regardless of whether r is particularly high or low in this particular case. Then we should divide by the value of r. This is useful empirically, even though it is not exactly the model laid out in Section 2. It remains to choose what value of r to divide by: we choose $4r_i$ in the case of swaps, and $2\frac{r_1+r_2}{2}$ in the case of mergers.[92]

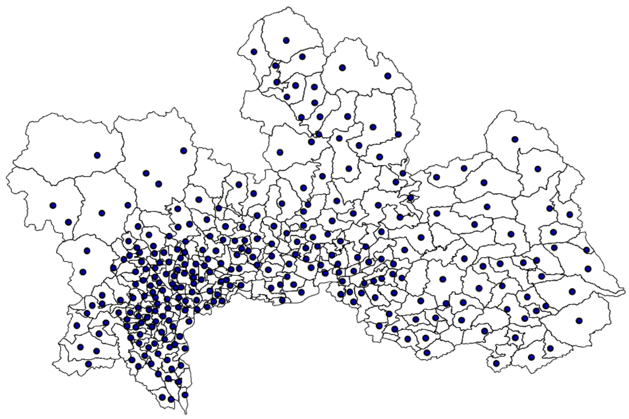
[92] Algebra based on i.i.d. measurement errors would suggest dividing by $\sqrt{2}$ instead of 2. The implications of such an approach are undesirable, however: carried out fully, enormous weight would be placed on observations involving large coalitions, because the i.i.d. assumption implies that the aggregate measurement error is smaller for these coalitions, compared to the true changes. A plausible model of error structures that does not display this phenomenon appears challenging to develop, and we thus use an ad hoc approach instead.

Figure 22: Public good spending per capita



Data points indicate actual spending by precursors to final municipalities: this data is from 1881, when the final municipal system was still under development. OLS is bivariate, predicting total spending based on population and intercept (the line is curved as a result of transformation to log scale). The Meiji "govt" line is based on the fixed cost plus variable cost associated with the three data points discussed in the main text, with an adjustment to take into account that some services were paid not paid for by municipalities when the 1881 data was collected, and some revenue and associated expenses appears not to have been included. The Showa "govt" line is exactly the functional form provided in 1950 government documents describing the efficiencies of scale in the provision of local public goods, but has been normalized such that it is equal to "govt (meiji)" at a population of 3165 (the reference population for the Meiji government document).

Figure 23: Predicted mergers vs. actual mergers

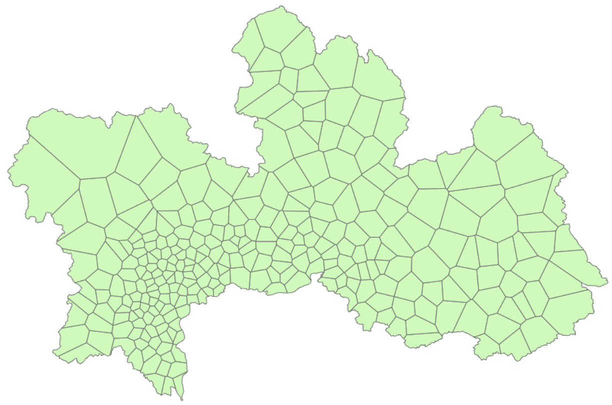


M Predicted Partition for Central Planner

The polygons in Figure 23 show the actually observed partition chosen by the central planner in Gifu. The dots in the figure correspond to the centroids of municipalities the central planner is predicted to create with $\beta_1 = -0.08$. A good fit of the model with the observed data is indicated by one centroid per observed merger, as this corresponds to central planner being predicted to create a municipality that corresponds to each one that was actually created. Areas where there are multiple centroids for each observed merger, or fewer centroids than observed mergers, are areas where the model fit is not as good. A problematic area is evident in the north of Figure 23, where the mergers that are predicted are too small relative to the actually observed mergers. This corresponds to Gujou county. Unfortunately, qualitative sources do not give any indication regarding why the mergers chosen by the central planner in this county appear to differ from the pattern of mergers elsewhere in Gifu.

Figure 24 shows Voronoi cells calculated based on the centroids of the optimal partition. If a new player with very small population were added to the data, the cells indicate which municipality the social planner would assign the new player to. The model predicts substantial variation in the size of municipality between the densely populated plain in the middle of the prefecture, and the more mountainous areas at the edges.

Figure 24: Predicted boundaries



N Local Government in the Meiji Period

Matsuzawa [2013] provides a general qualitative overview of the period in which with the municipal mergers examined in this paper occurred. The Meiji period involved rapid administrative change, and while we focus our attention on the situation in 1890 (Meiji 23), when the mergers in Gifu prefecture were largely finalized, we will also describe the system in the years leading up to this as this is when many initial mergers occurred.

First, we will describe the system of taxation, and the degree to which it can be represented by a model with a single proportional tax rate. Second, we will describe the type of fiscal federalism in place, and the lack of large scale equalization payments. Finally, we will discuss the decision-making system: this was democratic, but with a restricted franchise, and a multi-tier voting system that gave extra weight to the elite. These three features of the data correspond to important assumptions made in the model in Section 2: proportional taxation, no intergovernmental transfers, and weighting by income.

Almost all municipal spending was devoted to three items: education, public works, and general administration. Education spending consisted mainly of spending on primary schooling, generally using a single school. Public works spending included spending on roads, irrigation, and flood prevention. General administration involved mainly maintaining the population register, collecting taxes, and some shared organizational overhead for the other expenditures. The major source of tax revenue was property tax, which was proportional to land holdings.[93]

The modern Japanese system for local government, both from an administrative and fiscal perspective, was established by a combination of the 1888 municipal administrative laws, the 1890 county and prefectural administrative laws, and the 1889 imperial constitution.[94] Fujita [1955], as well as most other historians of Japanese local government, regard this as period in which there was strong central control over local affairs. With some exceptions, this control tended to be exercised in a way that was technocratic rather than partisan.

In many prefectures, the *Meiji daigappei* municipal mergers coincided closely with the passage of the 1888 municipal laws, with the aim of completing the mergers at the time the laws came into force. Ido [1966] provides a summary of this merger process. The mergers resulted in an average of 5.15 old municipalities being amalgamated into one new one.[95]

In Yamanashi, Gifu, Nagasaki, and Nagano prefectures, however, the average number of old municipalities amalgamated into a new one was much lower: 1.39, 1.44, 1.77, and 2.27, respectively. This is because these four prefectures had already undertaken a set of municipal mergers around 1874-76, under the older "ward" ordinance (*daiku shouku sei*) of 1871. Thus, in these four prefectures, only a smaller number of mergers were necessary around 1888 in order to establish a system of local government consistent with the new laws.[96]

Because of the lengthier merger process in Gifu, a description of how the mergers in the prefecture were actually implemented requires a discussion of the entire 1871-1888 period. For this discussion, it is useful to follow the subdivisions in Yokoyama [1957], looking first

[93] The other major source of tax revenue was a household tax that was related to income, but was not strictly proportional. There appears to be debate in the literature regarding the exact nature of this tax Takayose [2000].The assumption used in this paper is that taxation is overall proportional, and thus that the non-proportionality in the household tax is due to the fact that poorer households derive less of their income from property, and thus are taxed more heavily on the household tax.

[94] These laws were the *shi-sei* and *chouson-sei*, covering cities and towns/villages, respectively, as well as the *gun-sei* for counties and *fuken-sei* for prefectures. A variety of other related laws were also put in place during this period. An authoritative reference here is Oishi [1961].

[95] According to Ido [1966], at the end of 1888 there were 71,314 municipalities, 2482 of which were in special areas covered by a different set of laws, and 68,832 of which were covered by the standard set of laws. At the end of 1889, mergers within the latter group had reduced its number to 13,377. This was reported as a ratio of 5.14.

[96] In Gifu, in between the 1874-76 mergers and the 1888 mergers, there was a period with 19 splits but no mergers (*History of Gifu Prefecture*, p. 231). A more detailed model might thus account for the fact that in Gifu, the "Meiji mergers" actually occurred in two distinct stages. However, given that there were splits in between the two sets of mergers, there does not appear to have been any real commitment on the part of the government to the mergers of 1874-76. Thus, in this paper, we ignore the distinction between mergers that happened "early" and those that happened "later", and compare only the initial pre-merger boundaries with the final ones. The only exception is for the "early" mergers that actually took place before our covariates were collected: for these, our dataset contains only the merged municipalities, and we thus use these in our analysis. In one case, one of these "pre-merged" municipalities in our dataset was split, with portions going to two new amalgamated municipalities. For this case, we place the entire municipality with the amalgamation that received the majority of its surface area.

at the period before the local government organization law of 1878 (*Gun kuchouson hensei hou*), and then the period after it.

N.1 Meiji Local Government, 1871-1878

After the Meiji restoration of 1868, important early objectives of the new regime included the abolition of the feudal system and the establishment of a modern administrative infrastructure. The former objective was accomplished with the mass seizure of feudal domains in 1869 (the *hanseki houkan*), and the latter began in 1871 with the *haihan chiken*, which replaced these 300+ feudal administrative divisions with a system of prefectures, governed by prefects.[97] Although central control was prioritized, these prefectures were given a certain degree of decision-making authority in order to be able to quickly respond to local conditions. Within each prefecture, the prefect and other important positions were centrally appointed, but there were also provisions for consultative bodies, including elected ones.[98]

The modern resident registration system was established as these reforms were ongoing. Under the 1871 *koseki* law, the residence of each individual was tracked by administrators at the local level. The regions covered by these administrators formed the wards and sub-wards of the "ward" ordinance of 1871.[99] Each ward was to have a head, and each of its constituent sub-wards a vice-head (*fuku-kuchou*). It is unclear whether these new wards were to replace the pre-existing local structure from the feudal period, or supplement it. Suzue [1992] provides a survey arguing for the latter, even though official source documents state that traditional local positions (*shouya*, *nanushi*, *toshiyori*) were to be abolished and replaced by the ward head and vice-head (Grand Council of State notice 117, 1872), and that the ward system established for resident registration, with its heads and vice-heads, formed the fundamental local administrative system (Grand Council of State notice 146, 1872). Regardless of the details, the system was revised almost as soon as it was in place: at an 1875 meeting (the *dai-ikkai chihoukan kaigi*) it was decided that both wards and sub-wards

[97]These prefectural boundaries were not as new as might appear: they were initially constructed by merging together historical provinces (*kuni*), whose boundaries had been generally unchanged for the past 600 years.

[98]The lowest level appointed officials, responsible for the *koseki* system discussed below, were drawn on to form one type of consultative body (the *kukochou kai*). A separate body could be constituted via elections, generally with franchise restricted to wealthy landowners (the *min kai*). According to one contemporary report, in 1875 there were 23 prefectures with the former type of body, 7 with the latter, and 19 without either (http://www.gichokai.gr.jp/hensen/01.html). These bodies continued in roughly the same form after the "three new laws" of 1878, discussed in the next section. These laws established formal limits on the remit of the assemblies: they were to deal only with matters of local taxation and expenditure, and could be dissolved by the central government. The central government was particularly concerned that decentralization could lead to factionalism and instability, and closely monitored the activities of the assemblies [Oshima 1994, p. 34].

[99]Each sub-ward was supposed to consist of 4-5 towns or 7-8 villages.

were to have leaders and vice-leaders.[100]

The wards of the ward system do not appear to have been carefully designed to reflect local cultural and geographic connections. One possibility is that the apparent lack of care given to drawing these boundaries is due to the speed with which the system was implemented. Alternatively, it may be an indicator that, notwithstanding official declarations to the contrary, the ward system was never intended to function as the main system of local governance.[101]

The authoritative description of municipal mergers during this period in Gifu is given in the *History of Gifu Prefecture*.[102] According to the 1872 Grand Council of State ordinances and some 1873 Interior Ministry directives, individual villages that had low population or limited land area were to be merged in order to prevent inefficient expenditure of public funds.[103] In discussion with the Ministry around May 1873, Prefect Yoshitsura Hasebe planned on implementing this policy in Gifu by merging those villages that did not have any inhabitants, and those that had originally been split due to manorial succession (*jitou koutai*). The Ministry, however, requested instead that a detailed survey be performed, and all villages with less than 50 koku (of assessed tax base) be merged because the burden of municipal expenditures there was too great. A survey of ward heads and vice-heads, including questions about potential mergers, was performed, and a set of mergers were carried out by 1875.[104] At the national level, however, a policy reversal had taken place, and from 1875 onwards, it was decreed that no further municipal mergers were to take place without a special reason.[105]

Turning to the public finance system, 1873 saw a reform of taxing authority under the *chiso* land tax system, which at that time accounted for a majority of national revenues. This reform changed the old in-kind tax system to a standard modern property tax: tax was to be paid in currency, at certain tax rate, on a certain assessed tax base. The tax rate was set

[100]These were to be *kuchou*/*fuku-kuchou* and *kochou*/*fuku-kochou*, respectively.

[101]Oishi [1961] and Oshima [1994] discuss how the ward boundaries did not reflect the natural boundaries of daily life at the village level. On the other hand, Tajima [1983] and Okumura [1984] provide examples of prefectures where ward boundaries did reflect traditional local divisions. According to the *gokumi hensei hou* (Grand Council of State notice 117, 1872), historical *go* (units of five households) were to be used for communication with the local populace, pointing to the inadequacy of the ward system on its own. Kato [1979] provides an example of this in Bungo (now part of Oita prefecture), as does the *Noumin seikatsu hensen* for Takizawa in Morioka prefecture (ch. 6 sec. 3.3). See also <http://www.town.minobu.lg.jp/chosei/choushi/shimobe/shimobechoushi08.pdf> (p. 659-660).

[102]around p. 222.

[103]The target villages were *chiseki kyouai* (small area) or *kokou kisyou* (small population).

[104]around p. 225.

[105]around p. 160-1. Source documents do not explain the reasons for this abrupt change. Wild speculation might suggest the following: a realization that the ward system should be replaced completely by the 1888 municipal system might lead to the conclusion that the time currently being spent on changing boundaries so as to better implement the ward system should instead be devoted to other issues.

Table 10: Local *minpi* expenditures in Ward 1, Sub-ward 4
(Kouyama and 30 other villages in Suntou county, Shizuoka prefecture)

	1875
Official vice-leader (*fuku-kochou*) salary	¥1014.000
Travel	100.600
Appearances at ward office	53.000
Writing brushes	22.695
Ink	9.420
Stationery (local paper)	23.120
“ (quality *Saduka-gami*)	37.145
“ (quality *Mino-gami*)	1.800
School	495.560
Road and bridge repair	204.720
Candles	10.280
Coal	12.915
Lamp oil	2.700
Shrine festival	86.000
Messenger wages	278.850
Weirs etc. (agricultural)	37.110
Flood prevention	63.300
Wild board abatement	6.500
Total	¥2459.706

Source: *History of Gotemba City*, p. 138-9.
Note: total should be ¥2459.715.

at 3%. Tax base was initially assessed using agricultural production data, with the objective that total tax owed under the new system should be roughly equal to that under the old system. In addition, the tax system was extended to urban areas: Takayose [2002] provides a detailed description of the new *chiso*, including its application to households in towns and cities.[106] Increased tax revenue was to be used for industrialization and militarization, major objectives of the Meiji regime.

Public finance at the local level was regarded as clearly secondary in importance to the collection of revenue for the national government. Here, the traditional *minpi*/*kyougihi* (“people’s expenditure” / “cooperative expenditure”) system was maintained: this consisted mainly of informal collections to pay for local public goods, organized and collected at the local level, with enforcement carried out through social ties rather than the legal system. Table 10 provides a breakdown of expenditures for a representative agricultural sub-ward.[107]

[106] The primary source here is Finance Ministry notice 98, June 1873.

[107] This sub-ward was located in a fairly mountainous region, as evidenced by the wild boar line item.

Table 11: Revenue and expenditure, national and local governments, 1873-78 (¥1000s)

	1873	1874	1875	1876	1877	1878
National tax	65,014	103,567	97,458	51,730	47,923	51,485
Prefectural tax	572	946	1,052	1,281	1,802	3,588
Informal tax (*minpi*)	16,238	17,467	21,339	23,436	17,785	14,212
Percentage national	79%	85%	81%	68%	71%	74%
(National) government expenditures	62,679	115,332	92,265	59,308	48,429	60,941
Official salaries	8,717	12,758	11,839	8,059	9,211	9,439
Local expenditures (*minpi*)	13,315	17,467	19,412	22,409	17,785	18,479
Prefectural tax expenditures	434	822	922	1,129	1,681	4,048
(National) government percentage	74%	79%	74%	65%	63%	66%

Source: Takayose 2000 Tables 2 and 3.

Personnel expenditures (for the vice-leader and messenger) totalled ¥1290, school expenditures ¥495, and public works (roads&bridges, weirs, and flood prevention) about ¥305. These line items made up 85% of total expenditures.

At the prefectural level, miscellaneous small taxes were used in addition to *minpi*, but informal levies remained the backbone of the system.[108] From 1872, the prefectural tax base included prostitutes, *geisha*, and other related female employment [Tomaru 2000]. From 1873 prefectures were allowed to levy a surtax on the central government tax base, but the rates that were allowed appear to be quite low.[109] Table 11 shows revenue and expenditure for national and local governments during this period: although official tax revenue for prefectural governments increased dramatically in percentage terms, overall the revenue system at the local level remained predominantly informal. The difference between the national percentage in revenue and in expenditure reflects the fact that some local expenditures were paid from national funds: we will argue that this is not relevant for the analysis in this paper, because the transfers in question are much larger at the prefectural level than at the municipal level, and in addition happen to be relatively small in the case of Gifu Prefecture.

Many aspects of the fiscal relationship between prefectures and municipalities are unclear for the early Meiji period, and sources often consider both levels of local government together. However, according to Fujita [1939], the *chiso* tax system ignored municipalities. The main assistance to local governments was through the traditional *joubikin* ("reserved funds") system, which was at the prefectural level. A fraction of taxes collected in each

[108]Officially, the official prefectural revenue sources were classified as levies (*fukin*) until 1874, and taxes (*fukenzei*) from 1875 onwards.

[109]For details, see Table 10 of Takayose [2002]: for Saitama Prefecture in 1877, *minhi* was equivalent to 55% of national taxes, but prefectural (official) taxes only 2%.

Table 12: Assistance to Prefectures (¥1000s)

	1876	1877	1878	1879
Salaries	2,453	2,703	2,823	2,699
Prisons	545	769	995	1,249
Other	711	504	295	458
Total general assistance	3,709	3,976	4,113	4,406
Public works	1,420	1,384	1,482	1,461
Maintenance	140	360	443	535
Normal schools	20	50	70	70
Elementary schools	700	425	425	361
(National) police	1,247	1,388	1,398	1,382
Prefectural police	834	1,629	1,480	1,247
Total specific assistance	4,341	5,236	5,298	5,056

Source: *Meiji zenki zaisei keizai shiryou shusei* vol. IV. This table is reproduced in Takayose 2000 as Table 35, but with the units reported as ¥ rather than ¥1000s.
Note: some totals appear to be calculated incorrectly. "Other" line item is authors' calculations.

prefecture (originally each *han*) was retained in that prefecture for local expenses, rather than being transferred to the central government.[110] The assistance provided through this system was divided into "general" assistance (*fukenhi hojo*) and "specified" assistance (*hojokin*), and a breakdown of these payments is given in Table 12. The "general" assistance paid mainly for salaries and the operation of prisons. The salaries in question were likely for personnel performing duties required by the national government, and the prisons were holding criminals convicted of violating national laws. This portion of the assistance thus corresponds roughly to a set of responsibilities delegated from the national government to the prefectures. The "specified" assistance was intended to defray expenses for specific local services. These payments, however, were not made with the objective of equalizing revenues or otherwise redistributing resources, but were instead based on a formula that considered population and the amount of agricultural production.[111] The intent thus appears to be that the assistance payments should cover a fraction of the cost of providing certain services. We will examine each of the major services in turn.

First, Table 13 shows the source of funds for prefectural police expenditures. Takayose

[110]Later on, the upper limit on this reservation system would be more strictly controlled by the central government rather than by tradition, with the limit being reduced over time.

[111]Exceptions to this formula were made for prefectures with international ports or large rivers. See, for example, Takayose [2000], p.164. The original source documents are available in the *Fuken-sei shiryou*.

Table 13: Prefectural police expenditures by source of funds, all prefectures (¥1000s)

	1876	1877	1878
Official funds	1,961	2,994	3,041
Informal tax funds	1,120	1,369	1,599
Percentage official funds	64%	69%	66%

Source: Nakajima 1915, reproduced in Takayose 2000 as Table 39.

Table 14: Prefectural police expenditures by source of funds, Gifu Prefecture

	1875	1876	1877	1878
Official funds	¥6,540.381	¥13,015.312	¥14,279.950	¥14,161.683
Informal tax funds	16,289.954	21,633.889	32,136.798	31,357.690
Percentage official funds	29%	38%	31%	31%

Source: *History of Gifu Prefecture*, Table 89.

[2000] equates "official funds" (*kanpi*) with funds from national tax revenue, and concludes that the national government is paying for over 60% of local prefectural police expenditures, with the prefectural government responsible only for about 1/3.[112] He explains that this division was formalized at an 1875 meeting, with the distribution of "official funds" to be based on prefectural population. Data shows that, across prefectures, there were substantial differences in the percentage of local funds in police expenditures. This data is shown for Gifu Prefecture in Table 14: official funds cover only 1/3 of expenditures, rather than the national average of 2/3. Source documents suggest that these differences have their origin in the formulae used, which appear to have prioritized police in major urban centers and important ports.[113] Thus, the payments to "ordinary" prefectures lacking these special features are lower than aggregate data would suggest.

Continuing, Table 15 shows expenditures on education. Here "official funds" are much

[112] Reality may have been slightly more complicated, as official prefectural tax revenue was likely included in "official funds". However, according to Oshima [1994, p. 117], this prefectural tax revenue did not exceed 1/20 of the informal *minpi* revenues, and thus Takayose's conclusions stand because the percentages he reports would not change materially with a more detailed analysis.

[113] An early source document here is Grand Council of State ordinance 16, 1883: this appears to set a national assistance rate of 60% for Tokyo, and 30% for other prefectures. This may be related to distinction in nomenclature between the police in Tokyo (*keishichou*, headed by the *keishi soukan*) and in other prefectures (*fuken keisatsu*) that continues to the present day. Takayose [2000] (p. 83) compares the funding calculations actually used, and compares them to a simpler formula based on population and surface area. He concludes that there were additional subsidies to Tokyo (450%), Kyoto (350%), Osaka (350%), Kanagawa (70%), and Hyogo (70%).

Table 15: Elementary school funding (¥1000s)

	1875	1876	1877	1878
Rollover/Savings/Interest	1,446	1,838	2,021	2,274
Informal tax	3,286	3,424	2,697	3,947
Tuition	356	393	358	362
Miscellaneous	497	501	496	485
Local tax	-	-	159	471
Official funds	609	546	449	444
Percentage official funds	9.8%	8.1%	7.3%	5.6%

Source: Chiba 1962. This is reproduced in Takayose 2000 as Table 95, but with incorrectly calculated percentages.

Table 16: Revenue and expenses, Taiseisha school

	1875
Interest	¥100
Informal tax	108
Tuition	6
Total revenue	¥214
Teacher salaries	¥57
Miscellaneous salaries	78
Books and equipment	20
Maintenance etc.	10
Total expenses	165

Source: *History of Gotemba City* vol 5, p. 304, following Tsutsui 2005.

Table 17: Prefectural public works, source of funds (¥1000s)

	1876	1877	1878
National funds	1,403	1,333	1,462
Local funds	2,595	3,221	3,913
Percentage national	35%	29%	27%

Source: *Imperial Japan Statistical Yearbook*, reproduced in Takayose 2000 as Table 40.

less important than for the police, covering less than 10% of total expenditures.[114] According to the 1872 *gakusei* education policy, local governments were responsible for providing education, notwithstanding their almost complete lack of formal tax revenue. Tsutsui [2005] provides a detailed discussion of the situation in this period in part of Saitama Prefecture. Table 16 shows revenue and expenditure for the Taiseisha school of Ward 1, Sub-ward 4.[115] The interest revenue shown is from an endowment of ¥1000, collected through "donations" that appear to have had substantial non-voluntary characteristics. The *History of Gotemba City* (p. 314) reports on the case of Hagiwara Village, where an effectively mandatory collection was made, with the amount varying between ¥100 and ¥1, depending on the "donor". The vast majority of expenditures on education were thus local in nature, and, although the details are unclear, appear to have been paid for via a proportional tax of some sort.

The third major type of prefectural expenditure was public works. The 1873 Regulations on River, Port, and Road Repair and Construction (*kakoudouro shuchiku kisoku*) established a standard division between official funds and *minpi* for these projects.[116] Table 17 shows the source of funds for prefectural public works across Japan, with only about 30% being paid for by the national government.[117]

Finally, there were administrative expenditures. Table 18 shows the breakdown in source

[114]There was a further drop in this even low level of support in 1882, with the abolition of assistance payments from the national treasury. Strong national support for schools did not begin until 1918, with the introduction of mandatory schooling.

[115]This school was the 25th school district, serving the villages of Kamado, Hagikabu, and Numata. It was built in 1874, and destroyed in a fire in 1877. During this period schools were sometimes operated by groups of villages, although mergers due to the costs of operating a school were also common. A merger was in fact proposed in this case, and would have involved four additional nearby villages, but it did not take place. Although many mergers did in fact take place during the 1870s, according to Tomaru [2000] (p. 130) these mostly involved villages with extremely small populations, and there was no general tendency toward merging in average-sized villages.

[116]A rough summary would be that the fraction of funding from official funds depended on the size of the project in question. 1st class and 2nd class projects received some official funds, but 3rd class and below received none. The system was changed in 1875, such that regular maintenance would be paid for from *minpi*, but official funds would be provided in the case of major damage. National funding continued as a

Table 18: Administrative expenditures in Gifu prefecture, source of funds

	1880	1881	1882
National funds	¥55,545	¥56,484	¥63,577
Local funds	145,232	155,023	159,582
Municipal funds	95,748	91,078	117,661
Percentage national	18.73%	18.67%	18.65%

Source: *Imperial Japan Statistical Yearbook*.
Notes: "Local funds" are defined as prefectural assembly funds, county and ward bureaucrat salaries and travel expenses, within-area messenger and billboard expenses, ward head salaries, and expenses associated with the ward head. "Municipal funds" are defined as town hall expenses and assembly expenses.

of funds for these expenditures for Gifu Prefecture. Unfortunately, there is no data available from 1879 or earlier, so the table gives the three earliest years available. National funds account for about 18% of expenditures.

As shown by the comparison between police and education above, national funds are allocated more heavily to prefectural expenses than municipal ones. Thus, national funding of administrative expenses for municipalities was likely substantially less than 18%. Overall, it appears to be a reasonable assumption that municipalities were responsible for raising their own funds to provide public services.

N.2 Meiji Local Government, 1878-1888

In 1878 the "three new laws" were promulgated, regarding prefectural administration, county and municipal organization, and local taxes, respectively. This was a major change from the previous system of local government. This subsection describes the state of local public administration during the period after these laws, up until the time of the 1888 local government act and the finalization of the Meiji municipal mergers.

At the municipal level, the ward system previously in place was generally regarded as unsuccessful, the most common complaint being that ward and sub-ward boundaries failed to accurately reflect either traditional cultural boundaries or the patterns of contemporary daily life.[118] Wards were abolished, and a system of cities, towns and villages was restored. Towns and villages were grouped into counties, which nominally also provided public services

transitional measure until 1880, but was stopped thereafter.

[117] Kobayashi [1997], for example, emphasizes the importance of the prefecture in providing public works in the case of rivers.

[118] For example, see the discussion in Ido [1969].

Table 19: Municipal revenues (¥1000s)

	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888
Property levy (*chika*)	7,311	8,502	9,235	9,508	9,529	8,791	7,546	4,891	4,594	4,728
Land levy (*hanbestu*)	684	689	1,083	1,110	1,118	883	587	261	192	176
Household levy	3,867	4,387	5,105	5,464	5,583	5,313	4,444	6,019	5,608	5,441
Business and misc. levies	713	892	988	1,324	1,012	371	364	559	595	590
Rollover and misc.	990	1,660	1,342	1,589	1,013	1,385	1,439	2,774	2,182	2,322
Percentage *chika*	53.9%	52.7%	52.0%	50.1%	52.2%	52.5%	52.5%	33.7%	34.9 %	35.7%
Percentage *chika*, Gifu				72.8%	70.9%	63.3%	64.9%	46.7%	50.3 %	50.1%

Source: *Imperial Japan Statistical Yearbook*. For Gifu, *chika* and *hanbetsu* taxes were not reported separately for 1879-81, and thus the *chika* percentage calculation is omitted for those years. Some population-based taxes were reported separately, and are omitted from this table.

with their own bureaucratic apparatus. In practice, however, expenditures at the county level were minimal, the positions that did exist may have been sinecures, and no public services appear to have actually been delivered. Counties usually only appear in period documents when used for communication, organization, or statistical purposes, and it appears that they can safely be disregarded for the purposes of this paper.

Under the new system, administrative boundaries were revised to reflect traditional divisions. The position of head (*kochou*) became a quasi-elected office, and in the view of Oshima [1994] the position was now likely to be occupied by the most powerful members of the village.[119]

The new municipal system was implemented beginning in 1880, and, while it was a substantial improvement on some dimensions, it also resulted in new problems. In Gifu, 24% of villages had 50 households or fewer, and another 36% had between 50 and 100.[120] Establishing a modern administrative infrastructure using units of this size appeared to be a challenging undertaking at best.[121]

For local public finance, a new local tax system was defined, including in particular a

[119]The Interior Ministry itself reports the situation with a slightly different emphasis, stating that the head is an official located below the prefect and (county) head in the administrative hierarchy, and needs to be closely monitored to ensure that they carry out their duties faithfully (notice 80, 1878).

[120]There were even some villages with fewer than 10 households. Details are provided in the *History of Gifu Prefecture*, Table 81.

[121]For example, in 1879 the prefectural assembly decided that all villages should have a village assembly, with 10 members in the case of villages of less than 200 households (*History of Gifu Prefecture*, p. 402). This was later revised downwards to 6 members, for villages of 300 households or less. Considering the costs of communication and travel given in Table 10, it seems that small villages faced a high per capita financial burden. A separate issue is whether there would even be 6 motivated householders present in a smaller village.

Table 20: Prefectural household levies, Urawa office, Saitama Prefecture (1881)

	Total Levy (¥)	Households	Levy per Household (¥)
1st class	10.00	5	2.00
2nd	14.00	10	1.40
3rd	16.80	14	1.20
4th	57.00	57	1.00
5th	47.00	59	0.80
6th	22.80	38	0.60
7th	122.40	306	0.40
8th	12.30	41	0.30
9th	28.00	140	0.20
10th	30.30	202	0.15

Source: *History of Urawa* vol. 3, p. 59. Reproduced by Takayose 2002 as Table 38.

newly created formal tax base at the prefectural level. No substantial change was made at the municipal level, though, with the traditional *minpi* system left in place [Fujita 1939].[122] Municipalities used a variety of methods to collect necessary funds, but, as shown in Table 19, the most important sources were the levy on property, and the levy on households. This property levy was strictly proportional, in the sense that it was collected as a percentage of the assessed tax base for the national *chiso* land tax. To avoid overtaxation, the ability of municipalities to collect levies on the *chiso* land tax base was restricted after 1885, resulting in a rise in the relative importance of household levies. The relative importance of tax bases varied substantially across prefectures.[123] The property levy appears to have been particularly important for municipalities in Gifu, making up half of collections even in later years. As the property levy was proportional, the proportional tax rate model used in this paper is thus particularly appropriate in the case of Gifu.

[122] A rough translation of the government transcript in Ogasawara [1878] would read "with respect to municipal expenditures, these are the responsibility of the residents of each municipality, are not categorized as local taxes, and the collection methods are thus not stated in the regulations regarding local taxation" (quoted in Oshima [1968]). As reported in Oshima [1994], Article 3 of the Local Tax Regulations states that necessary funds for each municipality are left as a matter for the municipal residents to resolve "cooperatively", and further implementation directives clarified that municipalities were free to use all traditional means to collect revenues, including levies on households and property. There was no further government interference until 1884, when in a further reform *kyougihi* ("cooperative funds") were relabeled as *chousonhi* ("municipal funds").

[123] Takayose [2002] examines six prefectures in the Tohoku region, and compares the revenue raised by other levies to that raised by land levies. In all prefectures land levies are the most important, with revenue from other levies equalling 96% (Fukushima), 78% (Miyagi), 75% (Iwate), 74% (Aomori), 44% (Yamagata), and

Table 21: Municipal household rates, Hyogo Prefecture (1880)

	Total Levy (¥)	Households	Levy per Household (¥)
1st class	2.00	5	0.40
2nd	3.85	11	0.35
3rd	6.00	20	0.30
4th	4.50	18	0.25
5th	5.40	27	0.20
6th	3.45	23	0.15
7th	1.20	12	0.10
8th	0.65	13	0.05
unclassified	0	3	excluded

Source: *History of Tatsuno* vol. 3, p. 46. Reproduced by Takayose 2002 as Table 39.

Table 22: Prefectural household levies, Tsuyama Town, Okayama Prefecture (1908)

	Households	Levy per Household (¥)	CDF
1st class	1	¥67,000	2%
2nd	3	59,000	8%
3rd	1	52,000	10%
4th	2	44,000	12%
5th	6	37,000	20%
6-10th	23	19,496	34%
11-15th	98	5,305	51%
16-20th	372	1,851	73%
21-25th	531	833	87%
26-30th	1072	268	97%
31-33rd	1371	78	100%
exempt	4		

Source: Sakamoto 1975, Table 13.

The most important source of funds other than the property levy was the household levy. This is sometimes viewed as a sort of (informal) poll tax; however, the literature dealing with this levy shows that this is clearly not the case, and a degree of proportionality was also used in assessing this levy.[124] Tables 20 and 21 show examples of the amounts collected via the household levy at the prefectural level and municipal level, respectively. In both cases, the amount collected from a household varies according to the classification of the household, which appears to have depended on the resources that each household had available.

According to Kashiwagi [1999], these classifications were done in an *ad hoc* manner, by the head and other powerful members of the village, and thus may have been devised to benefit the privileged. Circumstantial evidence for this can be seen by examining a later tax table of the same form, shown in Table 22. The amounts in this table, from 1908, are such that the richest tax payer is paying approximately 860 times as much tax as the poorest. In contrast, Tables 20 and 21 show the richest tax payer paying about 10 times as much tax as the poorest. Although there may have been an increase in inequality between 1880 and 1908, and the table from 1908 deals with a much larger population, it seems likely that the earlier tables are not equivalent to a strictly proportional tax on a certain tax base, but have rather been set such that wealthier households pay less tax in percentage terms. This is also likely given the electoral rules in place for municipalities. The franchise was restricted to taxpayers, with wealthier ones receiving greater representation, as will be discussed later.

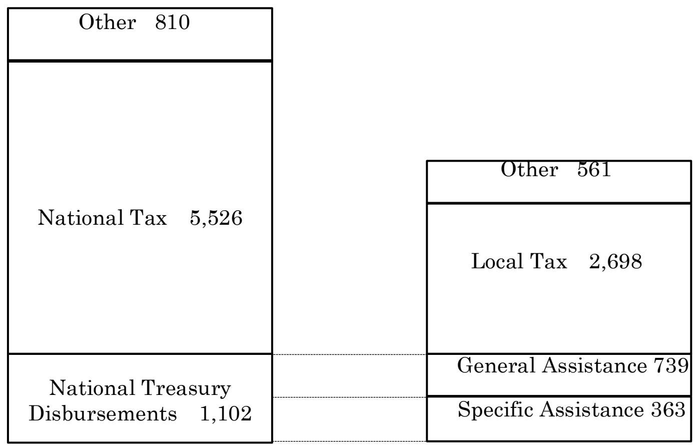
Intergovernmental transfers continued to be of minimal importance at the municipal level. Figure 25 shows the source of funds for expenditures at the national and local level in 1880. "General assistance" here corresponds to the salaries of certain personnel, the cost of collecting taxes, and certain other functions delegated from the national government to local governments. "Specified assistance" mainly consists of payments related to the construction of public works, such as the maintenance of major roads or recovery efforts after disasters [Oshima 1968, p. 88-89]. Both the general and specified assistance payments were related to the amount of work performed by the local government, rather than the availability of local taxes to fund this work. In particular, there was no intent to have the assistance payments act as equalization payments.[125]

41% (Akita) of the revenue raised from land levies.

[124] There is some debate regarding whether the tax took into account extenuating circumstances of individual taxpayers or not, with Takayose [2002] quoting Shukuri [1895] in support of the former position, and Minobe [1895] the latter. According to Mizumoto [1991], the calculation of levies was left at the discretion of each municipality, and seem to have been often decided as a *prix a la tete* (*mitatewari*). Further complicating the situation, there were some cases in which a poll tax *was* used: according to Takayose [2002], Saitama and Kanagawa Prefectures had such a system near the end of the 1870s.

[125] Takayose [2002] states that "despite the increasingly clear differences in economic strength between

Figure 25: Source of funds for national and local governments (1880) (¥1000s)



Source: Takayose [2002] Figure 4.

Table 23: Municipal expediture by type (¥1000s)

	1882	1883	1884	1885	1886	1887	1888
Public works	6,382	5,473	4,039	3,672	3,135	3,336	3,282
Hygiene	794	699	656	453	704	496	480
Industrial promotion	116	110	199	247	296	323	432
Town hall / administration	2,690	2,718	2,672	2,304	2,526	2,916	3,092
Assembly	541	485	252	154	180	197	200
Education	6,568	7,142	7,729	6,095	6,153	4,475	4,492
Emergency assistance / misc.	1,600	1,326	657	634	688	751	720
Total	18,690	17,953	16,204	13,559	13,682	12,495	12,700

Source: Calculated from municipal expenditure data in *Japan Statistical Yearbook*.

Table 24: Public education, source of funds (¥1000s)

	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888
Rollover/interest	2,274	2,480	2,376	2,395	2,061	1,855	1,477	1,406	1,201	1,401
Donations/misc. taxes	1,075	993	1,187	922	941	881	583	438	656	966
Informal levies (*kyougihi*)	3,356	3,581	4,453	6,037	6,988	6,850	6,961	5,501	4,146	3,971
Tuition	362	376	404	470	521	523	450	669	1,465	1,994
Local tax	471	823	1,069	1,309	1,504	1,534	1,536	1,401	1,274	1,197
Ministry of Education	444	470	203	-	-	-	-	-	-	-
Percentage informal levies	42.1%	41.1%	45.9%	54.2%	58.2%	58.8%	63.2%	58.4%	47.4%	41.7%
Percentage local tax	5.9%	9.4%	11.0%	11.8%	12.5%	13.2%	14.0%	14.9%	14.6%	12.6%
Percentage user fees	4.5%	4.3%	4.2%	4.2%	4.3%	4.5%	4.1%	7.1%	16.8%	20.9%

Source: Calculated from public education revenue data in the *Japan Statistical Yearbook*.

As in the 1870s, there continued to be only a very thin relationship between the national government and the municipalities. The transfers that did exist were mainly made by the prefectures. Table 23 shows the distribution of spending by municipalities in this period. Education and public works continue to be the most important line items. In both of these cases, the data shows that contributions from higher levels of government were relatively small.

Table 24 shows the source of funds for local public education. “Local tax” (i.e. prefectural tax) accounts for about 15% of expenditures, whereas informal taxes at the municipal level account for 50%. In addition, as in Tables 15 and 16, endowment interest is an important source of funding, and this generally has an original source within the municipality. While there was a small amount of direct national government funding until 1881, from a quantitative standpoint education was predominantly funded at the municipal level.[126]

The situation with public works was not as extreme as that with education, but the predominance of local revenue sources is still clear. Local tax regulations during this period eliminated national treasury payments for work funded by local taxes, thus making a clear distinction between projects undertaken by a local government, and those controlled directly by the national government.[127] Officially, local governments also had some financial responsibility for national government controlled projects in their jurisdiction, but Table 25 shows that these payments were in fact minimal. Effectively, the national government

regions in the 1880s, there was almost no equalization of government fiscal resources.” He further notes that there is actually a positive correlation between per capita local tax revenue and per capita assistance payments during this period.

[126]The sharp increase in tuition near the end of the table is due to a change in government policy.

[127]National government controlled projects were generally major roads, bridges, and other large-scale basic infrastructure. The national government also directly controlled maintenance once projects were completed.

Table 25: Public works, source of funds (¥1000s)

	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888
National assistance	1,471	2,278	338	739	1,034	1,246	2,156	1,808	1,983	1,748
Local expeditures	4,640	5,231	7,691	8,717	8,215	7,827	8,026	8,399	7,802	8,160
Percentage national	24.1%	30.3%	4.2%	7.8%	11.2%	13.7%	21.2%	17.7%	20.3%	17.6%
(Directly controlled)										
National treasury	208.2	133.4	119.6	248.2	331.0	460.9	514.2	307.2	810.2	741.0
Local tax	3.6	2.5	6.9	7.4	9.5	11.9	0.5	2.0	2.6	0.6
Percentage national	98.3%	98.1%	94.5%	97.1%	97.2%	97.5%	99.9%	99.4%	99.7%	99.9%

Source: Calculated from Takayose 2002 Table 58.

built certain public works by itself, and the remainder became the responsibility of local governments. The data in Table 25 reports an average of about 20% of funds for projects coming from the national government, but this figure includes projects directly controlled by the national government. The fraction of national funding for local government controlled projects is thus even less than this. Although detailed figures do not appear to be available, prefectural funding for municipal projects appears to have roughly the same structure as national funding for local projects.[128] In both cases, projects were funded by the higher-level government based on the characteristics of the project in question, rather than the ability of the lower-level government to pay for it. There was thus neither a *de facto* nor *de jure* equalization system in place in Meiji Japan.

N.3 Meiji Municipal Mergers

The literature on municipal mergers in Meiji Japan is voluminous but consists almost exclusively of case studies. We review this literature, with particular attention to the apparent incentives for these mergers.

Ido [1961] examines municipal mergers in Shiga Prefecture in 1873-4, and divides the reasons for the mergers into three groups:

A To improve existing administrative boundaries that were unclear. (90 cases)

B Agricultural land and population were too limited to expect the municipality to be able to manage itself independently. (70 cases)

[128] Matsuzawa [2009] (ch. 6) reports on the situation in Saitama Prefecture as an example. In 1880, public works regulations passed by the prefectural assembly restricted prefectural funds to only the construction of bridges for national roads. However, in 1883, according to Directive 99, funding could be used for the construction and maintenance of other bridges and roads as long as there were a public benefit. Municipalities could apply through their county office, which would investigate and forward the results to the prefectural government, which would evaluate the applications.

C Unclear. (86 cases)

Even in the (A) cases, there appears to have been underlying fiscal reasons for the mergers as well, relating to the reform of the *chiso* land tax system and expenses incurred performing certain functions delegated by the national government. According to Tanabe [1963], in addition to the *chiso* reforms, the end of the 1880s saw an increase in expenditure requirements for public schooling.[129]

Oguri [1953] examines correspondence between municipalities and the prefect of Saitama regarding undesired municipal mergers, and groups local opinions into the following categories:[130]

C Unclear. (6 cases)

D Inability to agree on a name for the amalgamated municipality. (31 items)

E The municipal merger group is inappropriate from the perspective of water (for irrigation). (30 items)

F There is opposition to the merger due to the "condition of the people". (76 items)

All these reasons can broadly be categorized as "heterogeneity related", with the water issues directly related to geological or geographic differences, and the inability to agree on a name due to historical differences. The last item is likely a euphemistic description of issues regarding social class, possibly including cases where some lower caste (*burakumin*) residents were to be added to an amalgamated municipality.[131]

Nakamura [1953] investigates the official 1889 merger report in Fukuoka Prefecture, and finds geographic considerations predominate:

G In mountainous areas, mountain ridges and rivers were generally used as boundaries.

H Rather than merging both banks of a river watershed, mergers concentrated on cases where (irrigation) ponds and weirs were being used cooperatively by upstream and downstream villages.

[129] The example given is that of Niita Village, in Tochigi Prefecture.

[130] For the purpose of counting items, any item of correspondence that refers to water issues appears to be categorized as such, even if it also mentions other issues. Thus, the relative importance of water may be overstated.

[131] Oguri [1953] also offers as a specific example a case that suggests a slightly different model. In Chichibu County, Saitama, it was difficult to agree on an allocation of public funds between a flat area involved in paddy rice production, and a more mountainous region involved in coal, silk, forestry, and manufacturing. A municipal merger would thus be inappropriate, according to period documents. This case suggests a more complicated model, as it involves differences in spending over public goods, and likely types of public goods, whereas the model used in this paper involves only a single public good provided at a fixed quantity.

I Discrimination and differences in occupation led to difficulties in carrying out mergers.[132]

Of these reasons, the first and last points can easily be thought of as heterogeneity, although the second point suggests that there may also have been some benefit from the internalization of externalities regarding irrigation facilities.[133]

Tanabe [1963] offers the following reasons for concerns about mergers:

J Different feudal lords, different tax rates, different traditions.

K Conflict over village financial resources.[134]

L Discriminated-against *buraku*.

Regarding the last point, Ido [1961] considers cases in Shiga Prefecture, and finds that in most cases where a merged municipality subsequently split, *buraku* split off (or perhaps, were split off) from other areas. In more recent research, Ioka [2000] examines the case of a separatist movement in Taishou Village in Nara Prefecture (now Gose City), and shows that this was related to discriminated-against *buraku*. Ioka (in his Table 2) compares different parts of the village (at the *oaza* level), and finds that the household levy for discriminated-against areas is remarkably low. This difference may have been due to basic differences in income and occupation, but calls for "equality" in paying for public services appears to be one of the causes of municipal partition.

Yamada [1966] looks at the example of Yoshino (*yoshino-gou*) in Nara Prefecture, and finds that

M (Forestry) resource royalties made mergers difficult.[135]

According to Yamada's Table 4, in 1891 these royalty revenues made up 65% of all revenues in Kawakami Village. As any merger would have led to sharing this revenue stream, and thus a reduction in per capita revenues, mergers tended not to be popular with villages receiving this sort of revenue.[136]

[132] Nakamura offers an example where an area consisting of the descendents of samurai was unwilling to merge with another area.

[133] See Appendix D for further discussion of externalities.

[134] This refers to *iriai*, cooperatives that controlled communal resources such as forest. An example was given of Uenohara forest, control of which was split across 13 different villages, and in 1876 served as an impediment to municipal mergers.

[135] This royalty system was established in 1871, and officially named *kaisankin* in 1876. There is also some evidence for benefits from the internalization of externalities, particularly with respect to common natural resources and irrigation infrastructure. Taking account of this, however, would require a substantially more complicated model. We thus ignore this benefit from mergers in this paper. See also Appendix D.

[136] Although this is a separate revenue stream from property taxes, and thus is not captured exactly by the model used in this paper, it fairly clearly corresponds to the case where there is a richer municipality that is unwilling to merge with a poorer one.

Finally, Morishima [1973] looks at Hiyoshi Village in Kyoto Prefecture, finding that

N Communal forest and pasture acts as a financial resource, and appears to encourage the areas that possess it to engage in separatist activity

Overall, the literature regarding the Meiji municipal mergers appears to provide evidence for the following costs and benefits of mergers:

1. Efficiencies of scale, including those in land taxation, education, roads and bridge repair, irrigation, flood prevention, and communication with higher levels of government. Merging with closely connected municipalities allowed for economies of scale in these areas to be exploited.

2. Difficulties when merger partners differ in production activities (e.g. paddy rice vs. dry rice vs. forestry), possibly due to difficulties setting rules for taxation. Similarly, differences in geography, occupation, or income.[137] Also, differences in class (former samurai, *burakumin*) and differences in formal feudal lord. Access to particular additional revenue from, for example, forestry, also makes merging with other municipalities more difficult.

Finally, in the case of the Meiji mergers, it was difficult for municipalities to merge in the case where the amalgamated municipality would have a very large surface area. In mountainous regions, this would result in excessively difficult travel within the municipality itself, as mountain ranges would need to be crossed. This could lead to additional expenses or, alternatively, could be thought of as causing non-pecuniary difficulties related to heterogeneity. In the case of flat agricultural land the difficulties appear mainly to be due to differences in the resources held by different portions of a potential amalgamated municipality, or alternatively differences in the sort of irrigation needed. For a variety of reasons there appears to thus have been an upper limit on land area in an amalgamated area.

N.4 Franchise Rules

Under the new municipal laws, the electorate in cities was divided into three classes, and that in towns and villages into two. The total number of seats in the council was determined by municipal population (art. 11, *shi-sei*). The franchise was restricted to men at least 25 years old, paying more than ¥2 in *chiso* tax or direct taxes to the national government. The electorate was divided according to the amount of tax paid (art. 12, *shi-sei*).

[137] Here it is difficult to determine what is the ultimate cause, as differences in geography might tend to lead to differences in occupation.

Table 26: Election franchise weights, Takamastu City, Kagawa Prefecture (1890)

	First class		Second class		Third class	
Total tax paid by voters		¥1113		¥1114		¥1110
Election Day	18 March 1890		16 March 1890		14 March 1890	
	Name	Votes	Name	Votes	Name	Votes
(10 seats per class)	1-a	48	2-a	161	3-a	316
	1-b	45	2-b	150	3-b	249
	1-c	37	2-c	110	3-c	246
	1-d	37	2-d	97	3-d	240
	1-e	34	2-e	92	3-e	212
	1-f	33	2-f	88	3-f	204
	1-g	31	2-g	77	3-g	197
	1-h	30	2-h	71	3-h	192
	1-i	29	2-i	70	3-i	191
	1-j	29	2-j	59	3-j	190
Total votes		353		975		2237
Total voters		72		n/a		691
Electorate size		83		264		1119
Turnout		86.7%		n/a		61.8%

Source: calculated from Nishiyama 2007, Table 3.

Table 27: Municipal Franchise, Tsuyama Town, Okayama Prefecture (1908)

Tax classification	Number elected
1-5th class	2
6-10th	3
11-15th	11
16-18th	8
19-33rd	3

Source: Sakamoto 1975, Table 15.

Figure 26: Predicted and actual Standard Fiscal Need, Heisei data

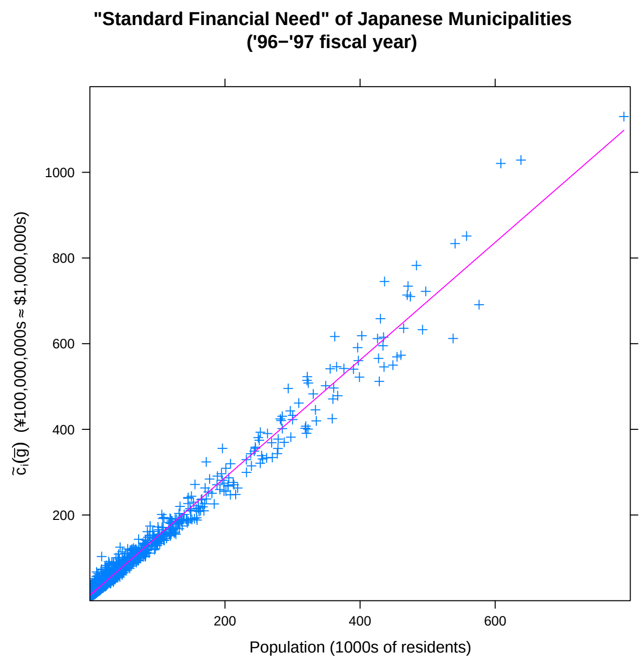


Table 26 shows the divisions of the electorate in Takamastu City. The number of seats assigned is directly proportional to the amount of tax paid. If, as previously argued, taxation is proportional, then the electoral power is also proportional to tax base. This provides justification for the modelling choice of weighting players by their tax base in the social planner's utility function, as these are the weights that appear to be accorded to individuals in the elections in this period.[138]

[138]Table 27 shows the situation in Tsuyama, Okayama, in 1908. This table (combined with the population data from Table 22) shows unequal electoral results in the municipality that implemented the comparatively progressive tax scheme of Table 22. It thus seems likely that either the franchise was even more skewed in the earlier period, or some regulations were put in place during the later period to require a roughly proportional tax system. Kashiwagi [1999] describes the municipal tax system during this period as one characterized by "arbitrariness and compassion". Within a village, the rich and poor were connected in many ways other than the tax system, and thus, even if it were possible, it may not have been in the interest of the elite to tax the less fortunate at an extortionary rate.

Table 28: Dependent variable is cost of providing services ('96-'97 fiscal year)

	I	II	III	IV	V
(Intercept)	1294.6	808.4	834.3	792.2	902.7
	(23.0)	(24.4)	(25.2)	(27.1)	(21.2)
POPULATION	136.4	136.0	136.6	142.3	142.5
	(0.3)	(0.3)	(0.3)	(1.7)	(1.3)
AREA		4.3	3.6	3.8	2.9
		(0.1)	(0.1)	(0.1)	(0.1)
INCOME.INEQ		0.04	0.03	-20.9	-12.4
		(4.8)	(4.9)	(4.3)	(3.3)
INCOME		-1070.4	-779.8	-164.9	-483.4
		(69.0)	(104.3)	(69.1)	(79.8)
IS.CITY		324.1	369.8	-16.2	295.4
		(54.9)	(54.2)	(59.2)	(48.1)
POP * INCOME.INEQ				1.1	0.2
				(0.1)	(0.1)
POP * INCOME				-30.5	-8.6
				(1.0)	(1.5)
POP * IS.CITY				5.4	-1.7
				(2.2)	(1.7)
PREFECTURE			X		X
N	3220	3216	3216	3216	3216

Units: ¥1,000,000 (roughly $10,000) per year. POPULATION is in thousands of residents, AREA is in square kilometers, INCOME is in ¥1,000,000 per capita per year, INCOME.INEQ is the coefficient of variation of income, IS.CITY is a dummy variable coded as 1 if the municipality in question is a city, and zero if it is a village or town. PREFECTURE is a set of dummy variables for each of the 47 prefectures, with the restriction that the sum of the coefficients on these variables must equal zero. Designated cities and special wards are excluded from the regression because they have additional responsibilities devolved from the prefectural governments, and thus have higher (and non-comprable) expenditures per capita.

Table 29: Dependent variable is cost of providing services

	96-97	06-07
(Intercept)	899.9	582.2
	(43.9)	(59.5)
POPULATION	129.4	131.5
	(0.5)	(0.6)
AREA	4.6	4.6
	(0.2)	(0.2)
N	1194	1194

Units: ¥1,000,000 (roughly $10,000) per year. POPULATION is in thousands of residents, AREA is in square kilometers, designated cities and special wards are excluded as in Table 28. The sample is further restricted to those municipalities that did not participate in a merger in order to have the same sample in both periods. Thus, the change in coefficients represents a change in national government transfer policy on the same group of municipalities during the period in question. Inflation during this period was negligible.

O Post-Meiji Municipal Mergers

The comparison of Figure 3 and Figure 4 suggests that perhaps the model developed in this paper, although intended for the data from the Meiji period, could be used to perform a more general analysis of municipal mergers in Japan. Since the beginning of the modern municipal system described in Appendix N, there have been three waves of mergers: Meiji, Showa, and Heisei. The Meiji mergers were centralized. The Heisei mergers were decentralized, with the national government offering a specific set of financial incentives (including both a "carrot" and a "stick") in order to encourage municipalities to merge.[139]

The Showa mergers, however, appeared to have characteristics of both centralized and decentralized mergers. There was substantial involvement of higher levels of government, both national and prefectural. At the prefectural level, committees drew up formal merger plans for the entire prefecture.[140] On the other hand, the final mergers had to be approved at the municipal level. One interpretation of this is that the municipal approval was mere window dressing, and municipalities could not refuse to participate in the national government plan. Our simulation results suggest another potential explanation for the seemingly

[139] For a recent discussion of the Heisei mergers in the domestic literature, see Machida [2006]. The general consensus appears to be that mergers occurred democratically, subject to the financial incentives. The "stick" portion of the national government funding formula change in particular appears to have led many small municipalities to participate in mergers. This qualitative discussion agrees with the theoretical results in Weese [2015] regarding when the "stick" should be used.

[140] In the case of Aomori Prefecture, these plans were actually based on a formal matching model, complete with a payoff structure and an approximation algorithm.

contradictory "both centralized and decentralized" nature of the Showa mergers.

As documented in Appendix N, during the Meiji period there were effectively no transfers from the national government to municipalities, and only extremely limited assistance from prefectures. This allows for the simple model developed in Section 2. After World War II, however, the Shoup Report commissioned by occupation forces recommended revisions to the municipal finance system. This resulted in the *Heikou Koufukin* (later renamed the *Chihou Koufuzei*), a transfer system that would eventually grow to enormous size. Two stylized facts regarding this transfer system are important: during the Showa period, it was widely considered to provide inadequate equalization for capital costs, while in the Heisei period capital costs were seen as overstated, and the system was seen instead as providing inadequate equalization for larger cities.

A stylized version of the transfer system in place throughout the post-war period is that it is based on lump-sum transfers.[141] Previous analysis shows that these transfers can be modelled as a fixed plus variable amount: this is directly related to the fact that the cost of providing services can be modelled in this way. Thus, rewrite the budget constraint of Equation 2 as

$$(\gamma_1 - T_1) + (\gamma_2 - T_2) \sum_{i \in m} p_i = \tau_m \sum_{i \in m} y_i \tag{36}$$

where T_1 is the fixed transfer amount, and T_2 the variable transfer amount, depending on the amount of municipal services that need to be provided. In Equation 36, a transfer scheme of this sort, from the perspective of the municipalities, is equivalent to a change in the fixed and variable costs to

$$\begin{aligned} \tilde{\gamma}_1 &= \gamma_1 - T_1 \\ \tilde{\gamma}_2 &= \gamma_2 - T_2 \qquad (37) \\ & \qquad\qquad (38) \end{aligned}$$

Thus, to simulate the results that would occur in a decentralized set of mergers with a certain equalization transfer scheme, we need only to change the parameters γ_1 and γ_2 to $\tilde{\gamma}_1$ and $\tilde{\gamma}_2$ when running the decentralized simulations, but then retain the original γ_1 when calculating the optimal partition from the perspective of the social planner.[142] We can thus ask what the effect of an equalization system of various sorts might have been on municipal mergers,

[141] The details of the system are quite complicated, and subsidies were also present. The appendix of Weese [2015] provides a brief English-language description.

[142] For calculating the socially optimal partition, γ_2 is irrelevant, as discussed above. It matters in the decentralized case because higher variable costs will result in greater tax payments and thus more interest in finding merger partners with substantial tax bases but few people to consume services.

by asking what the core of the decentralized coalition formation game would look like under different parameters for the cost function.

We first consider the case where the variable cost is fully subsidized: $c(P) = \gamma_1$ for all populations P. This is a situation often considered in the theoretical literature, and corresponds very roughly to the case of the equalization payments in the Showa period. Column V of Tables 7 and 8 show that in this case the number of mergers is very close to that of the social planners optimal partition, and there is very little inefficiency. This result provides a potential explanation for the contradictory nature of the Showa mergers, which were apparently both centralized and decentralized at the same time.[143] With an equalization system of the sort in place during the Showa period, decentralized coalitions were very similar to those that the social planner would have selected. Thus, during the Showa period, there was close to no contradiction between the centrally planned merger pattern, and one that municipalities would have wanted to carry out.[144]

Now, consider a transfer scheme of the sort in use in the Heisei period. As documented by DeWit [2002] and others, the transfer system by this point had changed into one that was exceedingly generous with respect to capital investments, which were large for smaller municipalities, but did not really adequately compensate municipalities for the variable costs incurred. The extreme case of such a transfer scheme would be one in which the fixed cost is completely subsidized, in which case no players would be interested in any mergers in the decentralized case. In order to cause decentralized mergers to occur, the national government offered a set of financial incentives, both rewarding those municipalities that chose to participate in mergers, and penalizing those that did not. In an extremely rough sense, these incentives correspond to municipalities becoming responsible for a portion of the fixed cost. We calculate the fraction of the fixed cost based on a simplification of the calculations in Weese [2015]. Table 28 shows that the transfers during this period correspond roughly to the fixed cost plus variable cost system in place since the Showa period. Table 29 shows that the changes in the transfer system during the merger period, designed to provide incentives for merging, correspond roughly to a decrease in transfers of a lump sum of about

[143] Tanaka and Kadotami [1963] summarizes the view of the Showa mergers as centralized, citing Kawaguchi [1960b], Kawaguchi [1960a], Kawaguchi [1961], Oshima [1958], Oshima [1959], and Fukutake [1959]. Steiner [1965], however, gives a case study where local politics played a key role in the merger process. More recent research includes Ichikawa [2011], who emphasizes the importance of both local governments and the national government in the merger process, and Arakaki [2010], who argues that the large number of municipal splits is evidence of central control.

[144] One might imagine, for example, the central planner began by creating a partition. This was either then modified to ensure that it corresponded to a core partition, or (more likely, given the anecdotal evidence) the small number of reluctant municipalities were bludgeoned into accepting the proposed partition, even though blocking coalitions existed. An explanation of this sort does not appear anywhere in the literature, but instead arises from the simulations performed based on the model in this paper.

¥300 million per municipality, but the transfer corresponding to the variable cost component did not change. The merger "incentive" thus corresponds to roughly a third of the fixed cost, as the remaining two thirds was subsidized by the transfer scheme. Column VI of Table 7 and 8 thus reports the case with municipalities considering a cost equal to only one third of the fixed cost.[145]

[145] This approach is a simplification based on the analysis of the transfer system in Weese [2015].

References

Aitken, Robert (1977). "The Wilderness Areas in Scotland." PhD Thesis. University of Aberdeen.

Arakaki, Jiro (2010). "The formation process of the municipal amalgamation policy". 16:65–80. [In Japanese].

Barros, Ana Isabel (1998). *Discrete and Fractional Programming Techniques for Location Models*. Dordrecht; Boston: Kluwer Academic Publishers.

Berry, Steven and Ariel Pakes (2007). "The Pure Characteristics Demand Model". *Int. Econ. Rev.* 48 (4):1193–1225.

Bixby, Robert E. (2012). "A Brief History of Linear and Mixed-Integer Programming Computation". *Doc. Math.* Extra Volume ISMP:107–121.

Carroll, Raymond J. and Peter Hall (2004). "Low Order Approximations in Deconvolution and Regression with Errors in Variables". *J. R. Stat. Soc. Ser. B Stat. Methodol.* 66 (1):31–46.

Chiba, Masaji (1962). *Gakku Seido No Kenkyū : Kokka Kenryoku to Sonraku Kyōdōtai*. Tōkyō: Keisō shobō.

DeWit, Andrew (2002). "Dry Rot: The Corruption of General Subsidies in Japan." *J. Asia Pac. Econ.* 7 (3):355–378.

Dinkelbach, Werner (1967). "On Nonlinear Fractional Programming". *Management Science* 13 (7):492–498.

Fan, Jianqing (1991). "On the Optimal Rates of Convergence for Nonparametric Deconvolution Problems". *The Annals of Statistics* 19 (3):1257–1272.

— (1992). "Deconvolution with Supersmooth Distributions". *The Canadian Journal of Statistics / La Revue Canadienne de Statistique* 20 (2):155–169.

Fontanari, Steno (2000). "Sviluppo di metodologie Gis per la determinazione dell'accessibilità territoriale come supporto alle decisioni nella gestione ambientale". Università degli Studi di Trento.

Fox, Jeremy T. (2010). "Identification in Matching Games". *Quant. Econ.* 1 (2):203–254.

Fujita, Takeo (1939). "Fuken Zaisei Seido no Seiritsu: Meiji 10 nen no Chihouzei Kisoku wo Chuushin toshite". - - 49 (3):487–502.

— (1955). *Nihon Chihou Zaiseiron*. Revised ed. Touyou Keizai Shinpousha.

Fukutake, Tadashi (1959). *Nihon sonraku no shakai kōzō*. Tōkyō: Tōkyō Daigaku Shuppankai.

Grenander, Ulf (1981). *Abstract Inference*. New York: Wiley.

Horowitz, Joel L. (1992). "A Smoothed Maximum Score Estimator for the Binary Response Model". *Econometrica* 60 (3):505–531.

Ichikawa, Yoshitaka (2011). "Japan's Municipal Mergers in Showa and Heisei Era : A Comparison of Two Government-Led Merger Promotion Policies". *Doushisha Hougaku* 63 (1):331–353. [In Japanese].

Ido, Shozo (1961). "Shiga-Ken Niokeru Kusei to Meiji 6-12 Nen No Chouson Gappei". *Jpn. J. Hum. Geogr.* 13 (5):432–439.

— (1966). "Some Notes on the Changing Process of Village Territories in the Early Meiji Era:The Case Study on Nagano and Yamanashi Prefectures". *Jpn. J. Hum. Geogr.* 18 (4):364–384. [In Japanese].

Ido, Shozo (1969). “A Study on the Local Government and the Amalgamation of Towns and Villages in the Early Meiji Era”. *Jpn. J. Hum. Geogr.* 21 (5):481–505. [In Japanese].

Ioka, Yasutoki (2000). “Taishouki No Chouson Gappei to Buraku Mondai: Nara-Ken Minamikatsuragi-Gun Taishou-Mura Bunri Undou Wo Chuushin Ni”. *Kenkyuu Kiyou Nara Prefect. Cent. Hist. Rec. Discrim.* (7):43–74.

Kashiwagi, Atsushi (1999). “The Social Construction of the Sharing of Educational Expenses in Rural Communities. As a Case in Point : The Transition Process of Educational Expense Burden in a Village in Saitama Prefecture.” *Jpn. J. Educ. Res.* 66 (2):173–182. [In Japanese].

Kato, Yasunobu (1979). “Meiji Shoki Niokeru Chihou Gyousei Seido: Daiku to Shouku Sei Shita No Bungo”. *Oita-Ken Chihou Shi* 92:43–66.

Kawaguchi, Akira (1960a). “Chouson Gappei to Nouson-1-”. *Q. J. Agric. Econ.* 14 (1):1–27.

— (1960b). “Chouson Gappei to Nouson-2-”. *Q. J. Agric. Econ.* 14 (4):117–166.

— (1961). “Chouson Gappei to Nouson-3-”. *Q. J. Agric. Econ.* 15 (3):35–77.

Kneip, Alois, Léopold Simar, and Ingrid Van Keilegom (2015). “Frontier Estimation in the Presence of Measurement Error with Unknown Variance”. *Journal of Econometrics* 184 (2):379–393.

Kobayashi, Kazumi (1997). “A Study on the Public Works of the KAKOGAWA River in the Early 20th Century”. *Mem. Osaka Kyoiku Univ. II Soc. Sci. Home Sci.* 46 (1):33–50.

Langmuir, Eric (1984). *Mountaincraft and Leadership: A Handbook for Mountaineers and Hillwalking Leaders in the British Isles.* Edinburgh: Scottish Sports Council.

Machida, Toshihiko, ed. (2006). *Heisei daigappei no zaiseigaku.* Tōkyō: Kōjinsha.

Manski, Charles F. (1975). “Maximum Score Estimation of the Stochastic Utility Model of Choice”. *J. Econom.* 3 (3):205–228.

Matsuzawa, Yūsaku (2013). *Chōson gappei kara umareta Nihon kindai : Meiji no keiken.* Kōdansha sensho mechie 563. Tōkyō: Kabushiki Kaisha Kōdansha.

Matsuzawa, Yuusaku (2009). *The Origins of the Meiji-Era Local Government System : Hegemonic Crisis and Institutional Changes in Modernizing Japan.* [In Japanese]. Tokyo: University of Tokyo Press.

Mizoguchi, Tsunetoshi (2004). *Edo-Meijiki Ni Okeru Chishi No Zuzouka Ni Yoru Souzouteki Chiiki Ron.* Kenkyuu Seika Houkokusho 14580084. Nagoya University.

Mizumoto, Tadatake (1991). “A Study on Statements of Protest of Regardin Household Tax : A Case Study on Yamaguchi Prefecture”. *Bull. Coll. Agric. Utsunomiya Univ.* 14 (3):13–36. [In Japanese].

Morishima, Mitsuko (1973). “A Case Study of the Regional Structure of Rural Communities in Tanba Mountainous District, Kyoto Prefecture”. *Jpn. J. Hum. Geogr.* 25 (1):71–94. [In Japanese].

Naismith, W. W. (1892). “Excursions: Cruach Ardran, Stobinian, and Ben More”. *Scott. Mt. Club J.* 2 (3):135.

Nakajima, Nobutora (1915). *Dai Nihon Chihō Zaiseishi.* Keizai zensho dai 6-kan, dai 8-hen. Tōkyō: Hōbunkan.

Nakamura, Masao (1953). “Before and After the Establishment of Municipalities”. *Jpn. Sociol. Rev.* 3 (3):127–130. [In Japanese].

Nishiyama, Ichiroh (2007). “Fiscal and Administrative History of Shi, Chou and Son (Municipalities) of Kagawa County in Meiji Era (1)”. *J. Econ. Manag. Inf. Sci.* 7 (1):27–62. [In Japanese].

Oguri, Hiroshi (1953). “The Reshuffling of Towns & Villages in 1889 and Rural Communities in Saitama Pref.” *New Geogr.* 2 (1):29–40. [In Japanese].

Oishi, Kaichirou (1961). *Nihon Chihōzai Gyōseishi Josetsu : Jiyū Minken Undō to Chihō Jichisei*. Tōkyō: Ochanomizu Shobō.

Okumura, Hiroshi (1984). “”Daiku Shouku Sei” Ki No Chihou Gyouzaisei Seido No Tenkai – Hyougo-Ken Akou-Gun Wo Chuushin Toshite”. *J. Jpn. Hist.* (258):p38–61.

Oshima, Mitsuko (1994). *Meiji Kokka to Chiiki Shakai*. Tōkyō: Iwanami Shoten.

Oshima, Tarou (1958). “Chouson Gappei No Ronri to Mondaisei-1-”. 34 (10):84–96.

— (1959). “Chouson Gappei No Ronri to Mondaisei-2-”. 35 (1).

— (1968). *Nihon Chihō Gyō-Zaiseishi Josetsu*. Tōkyō: Miraisha.

Sakamoto, C (1975). “On the Problems of Local Rate Taxes, ”Kosûwari” at the end of Meiji era”. *Okayama Econ. Rev.* 6 (3-4). [In Japanese].

Skinner, George William (1988). “Nobi as a Regional System”. Second Workshop of the Nobi Regional Project. Nagoya.

Steiner, Kurt (1965). *Local Government in Japan*. Stanford, Calif: Stanford University Press. 564 pp.

Suzue, Eiichi (1992). “Administrative Position of Villages under ’Daiku-Shoku’ System”. *Shigaku* 62 (1):185–210. [In Japanese].

Tajima, Noboru (1983). “Daiku Shouku Sei to Kugikai Nitsuite”. *Kindaishikenkyu* 6 .

Takayose, Shōzō (2000). *Meiji Ishin to Chihō Zaisei*. Meiji chihō zaiseishi dai 1-kan. Tōkyō: Keisō Shobō.

— (2002). *Sanshinhōki No Chihō Zaisei*. Meiji chihō zaiseishi dai 2-kan. Tōkyō: Keisō Shobō.

Tanabe, Hiroshi (1963). “The Foundation of an Administrative Village “mura” in the Meiji Era: An Example of Niita-Mura, Tochigi Prefecture”. *Geogr. Rev. Jpn.* 36 (5):280–295. [In Japanese].

Tanaka, Issei and Masaaki Kadotami (1963). “A Cooperative Research Project on Educational Structure of Changing Rural and Mining Areas in Kyushu”. *J. Educ. Sociol.* 18:123–137. [In Japanese].

Tomaru, Taisuke (2000). *Gendai Chihou Jichi No Genkei: Meiji Chihou Jichi Seido No Kenkyuu*. Outsuki Shoten.

Tsutsui, Masao (2005). “Local Administration and Finance under the Local Government System of ’Daiku-Shoku-Sei’ : The Case of Gotenba and Oyama Districts in Shizuoka Prefecture”. *Ann. Hum. Soc. Sci. Fac. Econ. Shiga Univ.* 12:23–43. [In Japanese].

Weese, Eric (2015). “Political Mergers as Coalition Formation: An Analysis of the Heisei Municipal Amalgamations”. *Quantitative Economics* 6 (2):257–307.

Yamada, Masahiro (1966). “Process of Division of Yoshino-Gun into Modern Municipalities in the Meiji Era”. *Jpn. J. Hum. Geogr.* 18 (5):508–519. [In Japanese].

Yamaoka, Yoshiaki (1977). “An Historico-Geographical Study about the Dissolution of Communal Forest:In the Case of Takahashi-Yama in the North of Nara Prefecture”. *Jpn. J. Hum. Geogr.* 29 (3):313–332. [In Japanese].

Yokoyama, Yasuoki (1957). “Ibaraki-Ken Kara Mita Meiji Shoki No Chihou Seido Nitsuite Shiryou Wo Megutte”. *Leg. Hist. Rev.* 1957 (7):154–181.