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ELECTORATE REDISTRICTING FOR A SINGLE-MEMBER DISTRICT PLURALITY, TWO-BALLOT VOTING SYSTEM: TAIWAN'S ELECTORAL REFORM

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Abstract: In this study, we formulated a mathematical model for electorate demarcation in line with Taiwan's electoral reforms, minimizing legislative seats for the main opposition party in Taipei City. The model is compared with historical election data to establish characteristics that are most contested and germane to the reform. Examination of the constituency demarcation for the Seventh Legislator Election ascertains that electorate demarcation can/can not be manipulated to create electoral advantage. Demonstrable evidence of a bias toward disproportionate representation in the single-member district plurality, two-ballot voting system ultimately attests the importance of scenario analysis before adopting new electorate systems.

Keywords: Optimization, Electorate Redistricting, Breadth-First Search.

MSC:

1. INTRODUCTION

Prior to 2008, Taiwan's electoral system utilized a single nontransferable vote under multi-member district system (hereafter SNTV) (Grofman, 1999). Under the

SNTV, several elected representatives were drawn from an electorate based on existing administrative boundaries. Each voter cast just one vote, which was counted in terms of individual candidates, with several leading candidates being elected. However, representation has proved not to be truly proportional, in the sense that even a candidate winning a small number of votes might still get position. There are various scenarios by which such results can be realized.

As a cumulative effect of legislative inefficiency and public disquiet, the Legislative Yuan passed the landmark constitutional amendment and legislative reform proposals on August 23, 2004. This initiative virtually assured that the multi-member constituency electoral system would become history. On June 7, 2005, delegates from the ad hoc National Assembly passed the constitutional amendment. Moreover, the Seventh Legislative Election held on January 12, 2008, adopted not only the single-member district plurality (SMDP), two-ballot voting system, but also downsized the Legislature from 225 to 113 seats.

Implementation of the SMDP system carries an associated risk of subdivision of electorates, a practice that can in turn encourage gerrymandering (Grofman, 1990). In order to minimize this eventuality, it is generally accepted that certain principles must perform a governing role. Incumbent legislators have a vested interest in manipulating this process to their own advantage reminding us that the primacy of political variables need to be factored into consideration by researchers. To this end, a mathematical model is proposed for electoral district reapportion in Taipei City. By these means, it becomes possible to demonstrate the latitude that the current ruling party (DPP) may have to gain a favorable electoral demarcation. The data is derived from Public Official Election information published by the Central Election Commission (CEC) and Election Information Databank, and mainly includes information on vote shares and voter structure in Taipei City from the previous elections (including 2004 Presidential Election, 2006 election for Taipei City Mayor, as well as the Seventh Legislative Election).

The remainder of this paper is arranged as follows. Section 2 defines domain knowledge in terms of electorate demarcation, and reviews related literature. Section 3 formulates a mathematical model for electorate demarcation that is designed to minimize legislator seats for the main opposition party. This model is consolidated with the support of election data in Section 4. Section 5 concludes this paper.

2. LITERATURE REVIEW

In this section, we define the parameters of this research, review the related literature, and subsequently list the major 7th Municipality, County and City Legislator Electoral District Demarcation Rules related to Taipei City.

2.1. SMDP

The elements of an SMDP two-ballot voting system need to be explained separately. Since countries with a high degree of democratization often adopt both of these elements in their electoral system, the two terms are frequently grouped together. “SMDP” requires that there is adequate constituency demarcation where there is only one seat for each electorate. In most cases, constituency redistribution is required before the

implementation of an SMDP system. The "two-ballot" voting system means that each voter will get two ballot papers for the Seventh Legislator Election: one ballot paper is for casting a vote for a candidate, while the other is for casting a vote for the political party which the voter supports. While a district legislator is elected as a result of receiving the most votes cast in the election, legislators at large are elected based on the percentage of votes each political party gets. Each political party will be allotted national legislative seats according to the proportion of votes it has received. By adopting the two-ballot voting system, voters can ignore their political party preference when casting their vote for the legislative candidate of a specific constituency whilst concurrently casting their other vote for the political party they support. The two ballot papers need not be cast for the same political party.

The SMDP system stipulates that political parties compete for a single legislative seat, and consequently it tends to be unfavorable to small parties, unless the support for small parties is highly concentrated. A small third party cannot gain legislative power if it is based in a populous area, since the number of seats for large political parties will increase, thereby creating a two-party system (Cox, 1997; Duverger, 1972; Kim and Ohn, 1992; Riker, 1982; Riker, 1993). Thus after implementation of the SMDP, two-ballot voting system, it was anticipated that the ruling party, the Democratic Progressive Party (DPP) and its main opponent, the Chinese Nationalist Party (KMT), would benefit the most from the new system. This is owing to the fact that a legislator candidate in his/her electorate must obtain the highest number of votes in order to win the election under the SMDP system. Accordingly, those candidates belonging to political parties with fewer supporters will find it difficult to win an election by means of radical advocacy and the support of a small number of votes. Also, each political party will nominate only one candidate in each constituency (otherwise it will run against its own people). Thus, it was expected that elected legislators for most constituencies would be mainly drawn from the KMT or DPP. The two-ballot voting system also bring benefits to the two largest political parties, notwithstanding that for any constituency voters may vote for a candidate who does not belong to the two largest political parties if they prefer that candidate's political preferences, personal conduct, or image. The ballot papers for political parties would mainly go to the two largest parties. It would therefore be easier for them to get more seats in the legislature generally.

2.2. Redistricting and Gerrymandering

In order to halve the number of existing legislator seats and introduce an SMDP system, the electorates need redistricting. Administrative districts, population distribution, geographical environment, available transportation, historical source, and the number of public officials to be elected are all variable empirical factors that need to be taken into account. The principle "one person one vote; all votes are equal" must be upheld if legislators are to be elected on the basis of proper representation, legitimacy and fairness. In direct contravention of this widely held ideal, political science scholars (Cain, 1984; Erikson, 1972) maintain that constituency demarcation for the SMDP voting system actually makes gerrymandering easier than for other electoral systems. Political gerrymandering may be defined as the drawing of electoral district lines in a manner that discriminates against a political party (Grofman, 1990). The term originated in 1812 in

the context of an opposition party's iron-clad voting electorates being fragmented when Massachusetts' Governor Elbridge Gerry carried out an irregular electorate demarcation which looked like a salamander. This process enabled the ruling party to increase its state representative seats, but was criticized for being a selfish electorate demarcation only serving one party's interest. Hence, the term gerrymandering is a portmanteau of the name "Gerry" and the word "salamander" (Gilligan and Matsusaka, 1999; Issacharoff, 2002; Owen and Grofman, 1988).

In essence, the practice boils down to the strategy of "packing" and "cracking" votes (Sherstyuk, 1998; Vickrey, 1961). "Packing" is the result of redistricting that places the maximum number of supporters of an opposition candidate into an electorate which is already his or her major source of votes, leading to a "waste" of many votes. Since the opposition's candidate, who is supported by voters, is certain to win that election, putting more voters with similar preferences into the same electorate merely transforms a certain victory into a landslide victory, in the absence of any concomitant increase in their number of elected seats. "Cracking," by contrast, is the result of redistricting that divides the opposition's supporters into different electorates, thereby diluting the impact of their votes and making it impossible for their candidate to be elected.

Because constituency-demarcation rules under the new electoral system furnish the constraints of the mathematical model employed in this research, a description of the major demarcation rules related to Taipei City follows.

2.3. Principles for Taipei City Demarcation

This section summarizes the major constraints related to Taipei City, which formulate the mathematical model for this research.

- Electorate demarcation is closely related to population distribution. Population change in counties and cities in the coming two years may change the allotment of legislator seats. The CEC has estimated a slight change in the population of counties and cities that have occurred by February 2007, "but the change is projected to be very limited. The possibility of such a population change necessitating a change in the calculation of seat allotment for counties and cities is very remote." According to the CEC's calculation, based on a population of 2,619,117 at the end of November 2005, Taipei City would elect eight legislators (TFD, 2006).
- The population of an individual electorate should not be more than 15% larger or smaller than the average as calculated by dividing the total population by the number of seats for the respective special municipality, county or city.
- Non-adjacent districts should not be apportioned as one electorate.
- An individual village or borough should not be partitioned.

3. RESEARCH METHODOLOGY

In the first instance, this study investigates all legal possibilities for constituency demarcation for Taipei City, based on 7th Municipality, County/City Legislator Electoral District Demarcation Rules. Then a model is established which minimizes the ruling

party's (the DPP's) legislator seats in Taipei City, based on historical electoral data, to demonstrate unfair demarcations which should not be adopted.

3.1. Districting Problem and Breadth-First Search

From a mathematical point of view, the redistricting based on principles in Section 2.2 falls within the districting problem of elementary graph theory in which m units are grouped into n zones such that some cost function is optimized, subject to constraints on the topology of the zones. A graph consists of a set of vertices, and a set of edges, where an edge is something that connects two vertices in the graph (Cormen, Leiserson, and Rivest, 2001). More precisely, a graph is a pair (V, E), where V is a finite set and E is a binary relation on V. V is called a vertex set whose elements are called vertices. E is a collection of edges, where an edge is a pair (u, v) with u, v in V. If some edge (u, v) is in graph, then vertex v is adjacent to vertex u. In a directed graph, edge (u, v) is an out-edge of vertex u and an in-edge of vertex v; the number of out-edges of a vertex is its out-degree and the number of in-edges is its in-degree. Tree edges are edges in the search tree constructed by running a graph search algorithm over a graph. Breadth-first search (BFS) is a traversal through a graph that touches all of the vertices reachable from a particular source vertex. In addition, the order of the traversal is such that the algorithm will explore all of the neighbors of a vertex before proceeding on to the neighbors of its neighbors. BFS uses two data structures to implement the traversal: a color marker for each vertex and a queue. White vertices are undiscovered, while gray vertices are discovered but have undiscovered adjacent vertices. Black vertices are discovered and are adjacent to only other black or gray vertices. The algorithm proceeds by removing a vertex u from the queue and examining each out-edge (u, v). If an adjacent vertex v is not already discovered, it is colored gray and placed in the queue. After all out-edges are examined, vertex u is colored black, and the process is repeated. Pseudo-code for the BFS algorithm is listed in Figure 1 (Siek, Lee, and Lumsdaine, 2002). In this study, each vertex represents one borough. If some edge (u, v) is in the graph, then borough v is adjacent to borough u, and vertices v and u may legitimately be apportioned to the same constituency.

```
BFS(G, S)
       for each vertex u in V[G]                    initialize vertex u
             color[u] := WHITE
             d[u] := infinity
             p[u] := u
       end for
       color[s] := GARY
       d[s] := 0
       ENQUEUE(Q, s)                                discover vertex s
       while ()
             u := DEQUEUE(Q)                        examine vertex u
             for each vertex v in Adj[u]            examine edge (u,v)
                   if (color[v] = WHITE)            (u,v) is a tree edge
                         color[v] := GARY
                         d[v] := d[u] + 1
                         p[v] := u
                         ENQUEUE(Q, v)              discover vertex v
                   else                             (u,v) is a non-tree edge
                         if (color[v]= GARY)
                                                    (u,v) has a gray target
                         else
                                                    (u,v) has a black target
             end for
             color[u] := BLACK                      finish vertex u
       end while
       return (d, p)
```

Figure 1: Pseudo-code for the BFS algorithm. Source: Siek, Lee, and Lumsdaine (2002)

3.2. Mathematical Model

Because of the principle that an individual village or borough should not be partitioned, in accordance with the district characteristics of Taipei City, we adopted a borough as the smallest unit. Given that Taipei City has m boroughs which should be apportioned to n constituencies with one legislative seat for each electorate, n number of legislators would be elected. To formulate the mathematical model, parameters and decision variables must first be defined:

a_i : population of borough i, $i = 1..m$;

b_i : number of voters voting for the KMT (blue) in the borough i, $i = 1..m$;

g_i : number of voters voting for the DPP (green) in the borough i, $i = 1..m$;

$$X_{ij} = \begin{cases} 1 & \text{if borough } i \text{ is apportioned to constituency } j \\ 0 & \text{otherwise} \end{cases} \qquad i = 1..m,\ j = 1..n$$

$$Y_j = \begin{cases} 1 & \text{if KMT wins the seat of constituency } j \\ 0 & \text{otherwise} \end{cases} \qquad j = 1..n$$

The objective function, minimizing the elected seats of the KMT, thus becomes:

$$\text{Min} \quad \sum_{j=1}^{n} Y_j \tag{1}$$

Since the population of an individual electorate should not be 15% larger or smaller than the average found by dividing the total population by the number of seats for the respective special municipality, county or city, the constraints are accordingly expressed as:

$$\sum_{i=1}^{m} a_i \cdot X_{ij} \le 1.15 \frac{\sum_{i=1}^{m} a_i}{n} = U \quad \forall j = 1..n \tag{2}$$

$$\sum_{i=1}^{m} a_i \cdot X_{ij} \ge 0.85 \frac{\sum_{i=1}^{m} a_i}{n} = L \quad \forall j = 1..n \tag{3}$$

Table 1 shows Taipei City's census-identified population as of November 2005. Based on the CEC's plan of eight seats, the upper limit U in Equation (2) equals 376,498; the lower limit L in Equation (3) equals 278,281. From Table 1, we see that Da-an District and Shihlin District satisfy the requirement that "the population of an individual electorate should not be 15% larger or smaller than the average found by dividing the total population by the number of seats for the respective special municipality, county or city." Da-an District and Shihlin District therefore do not have to be reapportioned. However, on the Taipei City Administrative Area Map (Figure 2), Shihlin District completely isolates Beitou District from other neighboring districts and the population of Beitou District is less than the lower limit of the constituency population. Consequently Beitou District cannot be apportioned as an electorate, and Da-an District and Shihlin District must be redistricted.

Table 1: Taipei City's census-identified population in 2005

District	Population
Songshan	207,961
Xingyi	230,898
Da-an	312,616
Zhongshan	217,037
Zhongzheng	157,975
Datong	127,434
Wanhua	195,334
Wunshan	258,738
Nangang	113,044
Neihu	261,526
Shilin	288,272
Beitou	248,282
Total	2,619,117

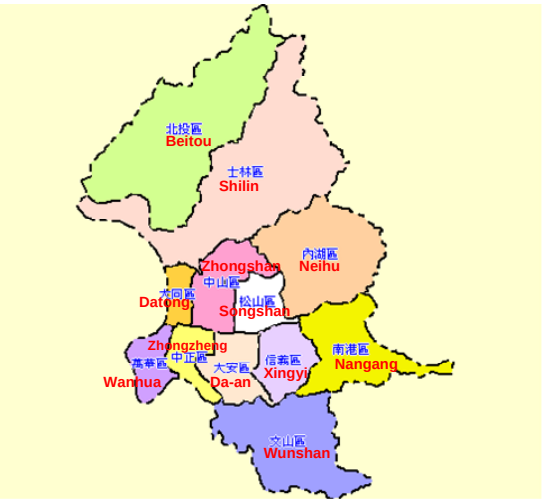

Figure 2: The Taipei City Administrative Area Map

A single borough cannot be apportioned to two or more electorates. That constraint is expressed as:

$$\sum_{j=1}^{n} X_{ij} = 1, \forall i = 1, 2, ..., m \tag{4}$$

Under the conditions defined by SMDP, the KMT's candidate can only win an election where the total number of votes in electorate j is greater than the total for the DPP's candidate. We will define a large positive number $M = \sum_{i=1}^{m} a_i$ so that:

$$-M(1-Y_j) \le \sum_{i=1}^{m} (b_i - g_i) X_{ij} \le MY_j, \forall j = 1, 2, .., n \tag{5}$$

Furthermore, non-adjacent districts should not be apportioned to the same electorate. This is a mandatory constraint which must not be violated. Figure 3 details the enlarged Neihu District in addition to part of the adjacent districts and boroughs. It clearly indicates which boroughs are adjacent and can therefore be put into one electorate. This study treats 449 boroughs in Taipei City (Figure 4) as nodes and applies a BFS algorithm to expand and examine all connected boroughs systematically until the population of boroughs apportioned to a single constituency is less than the upper limit of 376,084, but more than the lower limit of 277,975.

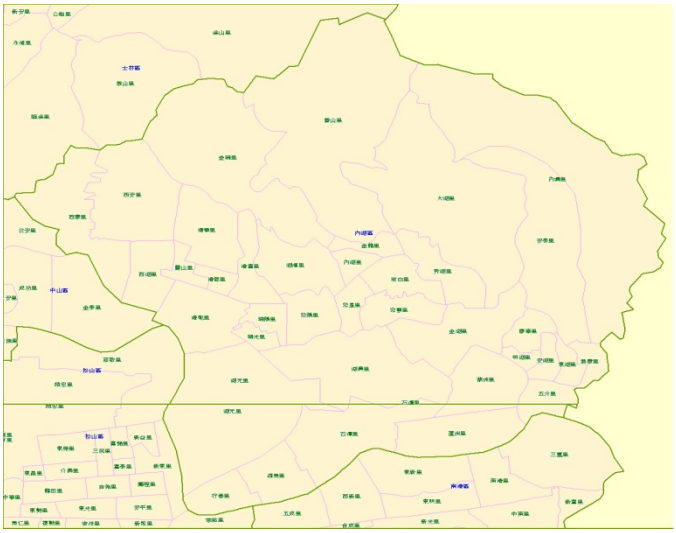

Figure 3: Neihu District and part of adjacent districts

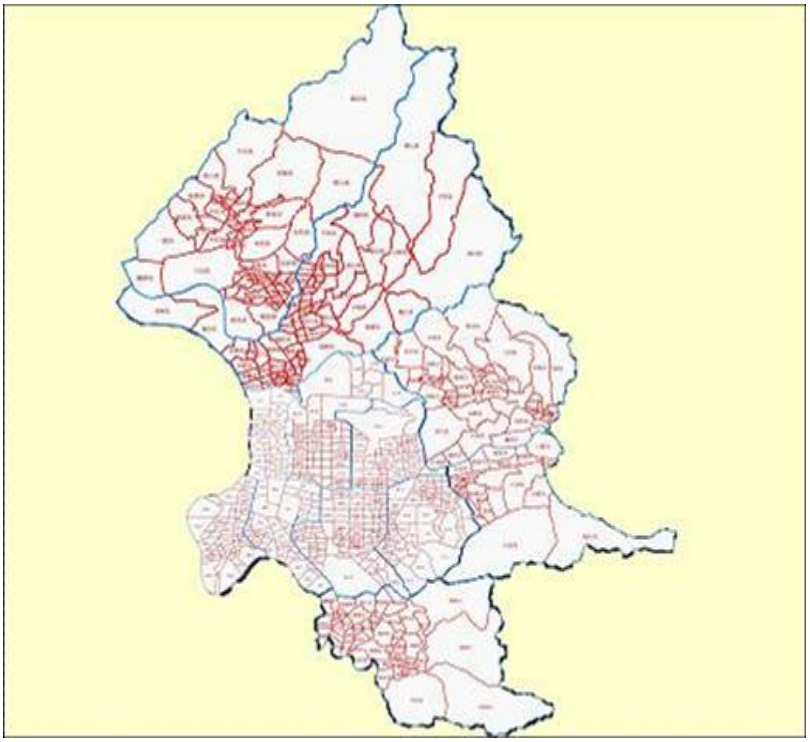

Figure 4: 449 boroughs in Taipei City Administrative Area

4. MODEL VALIDATION AND RESULTS

This section tests the formulated mathematical model on the basis of Public Official Election information published by the CEC and Election Information Databank, in conjunction with data on voter structure in Taipei City from the previous elections. It was deemed appropriate here to draw on the 2004 Presidential Election, the 2006 election for Taipei City Mayor, as well as the Seventh Legislator Election (see Table 2), because these elections were couched in terms of KMT and DPP voters. Incorporating the constraints of Equation (2), (3), and (4) into the BFS algorithm, we summarized 21,535 legitimate ways for dividing 449 boroughs in Taipei City into eight election districts. Based on the voter structure and share for each historical election, we were able to calculate the seats that would have been received by the opposition KMT and the ruling DPP and to demonstrate possible redistricting for the ruling party (DPP) to gain a favorable electoral demarcation.

Table 2: Vote shares of historical election for 449 boroughs in Taipei City

2004 Presidential Election			2006 election for Taipei City Mayor			**the Seventh Legislator Election**		
Borough	**KMT**	**DPP**	**Borough**	**KMT**	**DPP**	**Borough**	**KMT**	DPP
1	**2299**	**1614**	**1**	**1779**	**1129**	**1**	**1913**	961
2	**3246**	**2323**	**2**	**2443**	**1699**	**2**	**2653**	1526
3	**2796**	**1746**	**3**	**2102**	**1279**	**3**	**2282**	1219
4	**1667**	**1398**	**4**	**1300**	**1010**	**4**	**1377**	927
5	**2141**	**1301**	**5**	**1637**	**1011**	**5**	**1738**	881
…	**…**	**…**	**…**	**…**	**…**	**…**	**…**	…
446	**698**	**876**	**446**	**526**	**694**	**446**	**559**	531
447	**692**	**661**	**447**	**511**	**539**	**447**	**556**	406
448	**250**	**512**	**448**	**173**	**413**	**448**	**205**	322
449	**270**	**322**	**449**	**201**	**261**	**449**	**224**	192
Total	**897870**	**690379**		**692085**	**525869**		**767558**	450344
Percentage	56.53%	43.37%		53.81%	40.89%		62%	36%

To verify the chosen mathematical model, we incorporated the actual vote share of each borough for the Seventh Legislator Election and districting blueprint into the mathematical model. On January 31, 2007, the Legislative Speaker and Premier in Taiwan took draws to decide the legislative electoral districts of the last eight controversial counties and cities, including Taipei City, but after several rounds of negotiations yielded no significant results. The results of the draws had Taipei City adopt the original plan proposed by the Central Election Committee, which is shown in Figure 5. According to the districting blueprint, Taipei City's first constituency covers the Beitou administrative district and thirteen boroughs in the Shilin district. The second constituency is comprised of Datong district and 38 boroughs in the Shilin district, whilst the third constituency includes the Zhongshan district and 20 boroughs in the Songshan district. The fourth constituency encompasses both the Neihu and Nangang administrative districts, while the fifth covers Wanhua district and 21 boroughs in the Zhongzheng district. The sixth constituency extends to the Da-an administrative district, and the seventh constituency contains Xingyi district and 13 boroughs in the Songshan district. The eighth constituency incorporates the Wunshan district and ten boroughs in the Zhongzheng district. Table 3 lists the population in each constituency, which is notably lower than the upper limit of 376,084 and greater then the lower limit of 277,975 (CEC, 2007). Table 4 lists the vote shares for each constituency as calculated by the mathematical model. The results prove to be consistent with those of the Seventh Legislator Election, in which the ruling DPP suffered a crushing defeat in Taipei City.

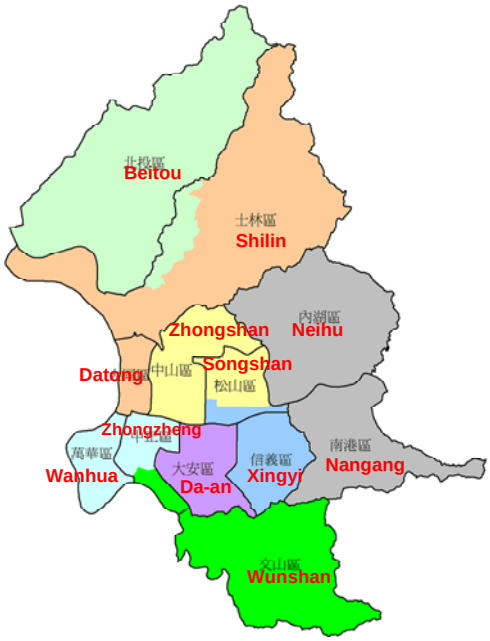

Figure 5: Comparison of Taipei City Administrative Area with Election District

Table 3: Taipei City's census-identified population after redistricting

Constituency	Population
1	334,363
2	325,598
3	345,086
4	371,665
5	307,963
6	311,626
7	308,313
8	300,300
Total	2,604,914

Table 4: Votes for the Seventh Legislator Election in Taipei City

Constituency	Votes for DPP	Votes for KMT	Seat allotted to
1	61408	94694	KMT
2	71119	81386	KMT
3	63773	99959	KMT
4	60004	105375	KMT
5	61480	87448	KMT
6	48240	99294	KMT
7	46059	95145	KMT
8	38261	104257	KMT
Total votes	450344	767558	

A central hypothesis advanced in this study is that voter structure and shares are integral to the engineering of electorate demarcation. We tested this hypothesis by applying our mathematical model to Taipei City's vote shares as recorded in the 2004 Presidential Election. 21,243 out of 21,535 legitimate ways of demarcation will allot six seats for KMT and two seats for DPP in Taipei City, and 292 demarcation results will allot seven seats for KMT and only one seat for DPP. Having then incorporated voter shares of the 2006 Mayoral Election for Taipei City into the mathematical model, there are 21,535 out of 21,535 legitimate ways of allotting six seats for KMT and two seats for DPP in Taipei City. Both sets of results accord with the prediction before the new constituency map is released that KMT would have won six seats and DPP would have won two seats for the Seventh Legislator Election in Taipei City. Next, having plugged the actual voter shares of the Seventh Legislator Election into the mathematical model developed in this study, it was found that there were 21,535 out of 21,535 legitimate ways of allotting eight seats for KMT and zero seats for DPP in Taipei City. The analytical results are consistent with the actual result of the Seventh Legislator Election in Taipei City, in which the opposition KMT won a landslide victory.

5. CONCLUSIONS

In this study, we formulated a mathematical model for electorate demarcation to minimize the legislative seats for the main opponent party (KMT) in Taipei City. A BFS algorithm was adopted to examine all legitimate ways of redistricting Taipei City. Although there are 21,535 legitimate ways for dividing 449 boroughs in Taipei City into eight constituencies, the 21,535 demarcations all allot eight seats for the opposition KMT and zero seats for the DPP by inputting the vote shares of the Seventh Legislator Election. The DPP had 36 percent of votes across Taipei City but received no seat at all, which demonstrated a huge disparity between votes and seats. Having reported the findings of this study, it is now an opportune moment to consider the extent of its contribution to the literature. First, our research adduces empirical support for the thesis that voter structure and vote shares play a constitutive role in determining the feasibility of any manipulation of electorate demarcation. Second, disproportionality arose in the Seventh Legislator

Election for Taipei City, and therefore scenario analyses are certainly needed before new electoral systems can be approved and implemented.

Although the DPP has 36 percent of votes across Taipei City, they are spread out across the territory rather than being concentrated in particular constituencies. The ruling DPP did not receive any electoral demarcation that could be construed as relatively in its favor. The demarcation was subject to the constraint that non-adjacent boroughs should not be apportioned as one constituency. The election results showed that the DPP suffered a sharp loss of seats, not only in Taipei City, but also in most of Taiwan; notwithstanding that the DPP garnered 38.17 percent of the votes, up slightly from the previous legislative elections in 2004. Conversely, the KMT, together with its ally, claimed only a slight growth in votes, but their share of seats shot up from one-half in 2004 to nearly three-quarters in the Seventh Legislator Election. Therefore the proportion of seats won differs hugely from the proportion of votes received. This appears manifestly unfair, and encapsulates the associated disadvantages of the SMDP, two-ballot voting system. Although there were 34 legislator-at-large seats available to be allotted in proportion with the total votes received by each party, this does not significantly ameliorate the overall distortion of proportional representation. With none of the small parties getting over the threshold (5 percent of party votes in the Seventh Legislator Election) no parties other than the opposition KMT and the ruling DPP have won any at-large seats in the election. This result proves consistent with previous studies which found that under the SMDP, two-ballot voting system small third parties cannot gain legislative power, thereby creating a two-party system (Cox, 1997; Duverger, 1972; Kim and Ohn, 1992; Riker, 1982).

Moreover, votes cast for losing DPP candidates or votes cast for winning KMT candidates in excess of the number required for victory were wasted. That a large majority of votes play no part in determining the outcome presents a significant criticism of the single-winner system when used for a legislature. It follows that proportional representation systems can be usefully referred to as a form of risk management, insofar as they attempt to ensure that almost all votes are effective in influencing the result, thus minimizing the number of wasted votes (Gudgin and Taylor, 1979). With the opposition KMT taking a three-quarter control of the next legislature, DPP lawmakers alone would stand no chance of meeting the required endorsements for asking the Grand Justices to look into any issue. Right after the election, the ruling DPP asked the Council of Grand Justices to examine the fairness of the SMDP, two-ballot voting system. For instance, whether more than three-tenth (34 out of 113) legislator-at-large seats should be allotted to take advantage of proportional representation systems?

Raising these questions at this late stage suggests that much scope remains for both the development of theoretical models and the subsequent empirical testing of their validity. This study may serve as a template for such future endeavors, given its marshalling of conclusive evidence with regard to the influences and disadvantages of the SMDP, and the importance of scenario analyses before any electoral reform.

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