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Abstract

In its widely-cited Investment Monitor, Access Economics publishes quarterly detailed information on most Australian investment projects that cost more than $5m, including a classification of projects as "possible", "under consideration", "committed", "under construction", "deleted" or "completed". We use these rich data to show that the evolution of projects can be conveniently understood in terms of a Markov chain. This framework provides several useful summary measures of the investment system as a whole, including estimates of the probability of a project moving from one state to another over multi-period horizons, likely bottlenecks in the system, the mean time spent in each state, the expected time taken for a project to enter a certain state such as "under construction" or "completed" and the possible implications of "speeding up" the system by regulatory reform. These measures could be of value to project proponents, capital markets and policy makers.

[1] We would like to acknowledge the help of Access Economics, and Steve Smith in particular, in providing us with the data used in this paper. We also thank Mei-Hsiu Chen, and Grace Gao for research assistance. In revising the paper, we have benefited from comments from Steve Smith. The views expressed herein are not necessarily those of Access Economics. This research was supported in part by the ARC.

1. INTRODUCTION

The consultancy firm Access Economics publishes quarterly the Investment Monitor, which lists all individual Australian investment projects valued at $5 million and over.[2] Each individual project in the Monitor is assigned a unique record number, so it can be tracked over all future editions of the publication. Also recorded are the company to which the project belongs, the cost of the project, a short qualitative statement of the project's status (e.g. "coal lease granted", "feasibility study underway"), date started, date completed, the industry classification and the number of individuals employed in construction and operation of the project. Most importantly, the status of each project in each quarter is classified as belonging to one of six possible categories: (1) *possible*, (2) *under consideration*, (3) *committed*, (4) *under construction*, (5) *completed*, and (6) *deleted*. See Table 1 for details of these categories.

Highlights from the Investment Monitor are frequently reported in the media and used to infer the health of the economy and/or the relevant sector such as mining. For example, in an article entitled "Investment Pours in: $28bn New Projects", The Australian newspaper reported on 7 November 2007 that "the investment boom has built up a new head of steam, with 130 new projects worth a total of $28 billion announced in the September quarter". But not all of these projects will eventually be undertaken and those that do proceed will take some time to be completed. Thus as the media typically overlooks the expected value of projects in a probabilistic sense, as well as the expected time until projects are completed, it is unwise for investors and others to necessarily act on this "headline" information.[3]

In this paper, we use the rich data from the Investment Monitor to show that the evolution of projects can be conveniently understood in terms of a Markov chain. This framework provides several useful summary measures of the investment system as a whole, including estimates of the probability of a project moving from one state to another over multi-period horizons, likely bottlenecks in the system, the mean time spent in each state, the expected time taken for a project to enter a certain state such as "under construction" or "completed" and the possible implications of "speeding up" the system by regulatory reform. These measures provide a more comprehensive and reliable picture of the economic significance of projects, and could be useful to project proponents, capital markets and policy makers. As the resources sector has formed the basis for much of Australia's recent economic growth and is an industry characterised by extended planning, capital

[2] According to Access Economics Investment Monitor, 2001-2007, these data are collected "from a variety of State and Federal Departments and private sources".

[3] Other examples of this type of gushing media coverage of the release of the Monitor data include "State Tops Project List", The West Australian, 26 February, 2001, "Good Times to Keep Rolling", Courier Mail, 7 November 2007 and "All Go on Mega Projects: $357 Billion of Projects in the Works", The Herald Sun, 7 November 2007. (The last article reports that "Australia has a whopping $357 billion worth of investment projects in the pipeline".)

raising, environmental approval and construction phases with many projects failing to reach completion, we focus on mining and energy projects.[4] The importance of understanding the workings of the approval process for resource projects is underscored by recent concern with avoidable delays in the state of Western Australia. For example, in its report to the Minister for Mines and Petroleum, entitled Review of the Approval Processes in Western Australia (Government of Western Australia, April 2009), the Industry Working Group wrote: "The resource sector (including mining and petroleum) is the key economic driver for the Western Australian and Australian economy. The Premier and his colleagues have made it clear that the State requires an approval system that provides a balance of social, economic and environmental needs which are in the best interests of Western Australia…We can no longer boast of our approval system being the best in Australia. It has deteriorated to where it is criticised for taking too long, being too costly, too bureaucratic, 'process driven' rather than being focused on outcomes, and not always representing the objectives of the elected government."[5]

2. THE MONITOR DATA

Table 2 indicates the industries that we consider involve mining and energy (or "resource") projects.[6] We tracked the relevant projects from the Monitor for the period 2001:1 to 2007:4, so there are 28 quarters. Over this period, there are 1,077 unique resource projects. To provide some appreciation of the nature of these data, Table 3 provides the history of 10 selected projects. Looking at the third last row, for example, it can be seen that project number 4,806 first entered the Monitor in 2002:1 as *under consideration* (state 2), and proceeded to remain in that state over the

[4] It is worth noting that the Australian Bureau of Agriculture and Resource Economics also publish information on possible resource projects. See, e. g., Lampard et al., who describe this work as follows: "ABARE's list of major minerals and energy projects expected to be developed over the medium term is compiled every six months. Information contained in the list spans the mineral resources sector and includes energy and minerals commodities projects and mineral processing projects. The information comes predominantly from publicly available sources but, in some cases, is supplemented by information direct from companies. The list is fully updated to reflect developments in the previous six months. The projects list is released around May and November each year." (M. Lampard et al., 2009, Minerals and Energy, Major Development Projects November 2009 Listing. ABARE: Canberra.) Additionally, the Australian Bureau of Statistics publish survey-based quarterly estimates of actual and expected investment expenditure by selected industry, one of which is mining. (ABS, Private New Capital Expenditure and Expected Expenditure Cat. No. 5625.0.)

[5] For related material on delays in project approval in WA, see WA Auditor General, Improving Resource Project Approval (Report 5, Performance Examination, WA Auditor General, Perth, October 2008). For a recent national study pertaining to petroleum projects, see Productivity Commission Review of Regulatory Burden on the Upstream Petroleum (Oil and Gas) Sector (Research Report, Productivity Commission, Melbourne, 2009).

[6] The Monitor field "Major Industry" was limited to include (1) Mining and (2) Electricity, Gas and Water. This means that excluded Major Industries are (1) Agriculture and Forestry, (2) Manufacturing, (3) Trade, (4) Accommodation, (5) Transport and Storage, (6) Communication, (7) Finance, Property and Business Services, (8) Government, (9) Community and Other Services and (10) Mixed Use. Within the "Transport and Storage" industry there exists a sub-industry "Pipeline and Other". Projects within this sub-industry were excluded due to the difficulty in differentiating (a) "Other" and "Pipeline" projects and (b) resource and non-resource related pipelines. As the majority are unlikely to involve the resources sector, projects classified under the sub-industry "Water Supply and Drainage" were also excluded. Further details of the data, and our edits, are provided in the Appendix.

ensuing 5 quarters. Thereafter, the project was *under construction* (state 4) for 4 quarters, and was *completed* (state 5) in 2004:3. The cost of this project was estimated to be $6m for the first 5 quarters of its history and was then revised upwards to $11m in 2003:2. The recorded life history of this project can be described as being "complete" within the window of the sample period as this history comprises a complete cycle of birth to death. For some other projects in Table 3, the life histories are incomplete as they are "alive" at the start and/or end of the window.

A histogram of project values is given in Figure 1. As can be seen, there are a large number of small projects that cost less than $50m, as well as several valued at over $4b (mostly LNG projects). Table 4 and Figures 2 and 3 summarise the data in terms of the number of projects and their value in each state. Several interesting patterns emerge including:

- Panel B of Figure 2 shows an upward trend in the average value of projects in most states. The relatively flat total number of projects (panel A), however, shows that this increase can mostly be attributed with increasing scale and cost of projects (but as values are expressed in terms of current prices, part of this is due to inflation in general).
- The number and value of projects categorised as either *possible* or *under consideration* are always substantially greater than the number *committed* or *under construction*. The last row of panel A of Table 4 reveals that on average 39+36=75 percent of the number of projects are *possible* or *under consideration,* while only 4+17=21 percent are *committed* or *under construction*; on a value basis, the corresponding figures are 78 percent and 20 percent. This may relate to the generally long preparation times required for resources and energy projects, but it may also reflect a reluctance to finally abandon nonviable projects.
- Panel C of Table 4 shows that the average value of *deleted* projects ($300m) is more than double that of *completed projects* ($139m). Indeed, the average value of *completed* projects is far less than that of any other state. As we move through the project pipeline, from *under consideration*, to *committed*, to *under construction*, to *completed*, the average value of projects declines successively, from $347, to $256m to $244m to $139m. This may suggest that smaller projects are more easily completed, or be interpreted as an early warning signal that many projects will possibly never be realised.
- The increase during 2005-2007 in projects *under consideration* in panels C and D of Figure 2 possibly reflects that capital markets were more enthusiastic for the resources sector. The exception to this trend occurs in 2007:4, when the value share for this category falls substantially.
- There is substantial quarter-to-quarter volatility in completions and deletions in terms of both the number and value (Figure 3).

Next, we consider the nature of projects when they are first listed in the Monitor, which shall be referred to as "new" projects. Table 5 and Figure 4 provide information on these projects. As is to be expected, the majority of new projects first appear as either *possible* or *under consideration*. As will be seen in Section 6, however, the probability that a project is ultimately completed depends very much on its initial state: the conditional probability of completion is much higher for projects that are initially *under consideration*, as opposed to *possible*. It is also of interest to note that the number of new projects shows a pronounced peak in the fourth quarter of 2006 with 72 new projects listed. The value of new projects peaks 9 months later in 2007:3. This period coincided with substantial buoyancy of the resources sector on the stock market.

3. TRANSITION MATRICES

The progression of a project through the six states listed in Table 1 can be thought of as a stochastic process occurring in discrete time. At the end of each time period *t*, a project either remains in its current state *i* or jumps to one of the five other states in period $t+1$. Define the state space:

$$S = \left\{ possible,\ under\ consideration,\ committed,\ under\ construction,\ completed,\ deleted \right\},$$

which is abbreviated to $S = \{1,2,3,4,5,6\}$. Let X_t be the state occupied by a project in period *t* and let $p_{ij} = P(X_{t+1} = j \mid X_t = i)$ be the conditional probability of the project moving from state *i* to state *j* at the end of period *t*, with $\sum_{j=1}^{6} p_{ij} = 1,\ i = 1,\ldots,6.$ These probabilities can be arranged in a 6×6 *transition matrix* $\boldsymbol{P} = [p_{ij}]$, which has unitary row sums. A key assumption is that the transitions through these six states exhibit first-order Markov dependence. That is, the following condition holds for all states *i, j* = 1, ...,6:

$$p_{ij} = P\left(X_{t+1} = j \mid X_t = i\right) = P\left(X_{t+1} = j \mid X_0 = x_0, X_1 = x_1, \ldots, X_{t-1} = x_{t-1}, X_t = i\right).$$

This states that the probability a project enters a state *j* in period *t*+1 is dependent only on the state it occupies at time *t* and is independent of the state occupied in *t*-1, as well as the states in all previous periods that make up the history of the process. The process is also assumed to be time homogenous, which means that the probabilities remain stable over time. These are significant assumptions and are key to deriving many of the results that follow. While we do not seek to formally test these assumptions in this progress report, it will be shown in Section 9 below that their implications match the data reasonably closely, so that first-order Markov dependence and homogeneity seem to be not grossly contradicted by the evidence.[7]

In order to estimate the transition matrix that describes the evolution of the projects, we begin by counting the number of transitions between each pair of consecutive quarters, $h = 1,...,27,$ for all 36 combinations of states $i, j = 1,...,6.$ Let c_{ijh} be the number of projects that move from state *i* to *j* over transition *h*. The transition matrix is then estimated as the average of the normalised count data:

$$\widehat{\boldsymbol{P}} = \left[\widehat{p}_{ij} \right] = \left[\frac{1}{27} \sum_{h=1}^{27} \frac{c_{ijh}}{\sum_{j=1}^{6} c_{ijh}} \right].$$

In words, $\widehat{p}_{ij}$, the $(i, j)^{\text{th}}$ element of $\widehat{\boldsymbol{P}}$, is the proportion of projects that make the transition from state *i* to state *j* in one quarter, averaged over the 27 transitions.

Table 6 gives the count data and the corresponding transition probabilities for three representative quarters, as well as the averages, $\widehat{\boldsymbol{P}}$, contained in the six last rows of column 11-16. This procedure is repeated with the value of the projects, rather than their number, and Table 7 contains the results. When using the value data, we recognise that all projects are not of economically equal size, so that $\widehat{p}_{ij}$ is now the share of the value of all projects moving from state *i* to *j* in one quarter, and is interpreted as the estimated probability of a dollar's worth of a project making such as transition. An element-by-element comparison reveals that the count and value estimates of $\widehat{\boldsymbol{P}}$ in Tables 6 and 7 are not too different.

The average transition matrix of Table 6 exhibits several interesting properties:

- For each state of origin, the highest probability move is no move. That is, the diagonal probability is the largest in each row, so that $\max_j \widehat{p}_{ij} = \widehat{p}_{ii},\ i = 1,\ldots,6.$
- Consider the elements $\widehat{p}_{55}$ (which refers to the probability that the project remains *completed*) and $\widehat{p}_{66}$ (remains *deleted*). In the Monitor projects in these categories are simply no longer recorded in subsequent quarters, so there are zero counts for transitions originating in states 5 and 6 in columns 4-9 of Table 6. Accordingly, we set $\widehat{p}_{kk} = 1$ and $\widehat{p}_{kj} = 0,\ k = 5,6,\ j = 1,\ldots,4,$ so states 5 and 6 are *absorbing*. When a project enters either of these states it remains there forever.

[7] A good reference on the theory of Markov chains is A. G. Pakes, "Lecture Notes on Markov Chains and Processes," School of Mathematics and Statistics, The University of Western Australia, 2009.

- The matrix has a near upper-triangular structure whereby $\widehat{p}_{ij} \approx 0, i > j$. If this property held exactly, then the system would be *irreversible* in the sense that projects would flow from lower states to higher ones, but not vice versa $\left(\widehat{p}_{ij} \geq 0, i \leq j, \widehat{p}_{ij} = 0, i > j\right)$. Thus, for example, once a project is *under construction* it cannot regress to *under consideration*. Such a property is appealing in this context.
- The largest off-diagonal element is $\widehat{p}_{34} = 0.264$, which indicates there is a 26 percent chance of a currently-committed project commencing construction in the subsequent quarter.

In what follows, for notational simplicity we omit the hat on the estimate of the transition probabilities.

4. THREE PROBLEMS

The above database comprises 1,077 projects, which is represented by the area of the large rectangle in Figure 5. In this section, we discuss three problems with the data and how we deal with them.

I. *Unobserved births.* As mentioned previously, some projects have incomplete life histories as their date of birth and/or death lies outside the sample period. Incomplete birth histories refer to those projects recorded as being in one of the six states in the first period of the sample, 2001:1, that are not identified as new projects in the Monitor. In order to obtain a more representative picture of the operation of the system, we proceed by deleting projects with missing birth records. This involves the 428 projects represented by the area of circle I in Figure 5.

II. *Unobserved deaths.* For similar reasons, we delete projects that do not enter the *completed* or *deleted* state by the end of the sample period, 2007:4. As shown by the area of circle II in Figure 5, this involves 531 projects.

III. *Backward moves*. The non-zero entries below the main-diagonal in the estimated transition matrix, p_{ij} for $i > j$, are the result of a number of projects moving "backwards", for example from *under construction* back to *committed*. As this represents a contradiction in terms of the definitions of states in Table 1 and is equivalent to "reverse aging" or getting younger with the passage of time, which does not make sense, we remove all projects that exhibit a backwards move at any point in the sample period.[8] Area III in Figure 5 indicates that there are 92 projects in this category.

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[8] Conceivably, another way to deal with this problem would be to augment the state space with a number of secondary states. But this would substantially increase the dimensionality of the problem without shedding light on the reason for the anomalous backward moves.

Figure 5 reveals a substantial overlap of the above problems. After deleting the projects with these problems, and avoiding double counting by allowing for the overlap, the original number of projects, 1,077, falls to 252. We shall refer to this restricted dataset as "*Project Set B"*, defined as

Project Set B:	*Projects that have a complete lifetime in the discrete time interval [2001:1, 2007:4], and do not exhibit a movement from state i at time t to state $j < i$ at time t+1, for any interval $(t, t+1)$ within the period.*

This restricted dataset thus refers to projects with a lifetime less than or equal to 28 quarters. The Appendix contains a further description of the data comprising *Project Set B*. We shall refer to the first data set that includes the incomplete histories as "*Project Set A*".

5. MORE TRANSITION MATRICES

Tables 8 and 9 present the results with *Project Set B*, and parallel Tables 6 and 7. The impact of the filtering can be clearly seen. First, all transition matrices are upper triangular in structure (by construction). Second, the effect of the removal of projects with incomplete histories is evident in the example transition matrices. In the first transition matrix (2001:1, 2001:2) there are no projects entering *completed* or *deleted*, while in the last (2007:3, 2007:4) all the transitions are into one of the two absorbing states. The movement of projects through the system is neatly summarised by Tables 10 and 11. From 2001:1 to 2004:4 more than 50 percent of projects are in one of the pre-construction states (*possible*, *under consideration*, *committed*), whilst thereafter the majority of projects are in one of the later states (*under construction*, *completed*, *deleted*).

The average transition matrix derived from *Project Set B*, given in the last six rows of columns 11-16 of Table 8 for the count data, displays several properties worth noting:

- As before, the diagonal probabilities dominate, so that the probability of a project remaining in its current state is always greater than the probability of it jumping to another state in the subsequent quarter.
- There are now two significant off-diagonal elements: the probability of moving from *committed* to *under construction* $p_{34} = 0.429$, and the probability of moving from *construction* to *completed* $p_{45} = 0.209$. These relatively high values imply that the second part of the overall system is faster than the first -- that is, projects move more quickly through states 3 and 4 than they do through the earlier states of *possible* and under *consideration*.

- The probability of projects leaving state 3 for state 4 $(p_{34} = 0.429)$ is actually greater than the proportion leaving state 4 $(p_{45} + p_{46} = 0.217)$. When there is initially the same volume of projects in states 3 and 4, this will result in a bottleneck of projects in state 4, under construction
- The probability of moving directly to *deleted* from *possible* $(p_{16} = 0.118)$ is higher than that from *under consideration* $(p_{26} = 0.039)$. Additionally, the probability of moving directly from *possible* to *completed* $(p_{15} = 0.015)$ is substantially lower than from *under consideration* to *completed* $(p_{25} = 0.108)$. Evidently, projects classified as *possible* have a lower chance of ultimate completion than those that are *under consideration*.

Figure 6 provides a visual representation of the upper triangular structure of the transition matrices in Tables 8 and 9.

6. MULTI-PERIOD TRANSITIONS

The last bullet point of the previous section noted the one-quarter impact of a project's starting point on its success; that is, over a one-quarter horizon, a project that is *possible* has substantially poorer outlook than one *under consideration*. As the system evolves over time, these differences become even more pronounced. In this section, we investigate this issue by considering multi-period transition probabilities.

Suppose a project is currently in state *i*. Then, the probability of moving to state *j* in the next quarter $t+1$ is p_{ij}, while for $t+2$ the probability is $\sum_{k=1}^{6} p_{ik} p_{kj}$, which will be denoted by $p_{ij}^{(2)}$. This $p_{ij}^{(2)}$ involves the direct move over the two quarters $i \to j \to j$, with probability $p_{ij} p_{jj}$, plus the five "indirect" moves $i \to k \to j$, $k = 1, \ldots, 6,\ k \neq j$, which has probability $\sum_{k=1, k\neq j}^{6} p_{ik} p_{kj}$. The whole set of multi-period transition probabilities can be conveniently formulated as follows. Let s_{it} be the proportion of projects in state i $(i = 1, \ldots, 6)$ in quarter t and $\boldsymbol{s}_t' = [s_{1t}, \ldots, s_{6t}]$ be the corresponding vector whose elements have a unit sum. It then follows from the definition of the transition probabilities that $s_{j,t+1} = \sum_{i=1}^{6} s_{it} p_{ij}$, or $\boldsymbol{s}_{t+1}' = \boldsymbol{s}_t' \boldsymbol{P}$. Accordingly, in period $t+2$ we have $\boldsymbol{s}_{t+2}' = \boldsymbol{s}_{t+1}' \boldsymbol{P} = \boldsymbol{s}_t' \boldsymbol{P}\boldsymbol{P} = \boldsymbol{s}_t' \boldsymbol{P}^2$, where $\boldsymbol{P}^2 = \boldsymbol{P}\boldsymbol{P}$. More generally for $\tau > 0$ steps into the future, $\boldsymbol{s}_{t+\tau}' = \boldsymbol{s}_t' \boldsymbol{P}^\tau$, where $\boldsymbol{P}^\tau$ is the τ-step transition matrix, defined as $\Pi_{t=1}^{\tau} \boldsymbol{P}^t$. The $(i, j)^{\text{th}}$ element of $\boldsymbol{P}^\tau$, $p_{ij}^{(\tau)}$, is the probability of a project moving from state *i* to *j* over τ periods and accounts for both the one-period and subsequent-period transitions. More formally, if X_t is the state occupied by a project in period *t,* then $p_{ij}^{(\tau)} = P(X_{t+\tau} = j \mid X_t = i)$. The τ-step distribution of projects can be expressed in scalar terms as

$$s_{j,t+\tau} = \sum_{i=1}^{6} s_{it} p_{ij}^{(\tau)}, \qquad j = 1,\ldots,6. \tag{6.1}$$

In what follows, we use the transition matrix estimated with the count data that is given in Table 8. For convenience, we reproduce it here:

State in period t	State in period t+1					
	1	2	3	4	5	6
1.Possible	0.798	0.021	0.012	0.036	0.015	0.118
2. Consideration	0	0.758	0.033	0.062	0.108	0.039
3. Committed	0	0	0.531	0.429	0.032	0.008
4. Construction	0	0	0	0.783	0.209	0.008
5. Completed	0	0	0	0	1	0
6. Deleted	0	0	0	0	0	1

As the system exhibits two absorbing states, the limiting distribution of projects consists of all projects being in either state *completed* or *deleted*. But it is still revealing to examine the path of adjustment to this steady state by plotting the multi-period transition probabilities for the absorbing states against the time horizon τ. Figure 7 contains plots of $p_{ij}^{(\tau)}$ against τ for $i = 1,\ldots,4, j = 5,6$. The difference between the one-quarter transitions p_{15} and p_{25} in the above matrix is $1.5 - 10.8 = -9.3$ percent, while it can be seen from panel A of Figure 7 that the difference in the cumulative effect after 28 quarters is much larger at $p_{15}^{(28)} - p_{25}^{(28)} = 38.3 - 81.9 = -43.6$ percent. In words, a project that commences as *under consideration* has a 82-percent chance of being completed after 28 quarters, while one starting as *possible* has only a 38-percent chance.

Next, to further illustrate the implications of the transition matrix, suppose that initially projects are equally distributed between the first four states, so that $s_t' = (1/4)[1,1,1,1,0,0]$. We can then use equation (6.1) to generate the evolution of the projects into the future. In Figure 8 we plot the proportion of projects in state *j* in τ quarters in the future, $s_{j,t+\tau}$, against τ. This shows how the distribution shifts over time, out of the four equi-probable transition states into the two absorbing states. As can be seen from panel A, for the first several quarters there is a hump in the proportion of projects in the state *under construction*, which reflects the bottleneck problem mentioned above; thereafter, this proportion converges to zero as projects move through the system and the number of projects flowing into this state from its immediate neighbour (committed) slows. The three other transition states decline monotonically to zero, while within the two absorbing states, the proportion *completed* converges to almost 80 percent and *deleted* to almost 20 percent (panel B of Figure 8).

7. MEASURING ELAPSED TIME

How long does an average project spend in a given state and how long does it take to get there in the first place? These important issues that reflect the structure of the transition matrix are considered in this section.

Occupancy Times

Denote the time that a project spends in state $i = 1,\dots,4$ on an individual visit as the random variable Y_i. This Y_i follows a geometric distribution, $P(Y_i = y) = p_{ii}^{\,y-1}(1 - p_{ii})$, with $E(Y_i) = 1/(1 - p_{ii})$, to be denoted by r_i. As projects only move *forward* through the first four states, the random variable Y_i is also interpreted as the *total* time a project spends in state *i*, so that r_i is the mean occupancy time. Clearly, the more inertia in the system, the higher are p_{ii} and r_i.

Table 12 gives in columns 8 and 15 the mean occupancy times for Project Sets A and B respectively, when the transition matrices are derived from both the value and count data. The average count transition matrix from Project Set B is given the middle part of columns 9-14. The occupancy times derived from this transition matrix are given in the corresponding rows of column 15, and these show that projects can expect to spend about 5 quarters in the state *possible*, 4 quarters under *consideration*, 2 in *committed* and 5 under *construction*. Filtering the data removes projects with longer lifetimes, and column 22 -- the differences between occupancy times implied by Set A and Set B -- shows that this has the impact of decreasing occupancy times, as expected. The last four rows of the table show the effect of using value as opposed to count data. In general, the value-weighted projects tend to move more quickly through the system than the projects themselves, especially in the *possible* phase. In other words, as they tend to move through the system faster, the system seems to favour larger projects.

Figure 9 employs a time-value metric to visualise the economic significance of projects in each phase. Take, for example, the shaded area at the top of the column headed "*Possible*". This rectangle has width equal to \$124m, the mean value of projects in this phase, and length 5.0 quarters, the mean occupancy time. Thus, the area is $124 \times 5.0 = 620$ millions of dollar quarters, which is a measure of the economic importance of this phase to the project system as a whole. The same area measures for the three other transition states are 418, 216 and 460. On this basis, the size of the system is $620 + 418 + 216 + 460 = 1,714$, so the relative contributions are

Possible 36%, *Consideration* 24%, *Committed* 13%, *Construction* 27%.

Thus in this sense, the state *possible* is the most important, followed by *consideration* and *construction*, the latter two being of roughly the same size.

Hitting Times

The hitting time, h_{ij}, is the expected number of periods taken for a project to first reach state *j,* given that it is currently in state *i*.[9] That is, $h_{ij} = E\left(T_j \mid X_0 = i\right)$, where $T_j = \min\{n \geq 0 : X_n = j\}$ is the number of periods until the project first enters state *j*, with $T_j = 0$ if $X_0 = j$, so that $h_{jj} = 0$. If we partition the state space *S* and use the law of total probability, this can be expressed as $h_{ij} = \sum_{k \in S} E\left(T_j \mid X_0 = i, X_1 = k\right) P\left(X_1 = k \mid X_0 = i\right)$, or since $P\left(X_1 = k \mid X_0 = i\right)$ is the transition probability p_{ik}, $h_{ij} = \sum_{k \in S} E\left(T_j \mid X_0 = i, X_1 = k\right) p_{ik}$. It follows that $E\left(T_j \mid X_0 = i, X_1 = k\right) =$ $1 + h_{kj}$, as the project takes one period to move from state *i* in period 0 to state *k* in period 1, while the remaining expected time to reach state *j* is simply the hitting time h_{kj}. Therefore, as $\sum_{k \in S} p_{ik} = 1$,

(7.1) $$h_{ij} = \sum_{k \in S} \left(1 + h_{kj}\right) p_{ik} = 1 + \sum_{k \in S} p_{ik} h_{kj} \quad i \neq j \in S.$$

To illustrate the workings of system (7.1), consider the hitting times for the state $j = 4$, under *construction*, $h_{i4}, i = 1, \ldots, 6.$ We solve the following system of equations:

$$\begin{aligned}
h_{14} &= 1 + p_{11}h_{14} + p_{12}h_{24} + p_{13}h_{34} + p_{14}h_{44} + p_{15}h_{54} + p_{16}h_{64} \\
h_{24} &= 1 + p_{21}h_{14} + p_{22}h_{24} + p_{23}h_{34} + p_{24}h_{44} + p_{25}h_{54} + p_{26}h_{64} \\
h_{34} &= 1 + p_{31}h_{14} + p_{32}h_{24} + p_{33}h_{34} + p_{34}h_{44} + p_{35}h_{54} + p_{36}h_{64} \\
h_{44} &= 1 + p_{41}h_{14} + p_{42}h_{24} + p_{43}h_{34} + p_{44}h_{44} + p_{45}h_{54} + p_{46}h_{64} \\
h_{54} &= 1 + p_{51}h_{14} + p_{52}h_{24} + p_{53}h_{34} + p_{54}h_{44} + p_{55}h_{54} + p_{56}h_{64} \\
h_{64} &= 1 + p_{61}h_{14} + p_{62}h_{24} + p_{63}h_{34} + p_{64}h_{44} + p_{65}h_{54} + p_{66}h_{64}.
\end{aligned}$$

This can be simplified by using the following information: (i) As states five and six are absorbing, it follows that $h_{5j} = h_{6j} = 0$ for all *j*. (ii) The probabilities in the lower triangle of the transition matrix are equal to 0. (iii) By definition, $h_{44} = 0$. Therefore, the above system reduces to:

$$\begin{aligned}
&\left(1 - p_{11}\right) h_{14} - p_{12}h_{24} - p_{13}h_{34} = 1 \\
&\left(1 - p_{22}\right) h_{24} - p_{23}h_{34} = 1 \\
&\left(1 - p_{33}\right) h_{34} = 1.
\end{aligned}$$

[9] For the underlying theory and qualifications, see A. G. Pakes, "Lecture Notes on Markov Chains and Processes," School of Mathematics and Statistics, The University of Western Australia, 2009. Much of the material that follows is from this source.

Commencing with the last equation and working backwards, we obtain:

$$(7.2) \qquad h_{34} = \frac{1}{1-p_{33}}, \quad h_{24} = \frac{1+\frac{p_{23}}{1-p_{33}}}{1-p_{22}}, \quad h_{14} = \frac{1+p_{12}\left[\frac{1+p_{23}/(1-p_{33})}{1-p_{22}}\right]+\frac{p_{13}}{1-p_{33}}}{1-p_{11}}.$$

As $r_i = 1/(1-p_{ii})$ is the mean occupancy time in transition state i, it follows that hitting times can be expressed as

$$h_{34} = r_3, \quad h_{24} = r_2(1+p_{23}r_3), \quad h_{14} = r_1\left[1+p_{12}r_2(1+p_{23}r_3)+p_{13}r_3\right].$$

Using in system (7.2) the probabilities from the average count transition matrix derived from the filtered data [given in the middle part of panel B of Table 12 and reproduced below equation (6.1) above], we obtain

$$h_{34} = \frac{1}{1-p_{33}} = \frac{1}{1-0.531} = 2.1, \quad h_{24} = \frac{1+\frac{p_{23}}{1-p_{33}}}{1-p_{22}} = \frac{1+\frac{0.033}{1-0.531}}{1-0.758} = 4.4,$$

$$h_{14} = \frac{1+p_{12}\left[\frac{1+p_{23}/(1-p_{33})}{1-p_{22}}\right]+\frac{p_{13}}{1-p_{33}}}{1-p_{11}} = \frac{1+0.021\left[\frac{1+0.033/(1-0.531)}{1-0.758}\right]+\frac{0.012}{1-0.531}}{1-0.798} = 5.5 \text{ quarters.}$$

These indicate that on average a project can be expected to reach the *construction* state almost one and a half years after it commences as being *possible* (h_{14}), one and a bit years from being under *consideration* (h_{24}), and slightly more than six months from *committed* (h_{34}).

Table 13 gives all the hitting times for states $i, j \in S$, which are computed in an analogous way to the above. Note that because they are absorbing, states *completed* and *deleted* have identical hitting times.

8. REDUCING RED AND GREEN TAPE

As mentioned in Section 1, recently there has been considerable concern regarding the functioning of the project approvals process in the state of Western Australia, which has a large resources sector. The seriousness of this issue is illustrated by the WA Minister for Mines and Petroleum describing as "the need for an efficient and timely approvals process" as his "number one priority in government".[10] Clearly, regulatory reform is called for, allowing projects to move more

[10] See Norman Moore, "Address to the Australian Institute of Company Directors," 18 February 2009, Perth. In this speech, the Minister goes on to indicate the importance of the resources sector by stating "all Western Australians, and indeed all Australians, should have an interest in the viability of the [resources] industry due to the incredible wealth and employment opportunities it creates"**.** The clear implication is a link between the efficiency of the approvals process and prosperity of the broader economy.

quickly through the system.[11] Our approach permits the identification of bottlenecks and in this section we investigate the effects of their elimination. We do this by examining the implications for project outcomes of changes in the key transition probabilities.

As $r_i = 1/(1-p_{ii})$ is the mean occupancy time, this time declines as p_{ii} falls, so that when the p_{ii} for the transitory states decline, projects move faster through the system. But as $\sum_{j=1}^{n} p_{ij} = 1,$ a change in p_{ii} implies that some of the off-diagonal probabilities also have to be adjusted accordingly. Let $\boldsymbol{P} = [p_{ij}]$ be the original $n \times n$ transition matrix, which we adjust by adding the matrix $\boldsymbol{A}$ to give the adjusted transition matrix $\boldsymbol{P} + \boldsymbol{A}$. If $\boldsymbol{\iota}$ is a vector of n unit elements, the row-sum constraint can be expressed as $\boldsymbol{P\iota} = (\boldsymbol{P} + \boldsymbol{A})\boldsymbol{\iota} = \boldsymbol{\iota},$ which implies that $\boldsymbol{A\iota} = \boldsymbol{0},$ a vector of zeros. In words, the elements of each row of the adjustment matrix $\boldsymbol{A}$ must sum to zero. We consider two approaches to this adjustment problem.

One approach is to subtract $0 < \alpha_i < p_{ii}$ from the diagonal element of the i^{th} row of the transition matrix and then evenly redistribute this quantity across the other elements of the row by adding $\alpha_i/(n-1)$ to each of the off-diagonal transitions. Thus, the $(i, j)^{th}$ element of the i^{th} row of $\boldsymbol{A}$ takes the form $a_{ij} = -\alpha_i$ if $i = j,\ \alpha_i/(n-1)$ otherwise, which satisfies $\sum_{j=1}^{n} a_{ij} = 0.$ Let δ_{ij} be the Kronecker delta $(\delta_{ij} = 1 \text{ if } i = j, \text{ zero otherwise})$ and let $\delta_{ij}\boldsymbol{\iota}'$ be a vector of zeros except for the i^{th} element, which is unity; that is, $\delta_{ij}\boldsymbol{\iota}'$ is the i^{th} row of the $n \times n$ identity matrix $\boldsymbol{I}$. Then, the i^{th} row of $\boldsymbol{A}$ can be expressed as $\boldsymbol{a}_i' = \dfrac{\alpha_i(1-n\delta_{ij})}{n-1}\boldsymbol{\iota}',$ and the $n \times n$ adjustment matrix is

$$\boldsymbol{A} = \begin{pmatrix} \boldsymbol{a}_1' \\ \vdots \\ \boldsymbol{a}_n' \end{pmatrix} = \frac{1}{n-1}\hat{\boldsymbol{\alpha}}(\boldsymbol{\iota\iota}' - n\boldsymbol{I}),$$

where $\hat{\boldsymbol{\alpha}} = \operatorname{diag}[\alpha_1, \ldots, \alpha_n]$.

A second approach to the adjustment problem is to employ some type of weighting scheme. Thus, rather than evenly distribute α_i across the row, we add to the off-diagonal transitions $a_{ij} = w_{ij}\alpha_i,\ i \neq j,$ with the weights w_{ij} satisfying $\sum_{j=1, j\neq i}^{n} w_{ij} = 1,\ i = 1, \ldots, n.$ Under this approach, we have, for $i, j = 1, \ldots, n,\ a_{ij} = \alpha_i\left[w_{ij} - \delta_{ij}(w_{ij} + 1)\right].$ The weights could reflect the idea that some pairs

[11] Overcoming infrastructure blockages and reducing skill shortages would also have the same effect of speeding up the system.

of states are closer "economic neighbours" than others, so that if a project spends less time in one state, then it is more likely to locate in a closer neighbour, rather than a more distant one.

To implement the above ideas, we start with the transition matrix reproduced below equation (6.1). In order to examine the essence of the issues, we simplify the structure of this matrix by setting to zero all the transitions that are less than 0.05, other than those involving the transition to state 4, *construction*. The row sum constraints are enforced by increasing the transitions to state 4, p_{i4}. This yields the "base case" matrix given in the left-hand side of panel A of Figure 10. As the first three states – possible, consideration, committed – all precede the construction phase, we shall change the nature of the system so that the average project spends less time in these states and commences construction sooner. Such a change is taken to be the response of the system to regulatory and other reform. To do this, we assume that the mean occupancy time in each of the pre-construction phases, defined as $r_i = 1/(1-p_{ii}),\ i=1,2,3,$ falls by 25 percent. This implies that the own-state probabilities (to be denoted by p_{ii}^{new} and p_{ii}^{old}) satisfy

$$\frac{\dfrac{1}{1-p_{ii}^{new}} - \dfrac{1}{1-p_{ii}^{old}}}{\dfrac{1}{1-p_{ii}^{old}}} = \frac{p_{ii}^{new} - p_{ii}^{old}}{1-p_{ii}^{new}} = 0.25,\ i = 1,2,3.$$

The transitions into construction, $p_{i4},\ i = 1,2,3,$ are then increased to satisfy the row-sum constrains, as before. This procedure can be regarded as an application of the weighted approach described above. The right-hand side of panel A of Figure 10 contains the new transition matrix.

Next, we examine the multi-period transitions associated with the new matrix, $p_{ij}^{new(\tau)}$, defined as the probability of a project moving from state *i* to *j* over τ periods. Panel B of Figure 10 plots the change in these probabilities, $\Delta p_{ij}^{(\tau)} = p_{ij}^{new(\tau)} - p_{ij}^{old(\tau)}$, against the horizon, τ, for transitions into the two absorbing states, *completed* and *deleted*. As can be seen from part (i) of this panel, the major impact is a substantial increase in the probability from *possible* to *completed*; over horizons of up to four years, this $\Delta p_{ij}^{(\tau)}$ increases steadily to reach about 15 percent and thereafter stays there. The change in the probability from *possible* to *deleted* is almost the mirror image of the above, so this asymptotes to about -15 percent [see part (ii) of panel B]. Over the first several years of the horizon, there also some modest changes in two other $\Delta p_{ij}^{(\tau)}$: From *committed* to *completed* and from *under consideration* to *completed*; in both cases, the change in the probability initially rises as a result of speeding up and then drop off to zero. In summary, these results illustrate the gains to be had from increasing the speed limits of the system by regulatory reform.

It is also interesting to examine the how the "faster" transition matrix influences the distribution of projects over time. We first specify the initial distribution of projects over the four transition states, $s_0' = [s_i],\ i = 1,...,4$, as the average proportions. For this purpose, we use the averages contained in columns 2-5 of the last row of Table 4, renormalised so they have a unit sum. We then use the information in columns 2-5 of Table 5, appropriately normalised, to feed into the system the arrival of new projects in each quarter.[12] Next, using the approach described in the subsequent section regarding the computation of the fitted distribution of projects, we compute two distributions in each quarter: (i) That derived from the original transition matrix contained below equation (6.1); and (ii) that from the faster transition matrix given in the right-hand side of Panel I in Figure 10.[13] The impact of speeding things up can then be assessed by examining the difference between the two distributions. Figure 11 contains the results in the form of the changes in the probabilities for each state in each quarter. Evidently, speeding up approvals leads to an increase in the proportion of projects in the construction phase by about 20 percentage points. As about 20 percent of projects are *under construction* on average, the speeding up of the approvals process causes this percentage to about double to 40 percent. This 20-point increase is offset by reductions in the proportions in the other three transition states, especially *under consideration*.[14]

9. ARE THE PROJECTS REALLY FIRST-ORDER MARKOV?

In a first-order Markov chain, memory lasts for one period, so that the entire history of a project is contained in its current state. There is no compelling prima facie reason to doubt that this one-period dependence is a reasonable way to describe the evolution of the projects, but no iron-clad guarantees can be given. In this section, we analyse some evidence on this issue.

[12] Two comments about this procedure are warranted. First, the simulation undertaken here is distinctly different to that described in the last paragraph of Section 6, where we investigated the distribution of projects starting from an arbitrary distribution and did not consider the arrival of new projects in each quarter. By contrast, here we use the observed data and consider the flow of new projects. Second, in these computations for both the initial distribution and the flow of new projects, we use the data from *Project Set A* as these data are a more accurate reflection of the actual movement of projects through the system over time. Nevertheless, for reasons discussed in Section 4, we continue to use the transition probabilities derived from *Project Set B*.

[13] This approach involves the application of equation (9.1) of the following section.

[14] Note that in Figure 11 there is a large drop in the change in the construction proportion in 2006:4 and corresponding increases for the other three states. This is due to a surge in the arrival of new projects at this time that commenced in the latter three states. It should be noted that we also compared the simulated shares with actual. The transition matrix dervived from Project Set A yields satisfactory results, but the predicted values derived from Set B are some distance away from actual. This is not unexpected given that Set B involves a substantial deletion of projects, so the analysis of simulated and actual does not involve a like-with-like comparison. The computations discussed in the paragraph above compare results derived from the Set B transition probabilities and its faster counterpart; as the two results are both based on Set B, they are comparable, which means that the changes in the probabilities in Figure 11 reflect only the impact of speeding up the process.

Occupancy Times Again

Column 5 of Table 14 reproduces from Table 12 the occupancy times of the projects. As these times are implications of the Markov model, a comparison with the "directly observed" occupancy times provides some indication of the ability of the model to match the data. Column 4 of Table 14 gives the corresponding times that are directly observed from the data. As can be seen from panel A, the times are substantially overestimated by the model when the data are not filtered to eliminate the incomplete life histories of the projects. On the other hand, when only the complete histories are considered, the model tends to underestimate the observed times, but now the agreement is considerably better (compare columns 4 and 5 of panel B). One way to summarise of goodness of fit of the model is as follows. If we let $T_i, \hat{T}_i$ be the observed and implied occupancy times spent in state *i*, then $T_i - \hat{T}_i$ is the prediction error and $\log\left(T_i / \hat{T}_i\right)$ is the logarithmic error, which is approximately equal to the proportionate error $\left(\hat{T}_i - T_i\right) / T_i$. The weighted average logarithmic prediction error is $E = \sum_{i=1}^{4} w_i \log\left(T_i / \hat{T}_i\right)$, where w_i is the weight accorded to state *i*. Using as weights the average shares for the count data given in the first four elements of the last row of Table 10, normalised so they have a unit sum, for Project Set B the error measure is $E \times 100 = 16.6$, or about 17 percent.[15] For the Project Set A data, the same error measure is -35.5 percent.

Observed and Fitted Distributions

In any quarter *t+1*, the number of projects in a given state *j* comprises two components, (i) those already in the system that occupied state *i* $(i = 1, \ldots, 6)$ in *t* and have now moved to *j*, which for *i=j*, includes projects previously in *j* and remain there; and (ii) projects that are new to the system in $t+1$ and locate directly in *j*. We can account for both types as follows. Let N_t be the number of projects in *t*, so that $N_{t+1} = N_t + \Delta N_{t+1}$, where $\Delta N_{t+1} = N_{t+1} - N_t$. If s_{it} is the proportion of the pre-existing projects in state *i*, then $s_{it} \cdot N_t$ is the corresponding number, and using the Markov chain, $N_t \sum_{i=1}^{6} s_{it} p_{ij}$ is the number of these projects in state *j* next period. Regarding the flow of new projects, the number in *j* in *t+1* is $\Delta N_{t+1} s_{j,t+1}^{new}$, where $s_{j,t+1}^{new}$ is the corresponding proportion. Accordingly, $N_{t+1} s_{j,t+1} = N_t \sum_{i=1}^{6} s_{it} p_{ij} + \Delta N_{t+1} s_{j,t+1}^{new}$ is the number of both types of projects in *j* at *t+1*, and the proportion is

[15] Using the count data, the average shares of projects for the first four states are 20, 20, 8 and 37 percent, respectively (last row of Table 10), so that the normalised weights are 24, 24, 9 and 44 percent.

(9.1) $$s_{j,t+1} = \alpha_t \left[\sum_{i=1}^{6} s_{it} p_{ij} \right] + (1-\alpha_t) s_{j,t+1}^{new},$$

where $\alpha_t = N_t / N_{t+1}$ is the share of pre-existing projects in the total number.[16] This equation shows that next period's proportion is a weighted average of two terms, one involving the flow of pre-existing projects through the system and the other the new projects.

To implement equation (9.1) for $j = 1, \ldots, 6,$ we proceed as follows:

- For $t = 0$, which corresponds to 2001:1, we set the initial distribution of projects to the corresponding observed vector of proportions in 2001:1, obtained by dividing columns 2 to 7 of Table 11 by the total number of projects (13) so that
$$\mathbf{s}_0' = \mathbf{s}_0'^{new} = (5/13, 1/13, 5/13, 2/13, 0/13, 0/13) = (0.39, 0.8, 0.39, 0.15, 0, 0).$$
- The average transition matrix is pre-multiplied by $\mathbf{s_0'}$ giving an estimated distribution of these 2001:1 projects in 2001:2 of $\mathbf{s}_0'\mathbf{P} = (0.31, 0.07, 0.21, 0.30, 0.06, 0.05)$. For this purpose, we use the transition matrix given in the middle part of panel B of Table 12 and reproduced below equation (6.1) above.
- The total number of projects grows from 13 in 2001:1 to 28 in 2001:2, so that $\alpha_0 = N_0 / N_1 = 13/28 = 0.46.$ Therefore, we weight $\mathbf{s}_0'\mathbf{P}$ by $13/28$ to reflect the proportion of 2001:1 projects that flow into the 2001:2 distribution.
- To the above vector we add $(1-\alpha_0)\mathbf{s}_1'^{new}$, where $\mathbf{s}_1'^{new}$ is the vector of new projects in 2001:2. This vector is weighted by $1-\alpha_0$ to reflect the share of new projects in the total distribution. From row 2 of panel A of Table 11, we have
$$\mathbf{s}_1'^{new} = (4/15, 5/15, 6/15, 0/15, 0/15, 0/15) = (0.27, 0.33, 0.40, 0, 0, 0).$$
- The final fitted distribution for 2001:2 is $\mathbf{s}_1' = \alpha_0 [\mathbf{s}_0'\mathbf{P}] + (1-\alpha_0)\mathbf{s}_1'^{new}$, which is equation (9.1) for $j = 1, \ldots, 6.$ This yields $\mathbf{s}_1' = (0.29, 0.21, 0.31, 0.14, 0.03, 0.02).$
- This process is then repeated for all subsequent quarters.

The fitted distribution of projects can be compared with the corresponding observed distribution, as in Figure 12. As can be seen, the correlations between actual and fitted range from 0.80 to 0.97; while not perfect, the model does a reasonable job in tracking the projects.[17] If we denote by s_{jt} and $\hat{s}_{jt}$ the actual and fitted proportion in state *j*, the quality of the predictions can be

[16] The methodology introduced here was used to simulate the distributions at the end of Section 8.

[17] Note that for the state *completed*, the correlation is 0.94 (panel E of Figure 12). Visually, due to the substantial distance between the two variables in the middle part of the period, this value might seem too high. However, it is correct and in part reflects the common upward trend.

assessed more formally with the test statistic $C_t = \sum_{j=1}^{6} \left(s_{jt} - \hat{s}_{jt}\right)^2 / \hat{s}_{jt}$, which under $H_0 : s_{jt} = \hat{s}_{jt}$, follows a χ^2 distribution with five degrees of freedom. All values of C_t are well below the 95 percent critical value of 11.07, so we are unable to reject the null, thus confirming that the predictions are indeed reasonable. Finally, Figure 13 presents a summary picture of the quality of the predicted shares by plotting against time a weighted average of the logarithmic prediction errors. This shows that the average prediction error is a reasonable 3 percent.

Stability of the Transition Probabilities

A further assumption underpinning the above analysis is time homogeneity, or that the transition probabilities $p_{ij} = P(X_{t+1} = j \mid X_1 = i)$ remain constant over time. As we estimate the transition probabilities by the observed proportions averaged over the entire sample period, one way to check stationarity is to use sub-samples. Panel A of Table 15 first gives the original transition matrix estimated from the full sample, from Table 8, and then two matrices derived by averaging the proportions over the first and second halves of this period. Panel A of Figure 14 is a scatter plot of one set of probabilities against the other and as most points are reasonably close to the 45-degree line, it can be concluded that there is not much instability over time. Next, as a modest sensitivity check, we omit from the full period the first and last years. This removes the "start-up" and "wind-down" effects found in the earlier and later observations that are caused by the requirement that all projects of *Project Set B* begin and end within the period 2001:1, 2007:4. As can be seen from panel B of Table 15 and Figure 14, the result of similar probabilities emerges once again. Accordingly, there does not seem to be much evidence against the assumption of stationarity of the transition probabilities.

We can also formally test for homogeneity between the two halves, that is, $H_0 : p_{ij}(1) = p_{ij}(2),\ i = 1,\ldots,4,\ j = 1,\ldots,6,$ where $p_{ij}(k), k = 1,2,$ is the $(i,j)^{th}$ transition probability in period *k*. As states 5 and 6 are absorbing, rows 5 and 6 of the two transition matrices are identical by construction. For this reason, the corresponding probabilities are excluded from the null. Denote the first and second halves of the sample S_1 and S_2, respectively, and let the number of observations in each be $N_1 = 14$ and $N_2 = 27 - N_1 = 13$. For $k = 1,2,$ let $\overline{c}_{ij}(k) = \left(1/N_k\right) \sum_{h \in S_k} c_{ijh}(k)$ be the average (over S_k) of the number of projects that move in one quarter from state *i* to *j*, and let $\overline{c}_i(k) = \sum_{j=1}^{6} \overline{c}_{ij}(k)$ be the corresponding row total, that is, the average number of projects originating in *i.* Define the estimator of the transition probabilities for S_k as

$\widehat{p}'_{ij}(k) = \overline{c}_{ij}(k)/\overline{c}_i(k)$, and that for the halves combined as $\widehat{p}'_{ij} = \alpha \cdot \widehat{p}'_{ij}(1) + (1-\alpha) \cdot \widehat{p}'_{ij}(2)$, where $\alpha = \overline{c}_i(1)/\left[\overline{c}_i(1) + \overline{c}_i(2)\right] > 0$ is the share of first half in the total. Then, the χ^2 statistic for testing H_0 is

$$\chi^2 = \sum_{k=1}^{2} \sum_{i=1}^{4} \sum_{j=1}^{6} \frac{\left[\overline{c}_{ij}(k) - \overline{c}_i(k)\,\widehat{p}'_{ij}\right]^2}{\overline{c}_i(k)\,\widehat{p}'_{ij}},$$

which, in view of the row sum constraints of the transition matrix, follows a chi-squared distribution with degrees of freedom equal to $max_{i=1,\dots,4,\, j=1,\dots,6}\left[i(j-1)\right] = 20.$ Additionally, the six elements in the off-diagonal lower triangle of the matrix are equal to zero by construction. This reduces the degrees of freedom to $20 - 6 = 14$. As shown in Figure 14, the observed $\chi^2 = 2.38$ for the entire sample and $\chi^2 = 2.49$ for the truncated sample. These values provide insufficient evidence to reject the null that the two transition matrices are equal.

Summary

On the basis of three types of checks on the basic workings of the model, it seems that the flow of resource projects through the various states of the investment process can be approximated by a first-order Markov chain. The average time that projects remain in each state is not too far away from that implied by the model; the fitted and actual distributions of projects are reasonably close; and the transition probabilities do not seem to vary systematically between the first and second halves of the period.

10. CONCLUDING COMMENTS AND FUTURE PROSPECTS

Access Economics' Investment Monitor provides detailed information on most major investment projects in Australia, including a classification of projects as "possible", "under consideration", "committed", "under construction", "deleted" or "completed". While these data are prominently reported in the press, they do not seem to have been previously analysed formally. In this paper, we reported our preliminary explorations with the Monitor data and showed that a Markov chain model gives a number of insights into the operation of the project system as a whole. This model seems to capture the dynamics of the system and leads to summary measures such as mean time spent in each state and the time taken to reach a certain state. We also illustrated how the approach can be used to analyse the possible implications of "speeding up" the system by regulatory reform. This information could be of use to the industry in question, as well as policy makers concerned with balancing environmental issues with economic development.

This research is ongoing and there are several possible future directions including:

- *Determinants of new projects*. It is of considerable interest to inquire about the impact of economic conditions (both current and expected) on the generation of new resource projects. One would expect world commodity prices, the exchange rate, costs and the ease or otherwise of gaining approval for projects as being important determinants. One approach could be to model the share of all projects that are new. In equation (9.1), $s_{j,t+1} = \alpha_t \left[\sum_{i=1}^{6} s_{it} p_{ij} \right] + (1-\alpha_t) s_{j,t+1}^{new}$, the term $\alpha_t = N_t / N_{t+1}$ is the share of pre-existing projects in the total number, so that $\alpha_t' = 1-\alpha_t$ is the share of new projects. To analyse the role of economic conditions, the logistic transformation of the share of new project α_t' could be regressed on relevant variables $(\boldsymbol{x}_t)$, that is, $\log\left[\alpha_t' / (1-\alpha_t')\right] = \boldsymbol{x}_t'\boldsymbol{\beta} + \boldsymbol{\varepsilon}_t$, where $\boldsymbol{\beta}$ is a vector of coefficients and $\boldsymbol{\varepsilon}_t$ is a disturbance term, so that $\alpha_t' = \exp(\boldsymbol{x}_t'\boldsymbol{\beta} + \boldsymbol{\varepsilon}_t) / \left[1 + \exp(\boldsymbol{x}_t'\boldsymbol{\beta} + \boldsymbol{\varepsilon}_t)\right]$. As $\alpha_t + \alpha_t' = 1$, $\left[\alpha_t / (1-\alpha_t)\right] = \left[\alpha_t' / (1-\alpha_t')\right]^{-1}$, so that this model implies for the pre-existing projects $\log\left[\alpha_t / (1-\alpha_t)\right] = -\{\boldsymbol{x}_t'\boldsymbol{\beta} + \boldsymbol{\varepsilon}\}$ and $\alpha_t = \exp\left(-\{\boldsymbol{x}_t'\boldsymbol{\beta} + \boldsymbol{\varepsilon}\}\right) / \left[1 + \exp\left(-\{\boldsymbol{x}_t'\boldsymbol{\beta} + \boldsymbol{\varepsilon}\}\right)\right]$.
- *A new new state.* Equation (9.1) is one way to take account of the entry of new projects into the investment pipeline. An alternative approach that treats new and pre-existing projects symmetrically is to add a state for new projects. That is, we add to the six previous states a new state that refers to projects "born" in *t+1*. Let the new state be labelled "0" and p_{0j} be the probability that a new project commences its life in state *j*, *j*=0,1,…,6, with $p_{00} = 0$ and $\sum_{j=0}^{6} p_{0j} = 1$. Then the transition matrix associated with the expanded 7×7 system is the original 6×6 matrix, $\boldsymbol{P}$, bordered by a column of zeros and a row of new project probabilities, $\left[p_{01} \quad \cdots \quad p_{06}\right]$:

$$
\begin{array}{r} \\ \text{0. New} \\ \text{1. Possible} \\ \vdots \\ \text{6. Deleted} \end{array}
\begin{array}{c} \begin{array}{cccc} 0 & 1 & \cdots & 6 \end{array} \\ \left[\begin{array}{c|ccc} 0 & p_{01} & \cdots & p_{06} \\ \hline 0 & & & \\ \vdots & & \boldsymbol{P} & \\ 0 & & & \end{array}\right] \end{array}.
$$

  This approach could be used to compare the actual and fitted distributions of the projects.

- *Speed of the system.* A related issue is whether the transition probabilities p_{ij} vary with economic conditions. In the previous section we provided some evidence that these probabilities were the same in the two halves of the period considered, but it still is useful to analyse further the possible dependence of the p_{ij} on economic variables. To illustrate a possible way of proceeding, let p_{ijt} be the proportion of projects in state *i* in period *t* that move to *j* in *t+1* and suppose this proportion depends on a single economic variable x_t as follows: $p_{ijt} = \phi_j^i + \theta_j^i \cdot f^i(x_t) + \varepsilon_{jt}^i$, for some function $f^i(x_t)$ and where ε_{jt}^i is a disturbance term. Here, for a fixed state of origin *i* (indicated by the *i* superscript on the right-hand side of the equation), there are $j = 1, \dots, 6$ equations for the original 6-state system, one for each destination state. The terms ϕ_j^i and θ_j^i are parameters in the j^{th} equation, which in view of $\sum_{j=1}^{6} p_{ijt} = 1$, satisfy the cross-equation constraints $\sum_{j=1}^{6} \phi_j^i = 1$ and $\sum_{j=1}^{6} \theta_j^i = 0$; the disturbances satisfy $\sum_{j=1}^{6} \varepsilon_{jt}^i = 0$. As there are six states of origin, there are also six sets of six equations, but due to the adding up constraints, there are only five independent equations in each set.
- *Transitions as a binary choice..* An alternative to the above approach to making the transitions time dependent is to treat a transition from one state to another as a discrete event determined by economic factors. If we record a move of a project from one state to another by a "1" and a "0" for remaining unchanged, a discrete-choice model, such as logit or probit, could then be used to analyse the dependence on economic variables.
- *Partial demographic accounting.* We used information on only those projects that experienced a complete "life cycle" within the sample period, that is, projects for which birth and death were both observed. This approach was adopted to eliminate projects that remained at either the beginning or end of the cycle for abnormally long times; the inclusion of these atypical projects could contaminate the results. An alternative approach that is more economical with data would be to eliminate only those parts of the histories of these projects that refer to the beginning or end of the process. This partial demographic accounting approach entails an unbalanced panel that contains substantially more observations than before.

APPENDIX

On checking the data, several issues were identified:

- *Issues that affect the number of projects*. (i) Three projects (project numbers 1332, 1387, 8281) went to the absorbing states *completed* or *deleted* at time t and then subsequently went to an earlier state in $t+1$. These projects were deleted from Project Set A. Note that this is different to the situation discussed in Section 4 where one reason for excluding projects from Project Set B was if they moved backwards from one transition state to another. (ii) In five cases, an existing project was wrongly assigned a new project number as it progressed through time. This problem was corrected.
- *Issues that do not affect the number of projects*. (i) Project number 30 is classified as *deleted* in 2004Q3 and 2004Q4; the observation for 2004Q4 was deleted. (ii) Projects with cost $0 are assumed to be n/a, and thus excluded from the calculation of means values. Most of these instances occur in the *possible* state of the project, but there are exceptions. Some projects also have gaps in the history of their value; for example, a project could start with some non-zero value, this subsequently become zero and then finally end with a non-zero value. We treat these instances as n/a. (iii) About 40 projects had missing data for 2006Q3. To correct this problem, we proceeded as follows:
    - If a state change for a project is observed in the subsequent quarter, 2006Q4, we then checked if it is assigned the "^" symbol that the Monitor uses to signify a project state change. If the symbol is present, we use for 2006Q3 the state recorded for 2006Q2. If the symbol is not present, we use the 2006Q4 state.
    - For projects whose first observation is in 2006Q4, we check if it has the "*" symbol that the Monitor uses to signify a new project. If the symbol is present, we do nothing. If the symbol is not present, we infer that the project should have been recorded as new in the previous quarter and add an observation for the project for 2006Q3.
    - For projects whose last observation is in 2006Q2 that is neither completed nor deleted, there is no way of knowing which states were occupied in 2006Q3. Accordingly, nothing is done about these. That is, the histories of these projects were included up to and including 2006Q2.
- *Number of observations*. After the above edits, there are a total of 1,077 projects, 13,383 project quarters and there are no value data in 3,670 cases.

- *Value data*. Not all observations have value data. All value related calculations only use observations with available data (i.e. averages only take into account projects for which we know the value).

  Details of the Project Set B data are contained in Figures A1-A4.

TABLE 1

STATES OF PROJECTS

State	Status	Definition
1	Possible	No early decision whether to proceed with the project is likely
2	Under Consideration	A decision whether to proceed with a project is expected in the reasonably near future
3	Committed	A decision to proceed has been announced but construction has not yet started
4	Under Construction	Projects which are underway
5	Completed	Projects completed in the preceding quarter
6	Deleted	Projects deleted in the preceding quarter

Note: Definitions according to Access Economics Investment Monitor (2001-2007).

TABLE 2

RESOURCE PROJECTS

Industry	Sub-Industry
Mining	Coal
	Metal Ores
	Oil and Gas Extraction
	Other
Electricity, Gas and Water	Electricity Supply
	Gas Supply

Note: Classifications of Industry and Sub-Industry according to Access Economics Investment Monitor (2001-2007).

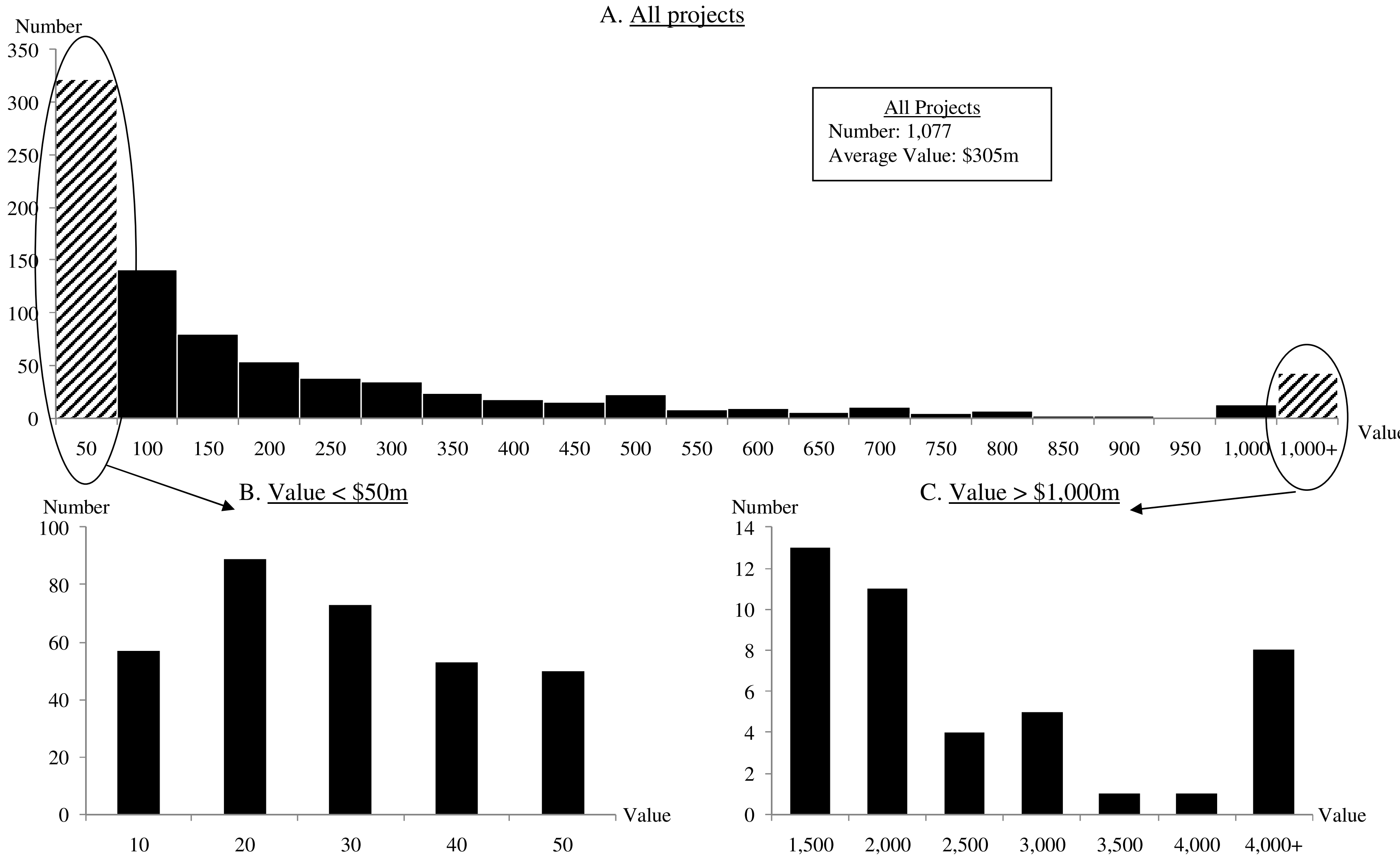
TABLE 3
EXAMPLES OF PROJECTS
(States; cost in parentheses, $m)
(Project Set *A*)

Project Number	Quarter 2001:1	2001:2	2001:3	2001:4	2002:1	2002:2	2002:3	2002:4	2003:1	2003:2	2003:3	2003:4	2004:1	2004:2	2004:3	2004:4	2005:1	2005:2
3	5 (320)																	
21	2 (200)	2 (200)	2 (200)	2 (200)	2 (200)	2 (200)	2 (200)	2 (200)	2 (200)	2 (200)	2 (200)	2 (200)	2 (200)	2 (200)	2 (200)	2 (200)	2 (200)	1 (200)
82	1 (170)	1 (220)	1 (220)	1 (220)	1 (220)	1 (220)	1 (220)	1 (275)	1 (275)	3 (275)	3 (355)	2 (355)	2 (355)	4 (355)	4 (355)	4 (355)	4 (355)	4 (355)
1,666	4 (800)	4 (800)	4 (800)	5 (800)														
2,376	1 (75)	1 (75)	1 (75)	1 (75)	3 (100)	3 (100)	3 (100)	3 (100)	3 (100)	3 (100)	3 (100)	4 (100)	4 (100)	5 (100)				
2,486	2 (-)	2 (-)	2 (-)	2 (-)	2 (-)	2 (-)	2 (-)	2 (-)	2 (-)	2 (-)	2 (-)	3 (-)	6 (-)					
4,542			1 (15)	1 (15)	1 (15)	1 (15)	2 (75)	2 (75)	4 (75)	2 (75)	2 (291)	2 (291)	3 (291)	4 (291)	4 (291)	4 (291)	4 (291)	4 (291)
4,806					2 (6)	2 (6)	2 (6)	2 (6)	2 (6)	2 (11)	4 (11)	4 (11)	4 (11)	4 (11)	5 (11)			
5,119						3 (40)	3 (40)	3 (40)	4 (40)	4 (40)	4 (40)	4 (40)	4 (40)	4 (40)	4 (40)	4 (40)	4 (40)	4 (40)
6,554													3 (-)	3 (-)	3 (-)	4 (-)	4 (-)	4 (-)

Notes:
1. To interpret this table consider, for example, the first entry in the second column, 5 (320). This indicates that project 3 occupied state 5 (*completed*) in the quarter 2001:1. This project is estimated to cost $320m.
2. Project details are as follows:

Project No.	Company	Project	Industry	Sub-industry
3	National Power Australia	Redbank Power Station (130MW), NSW	Electricity, Gas and Water	Electricity Supply
21	Noranda Pacific & Buka Minerals	Lady Loretta Silver, Lead, Zinc, Project, QLD	Mining	Metal Ores
82	North Ltd. (Rio Tinto)	Cowal Gold Project, NSW	Mining	Metal Ores
1,666	CS Energy, Anglo Coal	Coal Fired Baseload Power Plant (840MW), QLD	Electricity, Gas and Water	Electricity Supply
2,376	Hydro Tasmania	Woolnorth Property Wind Farm – Stage 2 (75MW), TAS	Electricity, Gas and Water	Electricity Supply
2,486	Exodus Minerals & Deep Yellow	Mikado (Mt. Lebanon) Gold Deposit, WA	Mining	Metal Ores
4,542	MIM Holdings	Rolleston Coal Mine, QLD	Mining	Coal
4,806	Mincor Resources	Upgrade of Redross Nickel Deposit, WA	Mining	Metal Ores
5,119	Power and Water Authority	Installation of Solar Dishes in Remote Comm., NT	Electricity, Gas and Water	Electricity Supply
6,554	Hydro Tasmania	Rosebery Diesel Generation Plant, TAS	Electricity, Gas and Water	Electricity Supply

FIGURE 1
PROJECT VALUES, 2001:1 – 2007:4
(Project Set *A*)



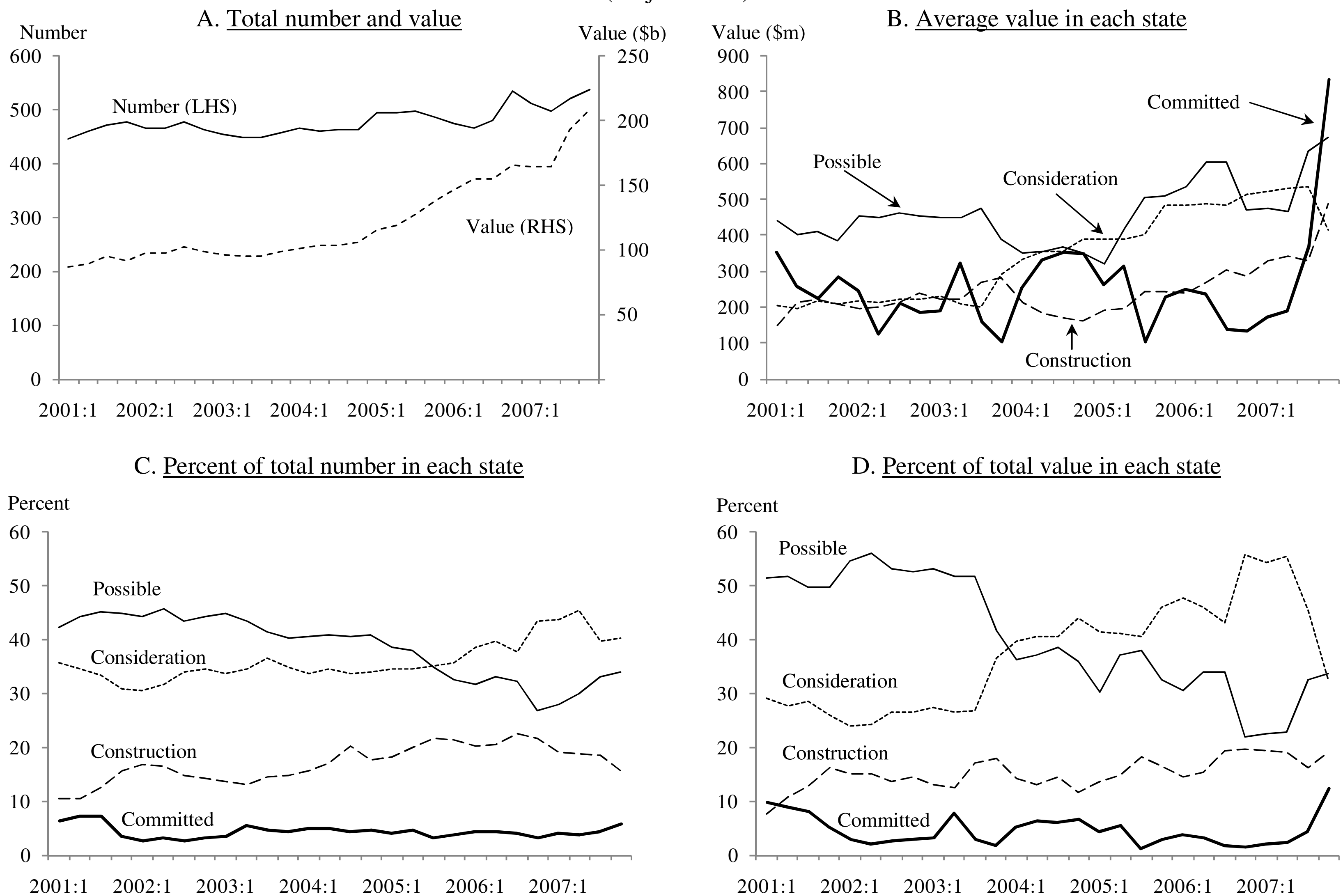
Note: 1. This figure displays the average values of projects over their entire recorded lifetime in the *Investment Monitor*. For example, project number 2,376 shown in Table 3 (Hydro Tasmania's 75MW Wind Farm) spends four quarters with a value of $75m followed by ten quarters at $100m. Its average lifetime value is thus $[4\times 75 + 10\times 100]/14$ = $92.9m. This project is recorded as part of the second column in panel A which gives the number of projects with value of $50m - $100m.

2. The average value of all projects (contained in the box in panel A) is the average of the average lifetime value of all projects.

TABLE 4
THE PROJECTS, 2001:1 – 2007:4 (Project Set *A*)

Quarter	A. Number							B. Value							C. Average Value						
	Percent of total							Percent of total							$m						
	Possible	Consideration	Committed	Construction	Completed	Deleted	Total	Possible	Consideration	Committed	Construction	Completed	Deleted	Total ($m)	Possible	Consideration	Committed	Construction	Completed	Deleted	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
2001:1	42.15	35.65	6.28	10.54	4.04	1.35	446	51.45	29.20	9.85	7.66	1.27	0.57	86,149	439	203	354	150	69	163	276
2001:2	44.23	34.42	7.19	10.46	3.27	0.44	459	51.64	27.67	9.00	10.62	0.98	0.09	88,652	402	195	257	214	79	39	270
2001:3	45.13	33.26	7.20	12.50	0.64	1.27	472	49.65	28.47	7.97	12.82	0.10	0.98	94,913	410	218	223	221	32	155	282
2001:4	44.98	30.75	3.56	15.69	3.77	1.26	478	49.78	26.01	5.23	16.07	1.58	1.34	91,595	383	209	282	207	85	408	269
2002:1	44.33	30.41	2.57	16.70	3.21	2.78	467	54.59	23.84	3.00	14.93	1.17	2.47	97,845	453	216	245	195	95	241	292
2002:2	45.82	31.69	3.21	16.49	1.07	1.71	467	55.99	24.21	1.92	15.16	0.51	2.21	97,580	448	213	125	200	99	540	295
2002:3	43.40	33.96	2.73	14.68	3.77	1.47	477	53.16	26.62	2.68	13.54	1.70	2.29	102,525	462	220	211	214	97	335	297
2002:4	44.18	34.48	3.23	14.22	2.59	1.29	464	52.47	26.65	2.84	14.54	0.48	3.02	98,707	454	221	187	239	43	497	304
2003:1	44.93	33.70	3.52	13.66	2.64	1.54	454	53.04	27.35	3.10	12.95	2.95	0.61	96,537	449	232	187	223	285	98	305
2003:2	43.56	34.67	5.33	13.11	2.67	0.67	450	51.78	26.44	7.85	12.40	1.23	0.30	94,727	450	210	323	222	116	143	300
2003:3	41.33	36.44	4.67	14.44	1.33	1.78	450	51.60	26.86	2.99	17.00	0.60	0.95	95,082	476	201	158	269	113	227	300
2003:4	40.26	34.79	4.38	14.88	2.41	3.28	457	41.78	36.65	1.79	17.86	0.57	1.34	98,679	389	292	104	280	63	165	302
2004:1	40.56	33.69	4.94	15.67	3.00	2.15	466	36.18	39.65	5.03	14.25	3.60	1.29	101,373	349	335	255	212	304	187	305
2004:2	40.74	34.64	4.79	16.99	1.96	0.87	459	37.23	40.61	6.40	13.00	2.46	0.29	103,232	356	355	330	184	318	300	315
2004:2	40.48	33.77	4.33	20.13	0.65	0.65	462	38.49	40.69	6.14	14.35	0.21	0.12	103,161	368	356	352	168	74	120	307
2004:4	40.95	34.05	4.53	17.67	2.59	0.22	464	35.95	44.14	6.56	11.60	1.75	-	105,585	352	388	346	163	154	-	315
2005:1	38.46	34.41	4.05	18.22	2.83	2.02	494	30.34	41.52	4.32	13.68	1.82	8.31	114,835	320	388	261	192	149	1,364	324
2005:2	37.85	34.62	4.66	19.84	2.02	1.01	494	37.21	41.22	5.54	14.77	0.82	0.44	118,494	420	391	313	197	108	173	337
2005:3	34.81	35.01	3.22	21.53	3.42	2.01	497	38.05	40.52	1.22	18.15	1.33	0.72	127,610	506	404	104	241	100	154	356
2005:4	32.65	35.73	3.70	21.36	4.52	2.05	487	32.48	46.12	2.80	16.49	1.42	0.68	137,803	509	485	227	242	115	118	388
2006:1	31.71	38.69	4.44	20.30	4.44	0.42	473	30.40	47.69	3.60	14.49	2.72	1.10	146,112	535	484	251	241	221	1,600	412
2006:2	33.05	39.70	4.29	20.60	1.93	0.43	466	33.87	45.90	3.06	15.40	1.54	0.22	154,742	602	487	237	271	264	171	440
2006:3	32.15	37.79	3.97	22.55	3.34	0.21	479	33.85	43.16	1.61	19.36	1.54	0.48	155,142	604	482	139	303	149	750	431
2006:4	26.78	43.45	3.18	21.72	4.12	0.75	534	21.87	55.78	1.38	19.53	1.36	0.08	165,420	470	515	134	286	118	67	406
2007:1	28.07	43.66	3.90	19.10	4.48	0.78	513	22.59	54.22	2.10	19.26	1.75	0.09	164,461	476	524	173	330	125	48	422
2007:2	29.84	45.36	3.83	18.75	2.22	-	496	22.72	55.32	2.19	19.19	0.58	-	164,520	467	529	189	343	120	-	443
2007:3	33.21	39.73	4.41	18.43	3.26	0.96	521	32.55	45.31	4.42	16.12	1.44	0.15	192,909	634	536	371	331	164	143	485
2007:4	34.08	40.22	5.77	15.64	3.54	0.74	537	33.61	32.61	12.43	19.00	2.17	0.18	208,100	672	416	834	488	238	190	520
Average	38.56	36.03	4.35	16.99	2.85	1.22	478	40.51	37.30	4.54	15.15	1.42	1.08	121,660	459	347	256	244	139	300	346

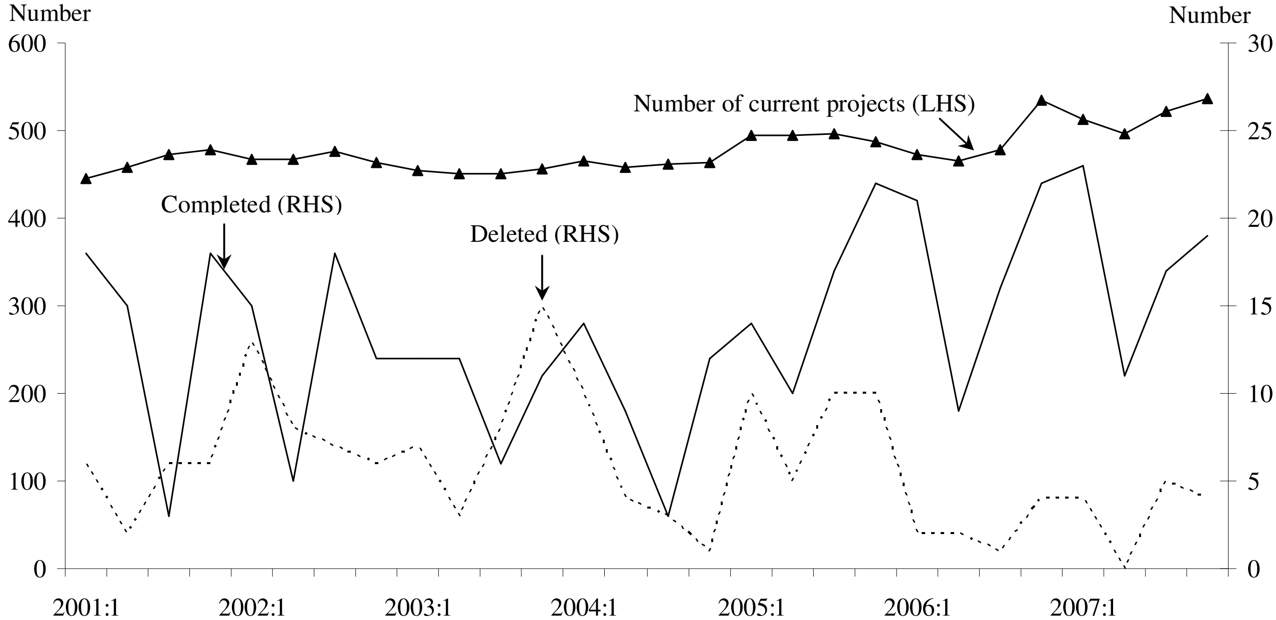
FIGURE 2
LIVE PROJECTS, 2001:1 – 2007:4
(Project Set *A*)



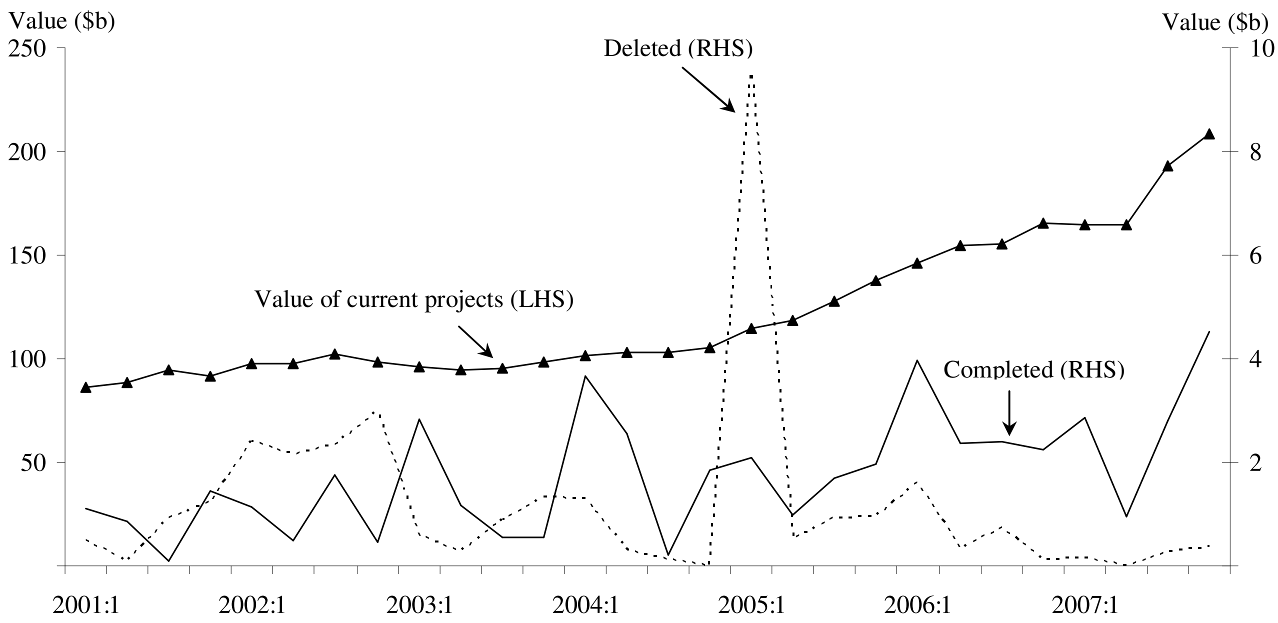
Note: For information on the other two states, completed and deleted, see Figure 3.

FIGURE 3
PROJECT SEPARATIONS, 2001:1 – 2007:4
(*Project Set A*)

A. Count



B. Value



Note: The 2005:1 spike in the value of deleted projects (panel B) is due to two large projects with a total value of $8.5b. The details of these projects are given below:

Project No.	Company	Project	Cost ($b)
891	Queensland Energy Resources	Stuart Oil Shale full-scale commercial plant, stage 3 (85,000 bd)	2.5
1356	Shell Australia / Woodside / Phillips / Osaka Gas	Sunrise Gas Development. LNG plant (7.5 mtpa), reserves from Evan, Loxton, Sunrise & Troubador Shoal fields.	6

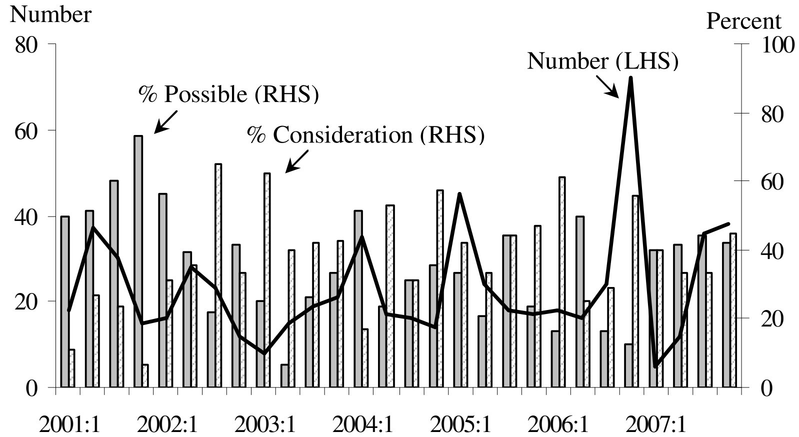
TABLE 5
NEW PROJECTS IN EACH STATE, 2001:1 – 2007:4 (Project Set *A*)

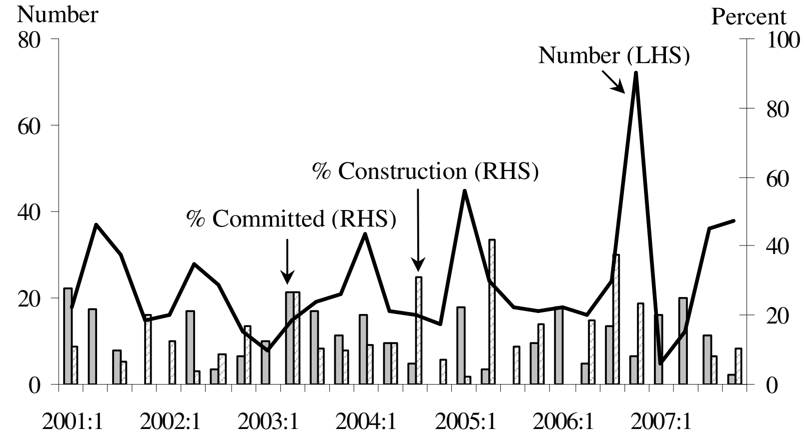
	A. Number									B. Value ($m)						C. Average Value ($m)					
							Total							Total						Total	
Quarter	Possible	Consideration	Committed	Construction	Completed	Deleted	New	Current	Finished	Possible	Consideration	Committed	Construction	New	Current	Possible	Consideration	Committed	Construction	New	Current
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
2001:1	9	2	5	2	-	-	18	446	24	175	28	227	47	477	86,149	44	14	45	47	40	276
2001:2	19	10	8	-	-	-	37	459	17	1,358	1,060	931	-	3,349	88,652	123	118	116	-	120	270
2001:3	18	7	3	2	-	-	30	472	9	1,058	856	415	130	2,459	94,913	176	214	138	65	164	282
2001:4	11	1	-	3	-	-	15	478	24	405	164	-	220	789	91,595	51	164	-	110	72	269
2002:1	9	5	-	2	-	-	16	467	28	7,070	56	-	38	7,164	97,845	1,010	28	-	19	651	292
2002:2	11	10	6	1	-	-	28	467	13	725	383	293	65	1,466	97,580	242	77	49	65	98	295
2002:3	5	15	1	2	-	-	23	477	25	1,040	3,102	25	11	4,178	102,525	520	259	25	11	261	297
2002:4	5	4	1	2	-	-	12	464	18	100	50	215	8	373	98,707	100	50	215	8	93	304
2003:1	2	5	1	-	-	-	8	454	19	120	936	12	-	1,068	96,537	60	187	12	-	134	305
2003:2	1	6	4	4	-	-	15	450	15	-	821	85	63	969	94,727	-	137	28	16	75	300
2003:3	5	8	4	2	-	-	19	450	14	685	460	345	151	1,641	95,082	228	77	115	76	117	300
2003:4	7	9	3	2	-	-	21	457	26	650	851	216	283	2,000	98,679	130	122	72	142	118	302
2004:1	18	6	7	4	-	-	35	466	24	86	186	712	254	1,238	101,373	17	62	142	64	73	305
2004:2	4	9	2	2	-	-	17	459	13	315	1,025	23	46	1,409	103,232	158	146	12	23	108	315
2004:2	5	5	1	5	-	-	16	462	6	1,029	554	50	292	1,925	103,161	343	111	50	58	138	307
2004:4	5	8	-	1	-	-	14	464	13	-	1,233	-	-	1,233	105,585	-	176	-	-	176	315
2005:1	15	19	10	1	-	-	45	494	24	6,953	1,304	1,113	25	9,395	114,835	869	163	124	25	361	324
2005:2	5	8	1	10	-	-	24	494	15	923	1,648	114	234	2,919	118,494	462	330	114	26	172	337
2005:3	8	8	-	2	-	-	18	497	27	6,400	1,423	-	9	7,832	127,610	1,067	285	-	9	653	356
2005:4	4	8	2	3	-	-	17	487	32	2,256	2,523	843	789	6,411	137,803	564	360	422	263	401	388
2006:1	3	11	4	-	-	-	18	473	23	780	5,932	148	-	6,860	146,112	260	539	37	-	381	412
2006:2	8	4	1	3	-	-	16	466	11	9,828	829	5	457	11,119	154,742	1,229	207	5	152	695	440
2006:3	4	7	4	9	-	-	24	479	17	635	324	311	708	1,978	155,142	212	108	104	79	110	431
2006:4	9	40	6	17	-	-	72	534	26	2,450	5,389	853	1,747	10,439	165,420	490	234	142	109	209	406
2007:1	2	2	1	-	-	-	5	513	27	530	10	200	-	740	164,461	265	10	200	-	185	422
2007:2	5	4	3	-	-	-	12	496	11	360	730	822	-	1,912	164,520	120	243	274	-	212	443
2007:3	16	12	5	3	-	-	36	521	22	13,379	2,361	473	239	16,452	192,909	1,338	295	95	80	633	485
2007:4	16	17	1	4	-	-	38	537	23	6,996	3,872	600	54	11,522	208,100	875	553	600	18	606	520
Average	8	9	3	3	-	-	23	478	20	2,368	1,361	323	210	4,261	121,660	391	188	112	52	252	346

Notes: 1. Columns 9 and 16 are equal to columns 8 and 15 of Table 4 respectively.
2. Column 10 is the number of projects that entered either the *Completed* or *Deleted* state in that quarter.
3. Column 9 (Total Current) in quarter t = [entry in t-1] + [column 8 (New) in t] – [column 10 (Finished) in t-1].

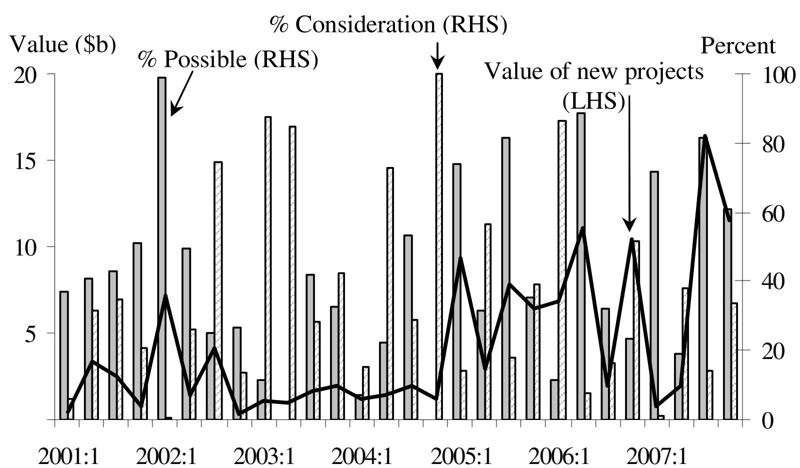
FIGURE 4
NEW PROJECTS, 2001:1 – 2007:4
(*Project Set A*)

A. <u>Count</u>





B. <u>Value</u>



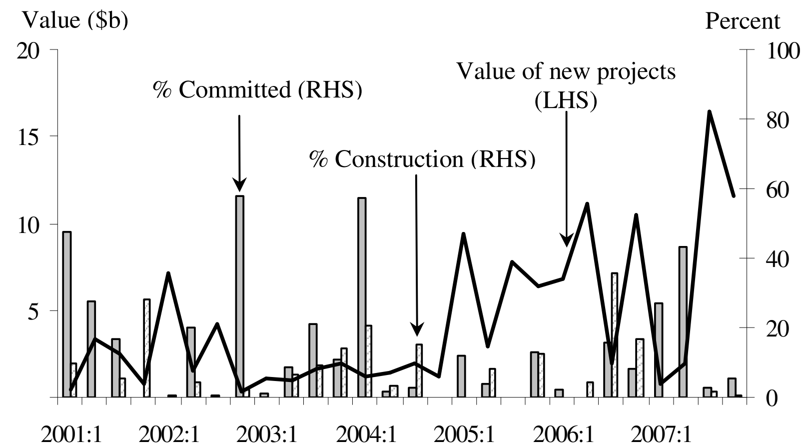


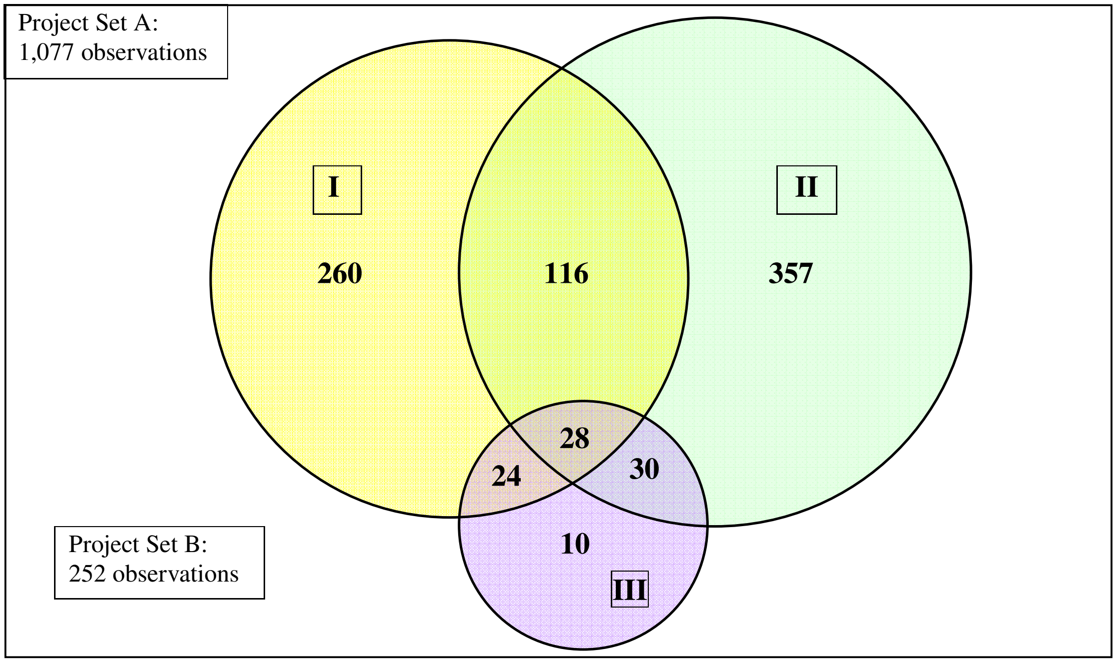
TABLE 6
EXAMPLES OF
TRANSITION MATRICES, COUNT DATA
(Project Set *A*)

Transitions from quarter		State *i* in period *t*	Number of transitions State *j* in period *t*+1							Transition probabilities State *j* in period *t*+1						
t	*t+1*		1	2	3	4	5	6	Total	1	2	3	4	5	6	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
2001:1	2001:2	1. Possible	183	3	0	1	1	0	188	0.973	0.016	0	0.005	0.005	0	1
		2. Consideration	1	145	7	3	2	1	159	0.006	0.912	0.044	0.019	0.013	0.006	1
		3. Committed	0	0	18	9	1	0	28	0	0	0.643	0.321	0.036	0	1
		4. Construction	0	0	0	35	11	1	47	0	0	0	0.745	0.234	0.021	1
		5. Completed	0	0	0	0	0	0	0	0	0	0	0	1	0	1
		6. Deleted	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2004:1	2004:2	1. Possible	181	4	0	0	1	3	189	0.958	0.021	0	0	0.005	0.016	1
		2. Consideration	2	144	3	7	0	1	157	0.013	0.917	0.019	0.045	0	0.006	1
		3. Committed	0	1	16	6	0	0	23	0	0.043	0.696	0.261	0	0	1
		4. Construction	0	1	1	63	8	0	73	0	0.014	0.014	0.863	0.110	0	1
		5. Completed	0	0	0	0	0	0	0	0	0	0	0	1	0	1
		6. Deleted	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2007:3	2007:4	1. Possible	167	1	1	0	0	4	173	0.965	0.006	0.006	0	0	0.023	1
		2. Consideration	0	197	4	5	1	0	207	0	0.952	0.019	0.024	0.005	0	1
		3. Committed	0	0	23	0	0	0	23	0	0	1	0	0	0	1
		4. Construction	0	1	2	75	18	0	96	0	0	0.021	0.781	0.188	0	1
		5. Completed	0	0	0	0	0	0	0	0	0	0	0	1	0	1
		6. Deleted	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Average over 27		1. Possible	173	4	1	2	1	3	183	0.944	0.024	0.003	0.008	0.004	0.017	1
2001:1 – 2007:4		2. Consideration	2	158	3	4	1	2	171	0.011	0.926	0.020	0.023	0.008	0.012	1
		3. Committed	0	1	13	6	0	0	20	0.008	0.030	0.667	0.264	0.013	0.018	1
		4. Construction	0	1	0	69	11	0	81	0.001	0.008	0.003	0.844	0.138	0.006	1
		5. Completed	0	0	0	0	0	0	0	0	0	0	0	1	0	1
		6. Deleted	0	0	0	0	0	0	0	0	0	0	0	0	1	1

TABLE 7
EXAMPLES OF
TRANSITION MATRICES, VALUE DATA
(Project Set *A*)

Transitions from quarter		State *i* in period *t*	Value of transitions ($m) State *j* in period *t*+1							Transition probabilities State *j* in period *t*+1						
t	*t+1*		1	2	3	4	5	6	Total	1	2	3	4	5	6	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
2001:1	2001:2	1. Possible	44,34	101	0	300	0	0	44,743	0.991	0.002	0	0.007	0	0	1
		2. Consideration	80	23,365	1,439	390	0	60	25,334	0.003	0.922	0.057	0.015	0	0.002	1
		3. Committed	0	0	5,611	2,875	0	0	8,486	0	0	0.661	0.339	0	0	1
		4. Construction	0	0	0	5,851	872	17	6,740	0	0	0	0.868	0.129	0.003	1
		5. Completed	0	0	0	0	0	0	0	0	0	0	0	1	0	1
		6. Deleted	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2004:1	2004:2	1. Possible	37,38	111	0	0	124	300	37,920	0.986	0.003	0	0	0.003	0.008	1
		2. Consideration	730	40,791	2,470	630	0	0	44,621	0.016	0.914	0.055	0.014	0	0	1
		3. Committed	0	0	4,105	983	0	0	5,088	0	0	0.807	0.193	0	0	1
		4. Construction	0	0	10	11,766	2,418	0	14,194	0	0	0.001	0.829	0.170	0	1
		5. Completed	0	0	0	0	0	0	0	0	0	0	0	1	0	1
		6. Deleted	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2007:3	2007:4	1. Possible	62,94	420	166	0	0	380	63,908	0.985	0.007	0.003	0	0	0.006	1
		2. Consideration	0	63,245	16,546	12,390	35	0	92,216	0	0.686	0.179	0.134	0	0	1
		3. Committed	0	0	8,523	0	0	0	8,523	0	0	1.000	0	0	0	1
		4. Construction	0	315	30	27,102	4,484	0	31,931	0	0.010	0.001	0.849	0.140	0	1
		5. Completed	0	0	0	0	0	0	0	0	0	0	0	1	0	1
		6. Deleted	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Average over 27 2001:1 – 2007:4		1. Possible	43,19	2,803	187	220	53	743	47,206	0.917	0.056	0.004	0.005	0.001	0.017	1
		2. Consideration	992	43,936	1,740	1,094	52	358	48,173	0.019	0.915	0.035	0.017	0.001	0.011	1
		3. Committed	43	109	3,063	1,383	8	88	4,695	0.014	0.022	0.658	0.282	0.002	0.023	1
		4. Construction	27	148	13	16,614	1,683	15	18,501	0.001	0.008	0.001	0.898	0.091	0.001	1
		5. Completed	0	0	0	0	0	0	0	0	0	0	0	1	0	0
		6. Deleted	0	0	0	0	0	0	0	0	0	0	0	0	1	0

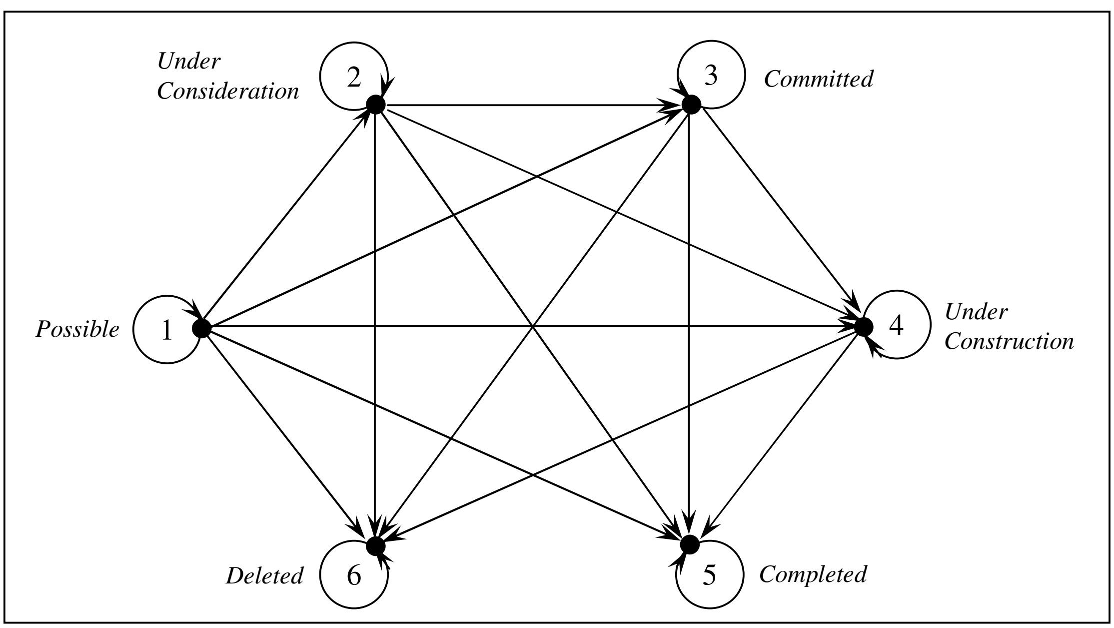
FIGURE 5
FILTERING THE DATA



Notes:

1. Area of whole rectangle = Entire sample of *Project Set A* (1,077 projects).
2. Area I = Projects starting before 2001:1 (260+116+24+28 = 428 projects).
3. Area II = Projects present and neither *completed* nor *deleted* by 2007:4 (357+116+28+30 = 531 projects).
4. Area III = Projects that move *backwards* (10+24+28+30 = 92 projects).
5. Rectangle-I-II-III+intersections = *Project Set B* (1,077-428-531-92+116+24+30+28+28 = 252 projects).

FIGURE 6
STATE TRANSITION GRAPH
(Project Set *B*)



Note: The figure indicates the one-quarter transitions of projects from state *i* to state *j*, *i*, *j* = 1, …, 6, $i \leq j$.

TABLE 8
MORE EXAMPLES OF
TRANSITION MATRICES, COUNT DATA
(Project Set *B*)

Transitions from quarter		State *i* in period *t*	Number of transitions State *j* in period *t*+1							Transition probabilities State *j* in period *t*+1						
t	*t+1*		1	2	3	4	5	6	Total	1	2	3	4	5	6	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
2001:1	2001:2	1. Possible	5	0	0	0	0	0	5	1	0	0	0	0	0	1
		2. Consideration	0	1	0	0	0	0	1	0	1	0	0	0	0	1
		3. Committed	0	0	0	5	0	0	5	0	0	0	1	0	0	1
		4. Construction	0	0	0	2	0	0	2	0	0	0	1	0	0	1
		5. Completed	0	0	0	0	0	0	0	0	0	0	0	1	0	1
		6. Deleted	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2004:1	2004:2	1. Possible	20	0	0	0	0	2	22	0.909	0	0	0	0	0.091	1
		2. Consideration	0	31	1	1	0	0	33	0	0.939	0.030	0.030	0	0	1
		3. Committed	0	0	9	3	0	0	12	0	0	0.750	0.250	0	0	1
		4. Construction	0	0	0	31	5	0	36	0	0	0	0.861	0.139	0	1
		5. Completed	0	0	0	0	0	0	0	0	0	0	0	1	0	1
		6. Deleted	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2007:3	2007:4	1. Possible	0	0	0	0	0	2	2	0	0	0	0	0	1	1
		2. Consideration	0	0	0	0	1	0	1	0	0	0	0	1	0	1
		3. Committed	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		4. Construction	0	0	0	0	13	0	13	0	0	0	0	1	0	1
		5. Completed	0	0	0	0	0	0	0	0	0	0	0	1	0	1
		6. Deleted	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Average over 27 2001:1 – 2007:4		1. Possible	13.6	0.4	0.1	0.6	0.2	1.1	16.0	0.798	0.021	0.012	0.036	0.015	0.118	1
		2. Consideration	0	15.1	0.6	1.2	0.7	0.7	18.4	0	0.758	0.033	0.062	0.108	0.039	1
		3. Committed	0	0	3.0	2.6	0.1	0	5.7	0	0	0.531	0.429	0.032	0.008	1
		4. Construction	0	0	0	25.3	6.3	0.1	31.7	0	0	0	0.783	0.209	0.008	1
		5. Completed	0	0	0	0	0	0	0	0	0	0	0	1	0	1
		6. Deleted	0	0	0	0	0	0	0	0	0	0	0	0	1	1

TABLE 9
MORE EXAMPLES OF
TRANSITION MATRICES, VALUE DATA
(Project Set *B*)

Transitions from quarter		State *i* in period *t*	Value of transitions ($m) State *j* in period *t*+1							Transition probabilities State *j* in period *t*+1						
t	*t+1*		1	2	3	4	5	6	Total	1	2	3	4	5	6	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
2001:1	2001:2	1. Possible	175	0	0	0	0	0	175	1	0	0	0	0	0	1
		2. Consideration	0	8	0	0	0	0	8	0	1	0	0	0	0	1
		3. Committed	0	0	0	227	0	0	227	0	0	0	1	0	0	1
		4. Construction	0	0	0	47	0	0	47	0	0	0	1	0	0	1
		5. Completed	0	0	0	0	0	0	0	0	0	0	0	1	0	1
		6. Deleted	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2004:1	2004:2	1. Possible	1,743	0	0	0	0	0	1,743	1	0	0	0	0	0	1
		2. Consideration	0	1,748	1,100	11	0	0	2,859	0	0.611	0.385	0.004	0	0	1
		3. Committed	0	0	816	577	0	0	1,393	0	0	0.586	0.414	0	0	1
		4. Construction	0	0	0	2,252	579	0	2,831	0	0	0	0.795	0.205	0	1
		5. Completed	0	0	0	0	0	0	0	0	0	0	0	1	0	1
		6. Deleted	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2007:3	2007:4	1. Possible	0	0	0	0	0	300	300	0	0	0	0	0	1	1
		2. Consideration	0	0	0	0	35	0	35	0	0	0	0	1	0	1
		3. Committed	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		4. Construction	0	0	0	0	1,854	0	1,854	0	0	0	0	1	0	1
		5. Completed	0	0	0	0	0	0	0	0	0	0	0	1	0	1
		6. Deleted	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Average over 27 2001:1 – 2007:4		1. Possible	985	68	10	69	15	76	1,223	0.759	0.045	0.013	0.059	0.015	0.108	1
		2. Consideration	0	1,271	94	77	25	71	1,539	0	0.769	0.048	0.058	0.079	0.047	1
		3. Committed	0	0	372	273	6	2	653	0	0	0.559	0.395	0.041	0.006	1
		4. Construction	0	0	0	2,579	591	7	3,177	0	0	0	0.818	0.175	0.006	1
		5. Completed	0	0	0	0	0	0	0	0	0	0	0	1	0	1
		6. Deleted	0	0	0	0	0	0	0	0	0	0	0	0	1	1

TABLE 10
PROJECTS WITH COMPLETE LIFE HISTORIES, 2001:1 – 2007:4
(Project Set *B*)

	A. Number							B. Value							C. Average Value						
	Percent of total							Percent of total							$m						
Quarter	Possible	Consideration	Committed	Construction	Completed	Deleted	Total	Possible	Consideration	Committed	Construction	Completed	Deleted	Total ($m)	Possible	Consideration	Committed	Construction	Completed	Deleted	Total
(1)	2) (	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
2001:1	38.46	7.69	38.46	15.38	-	-	13	36.91	1.79	50.78	10.51	-	-	447	55	8	45	47	-	-	45
2001:2	32.14	21.43	21.43	25.00	-	-	28	30.45	30.91	20.54	18.10	-	-	1,514	77	78	52	46	-	-	63
2001:3	38.00	20.00	14.00	24.00	-	4.00	50	30.75	33.31	20.75	13.51	-	1.67	3,590	138	171	106	44	-	30	103
2001:4	39.66	17.24	3.45	36.21	3.45	-	58	32.48	29.09	2.54	34.76	1.12	-	4,640	137	193	59	85	26	-	113
2002:1	33.33	21.21	4.55	31.82	9.09	-	66	35.21	24.84	4.18	24.36	11.42	-	5,218	153	144	73	71	99	-	109
2002:2	32.50	25.00	10.00	26.25	3.75	2.50	80	33.86	28.28	7.63	28.40	1.84	-	5,934	144	120	57	94	36	-	104
2002:3	24.72	32.58	4.49	29.21	5.62	3.37	89	18.21	37.82	2.88	22.91	4.76	13.43	7,821	110	141	56	85	74	350	117
2002:4	27.27	32.95	5.68	26.14	6.82	1.14	88	22.49	41.33	5.87	24.35	3.73	2.21	6,775	109	140	80	92	51	150	108
2003:1	29.76	32.14	3.57	29.76	2.38	2.38	84	24.41	36.44	3.88	28.18	-	7.09	6,488	106	124	84	87	-	230	108
2003:2	28.74	27.59	5.75	29.89	6.90	1.15	87	23.02	36.42	6.27	30.36	3.93	-	6,011	92	129	75	83	47	-	94
2003:3	25.00	28.13	9.38	29.17	3.13	5.21	96	25.06	33.10	9.76	26.93	1.65	3.49	7,333	131	128	90	82	40	85	103
2003:4	23.00	28.00	11.00	33.00	2.00	3.00	100	22.54	34.52	9.23	31.17	1.64	0.90	8,288	133	130	70	92	68	75	106
2004:1	18.97	28.45	10.34	31.03	7.76	3.45	116	18.23	30.10	14.57	29.60	4.57	2.94	9,563	145	115	139	88	62	94	107
2004:2	21.62	28.83	10.81	32.43	4.50	1.80	111	21.93	20.76	20.66	30.48	6.17	-	9,384	147	81	194	87	145	-	110
2004:2	22.32	27.68	7.14	41.07	0.89	0.89	112	22.34	20.26	16.00	41.28	0.12	-	9,300	139	79	248	89	11	-	104
2004:4	21.74	27.83	6.96	39.13	4.35	-	115	21.83	18.00	16.63	39.07	4.46	-	9,426	147	71	224	92	84	-	105
2005:1	16.39	24.59	7.38	40.16	8.20	3.28	122	14.94	15.96	9.23	48.59	10.13	1.15	10,896	136	83	126	120	110	125	114
2005:2	15.00	25.83	5.83	46.67	5.00	1.67	120	12.20	18.26	9.25	53.31	6.98	-	10,269	125	78	158	109	143	-	108
2005:3	7.89	19.30	2.63	51.75	11.40	7.02	114	7.82	10.63	1.19	59.77	13.28	7.31	10,077	131	67	40	116	103	184	107
2005:4	7.22	15.46	4.12	57.73	13.40	2.06	97	2.15	17.34	11.25	55.51	12.37	1.38	9,441	51	136	266	105	117	130	117
2006:1	8.05	12.64	6.90	52.87	19.54	-	87	6.12	19.23	11.87	54.82	7.96	-	9,195	141	177	182	117	52	-	119
2006:2	12.16	13.51	6.76	60.81	5.41	1.35	74	6.73	14.20	15.60	58.69	4.28	0.50	8,366	94	132	261	117	90	42	125
2006:3	9.86	11.27	5.63	56.34	16.90	-	71	6.54	14.14	5.39	66.61	7.32	-	8,147	133	165	110	147	50	-	127
2006:4	4.00	10.67	5.33	53.33	22.67	4.00	75	1.34	4.27	2.19	75.33	15.18	1.70	7,901	106	56	43	157	80	67	120
2007:1	7.14	8.93	5.36	44.64	28.57	5.36	56	4.24	1.72	1.90	65.46	24.75	1.93	6,743	143	39	43	184	104	65	135
2007:2	10.81	8.11	5.41	51.35	24.32	-	37	5.78	2.35	0.57	80.74	10.56	-	4,944	143	39	14	210	87	-	155
2007:3	6.45	3.23	-	41.94	38.71	9.68	31	5.93	0.69	-	36.63	51.10	5.65	5,061	300	35	-	143	216	143	175
2007:4	-	-	-	-	87.50	12.50	16	-	-	-	-	86.30	13.70	2,189	-	-	-	-	135	300	146
Average	20.08	20.01	7.94	37.04	12.22	2.71	78	17.63	20.56	10.02	38.91	10.56	2.32	6,963	124	102	103	100	73	74	112

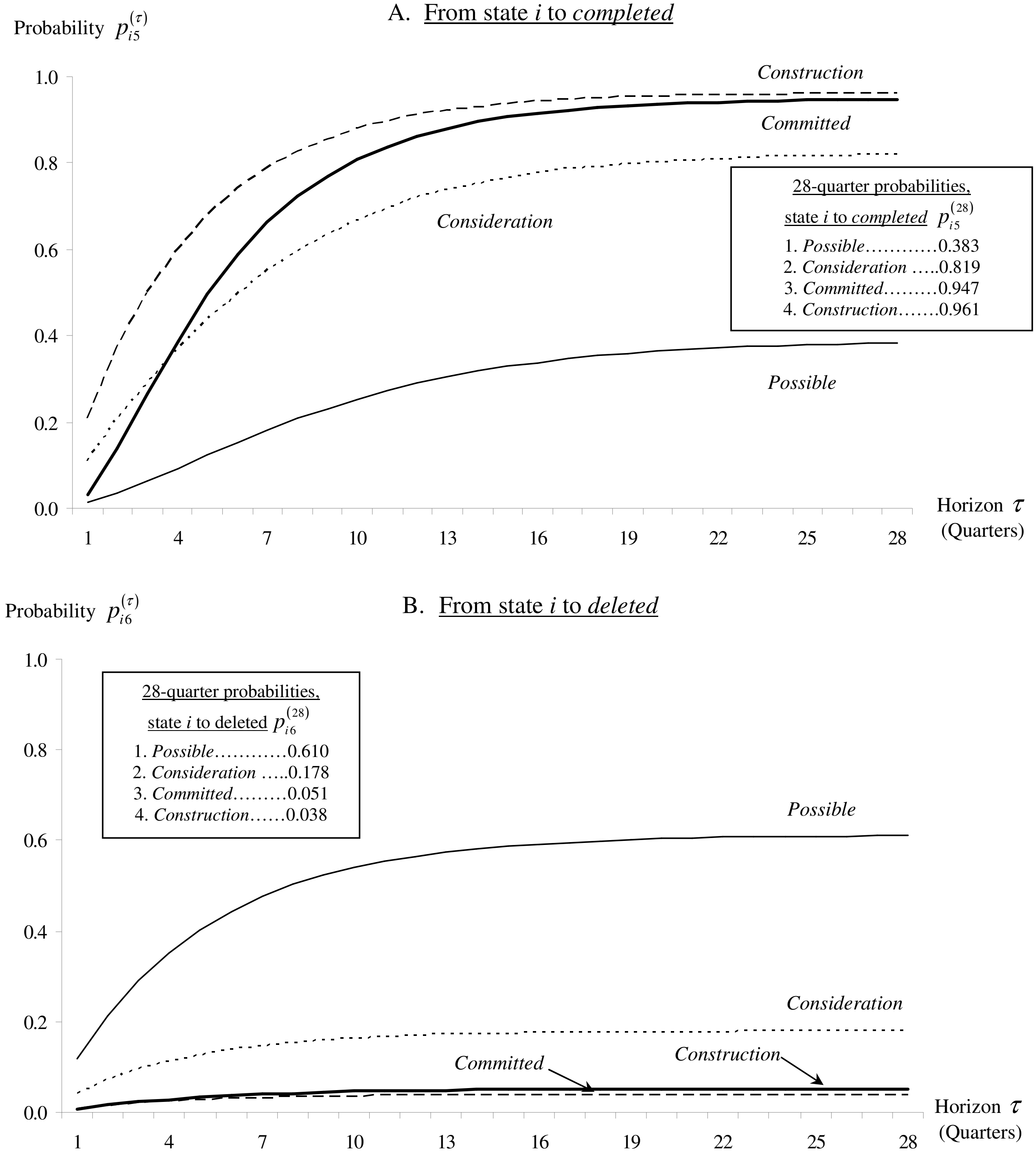
TABLE 11
NEW PROJECTS WITH COMPLETE LIFE HISTORIES, 2001:1 – 2007:4

(Project Set *B*)

Quarter	A. Number									B. Value ($m)						C. Average Value ($m)					
							Total							Total						Total	
	Possible	Consideration	Committed	Construction	Completed	Deleted	New	Current	Finished	Possible	Consideration	Committed	Construction	New	Current	Possible	Consideration	Committed	Construction	New	Current
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
2001:1	5	1	5	2	-	-	13	13	-	165	8	227	47	447	447	55	8	45	47	45	45
2001:2	4	5	6	-	-	-	15	28	-	286	460	311	-	1,057	1,514	95	92	52	-	76	63
2001:3	11	6	3	2	-	-	22	50	2	748	828	415	130	2,121	3,590	249	276	138	65	193	103
2001:4	6	1	-	3	-	-	10	58	2	171	164	-	220	555	4,640	34	164	-	110	69	113
2002:1	3	5	-	2	-	-	10	66	6	370	56	-	38	464	5,218	185	28	-	19	77	109
2002:2	6	7	6	1	-	-	20	80	5	500	283	293	65	1,141	5,934	500	71	49	65	95	104
2002:3	1	10	1	2	-	-	14	89	8	40	1,352	25	11	1,428	7,821	40	169	25	11	130	117
2002:4	2	3	1	1	-	-	7	88	7	100	50	215	-	365	6,775	100	50	215	-	122	108
2003:1	1	1	1	-	-	-	3	84	4	60	36	12	-	108	6,488	60	36	12	-	36	108
2003:2	1	1	1	4	-	-	7	87	7	-	6	5	63	74	6,011	-	6	5	16	12	94
2003:3	5	6	3	2	-	-	16	96	8	685	230	255	151	1,321	7,333	228	58	128	76	120	103
2003:4	2	5	3	2	-	-	12	100	5	175	302	216	283	976	8,288	88	76	72	142	89	106
2004:1	5	6	7	3	-	-	21	116	13	-	186	712	241	1,139	9,563	-	62	142	80	104	107
2004:2	4	1	2	1	-	-	8	111	7	315	200	23	20	558	9,384	158	200	12	20	93	110
2004:2	2	2	-	4	-	-	8	112	2	20	63	-	281	364	9,300	20	32	-	70	52	104
2004:4	1	3	-	1	-	-	5	115	5	-	111	-	-	111	9,426	-	56	-	-	56	105
2005:1	2	2	8	-	-	-	12	122	14	-	-	970	-	970	10,896	-	-	139	-	139	114
2005:2	-	4	-	8	-	-	12	120	8	-	136	-	211	347	10,269	-	45	-	30	35	108
2005:3	-	-	-	2	-	-	2	114	21	-	-	-	9	9	10,077	-	-	-	9	9	107
2005:4	-	2	1	1	-	-	4	97	15	-	73	814	69	956	9,441	-	37	814	69	239	117
2006:1	1	1	3	-	-	-	5	87	17	400	330	124	-	854	9,195	400	330	41	-	171	119
2006:2	3	-	-	1	-	-	4	74	5	42	-	-	41	83	8,366	14	-	-	41	21	125
2006:3	-	1	-	1	-	-	2	71	12	-	-	-	19	19	8,147	-	-	-	19	19	127
2006:4	-	3	2	11	-	-	16	75	20	-	10	28	836	874	7,901	-	10	14	84	67	120
2007:1	1	-	-	-	-	-	1	56	19	180	-	-	-	180	6,743	180	-	-	-	180	135
2007:2	-	-	-	-	-	-	-	37	9	-	-	-	-	-	4,944	-	-	-	-	-	155
2007:3	1	-	-	2	-	-	3	31	15	300	-	-	149	449	5,061	300	-	-	75	150	175
2007:4	-	-	-	-	-	-	-	16	16	-	-	-	-	-	2,189	-	-	-	-	-	146
Average	2	3	2	2	-	-	9	78	9	163	174	166	103	606	6,963	97	64	68	37	92	112

Note: Column 9 (Total Current) in quarter t = [entry in t-1] + [column 8 (New) in t] – [column 10 (Finished) in t-1]

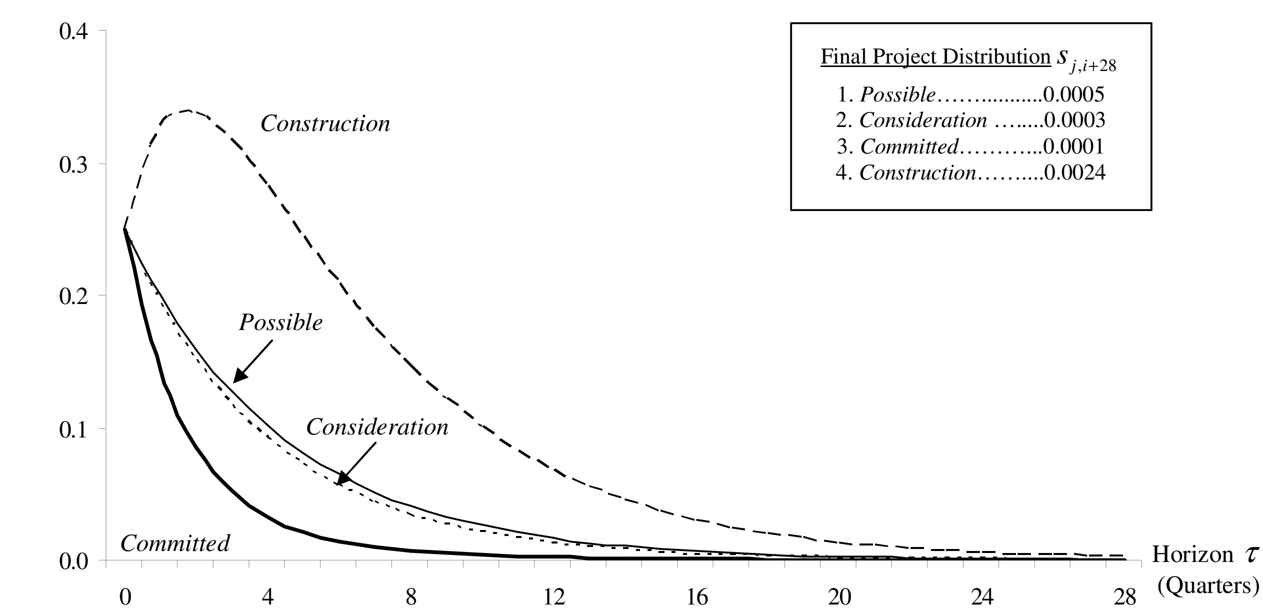
FIGURE 7
MULTIPERIOD TRANSITION PROBABILITIES
(Project Set *B*)



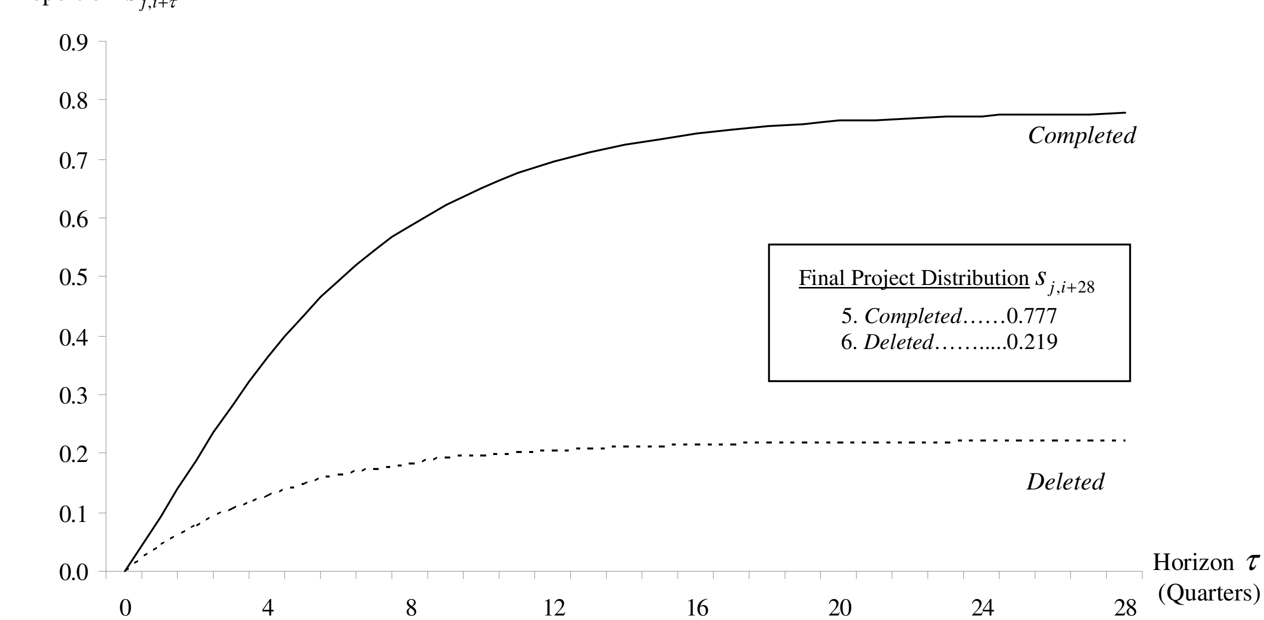
Note: Consider the transition probability matrix multiplied by itself τ times, $\boldsymbol{P}^{\tau}$. The $(i, j)^{\text{th}}$ element of this matrix, $p_{ij}^{(\tau)}$, is the probability of making the transition from state i to j in τ quarters. Panel A of this figure plots $p_{i5}^{(\tau)}$, where state 5 is *completed*, against τ. Panel B is the corresponding plot of $p_{i6}^{(\tau)}$, where state 6 is *deleted*. In both panels, the transition matrix is from Table 8.

FIGURE 8
SIMULATING LIFE TRAJECTORIES OF PROJECTS
(Project Set B)

A. Transition states



B. Absorbing states



Note : This figure plots the proportion of projects in state j after τ quarters, $s_{j,t+\tau}$, $j = 1,\ldots,6$, using $s'_{t+\tau} = s'_t P^\tau$, where $s'_{t+\tau} = [s_{1,t+\tau},\ldots,s_{6,t+\tau}]$ is the distributions at $t+\tau$ and $s'_t = [s_{1t},\ldots,s_{6t}]$ is the initial distribution. The transition matrix is from Table 8 and the initial distribution is $s'_t = (1/4)[1,1,1,1,0,0]$.

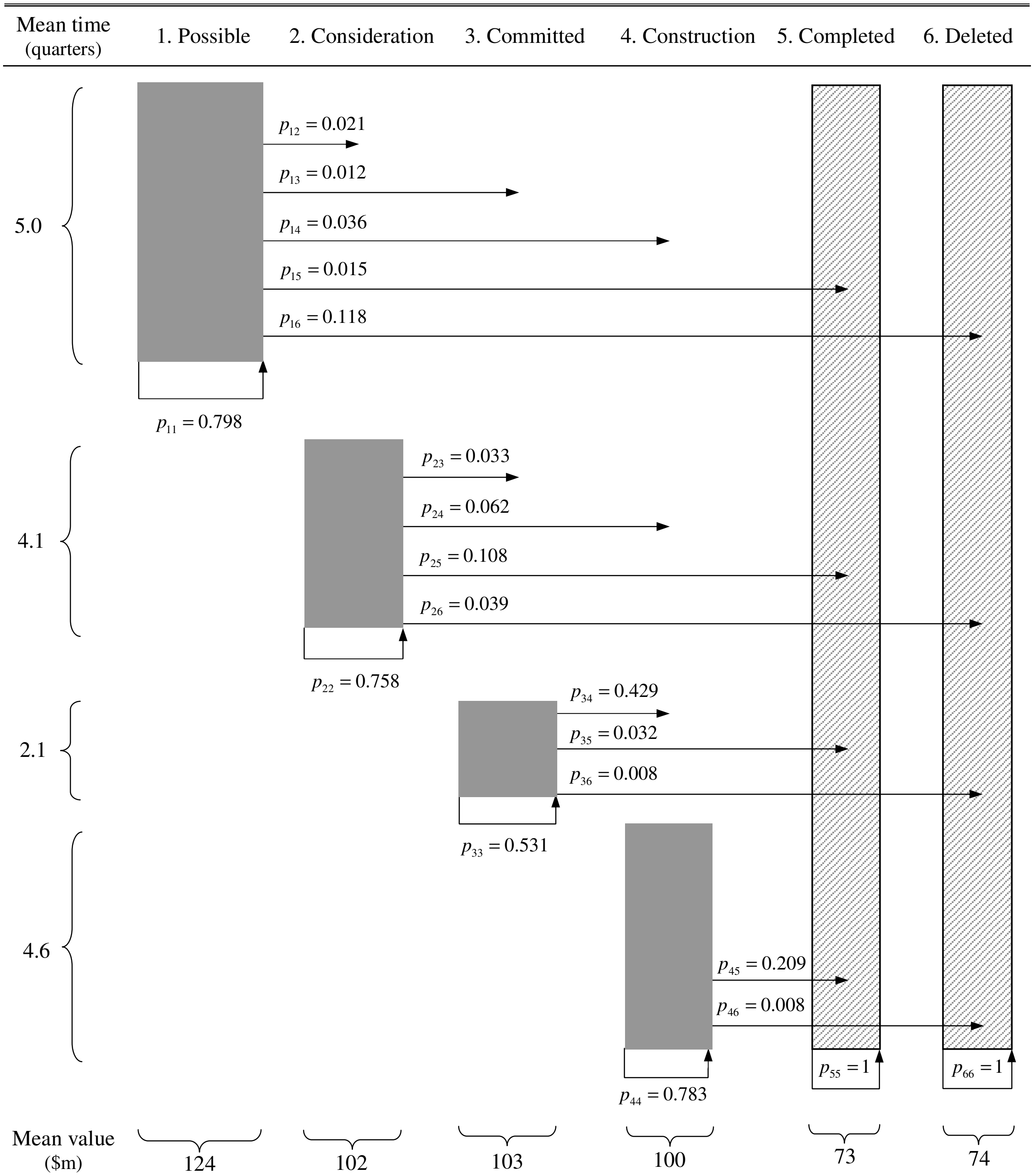
TABLE 12
COMPARISON OF VALUE AND COUNT TRANSITION MATRICES

State *i*	A. Project Set *A*							B. Project Set *B*							C. Difference, *B* - *A*						
	State *j*						Mean	State *j*						Mean	State *j*						Mean
	1	2	3	4	5	6	r_i	1	2	3	4	5	6	r_i	1	2	3	4	5	6	r_i
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
	Value, $\boldsymbol{P}_v^A$							Value, $\boldsymbol{P}_v^B$							Value, $\boldsymbol{P}_v^B - \boldsymbol{P}_v^A$						
1. Possible	0.917	0.056	0.004	0.005	0.001	0.017	12.10	0.759	0.045	0.013	0.059	0.015	0.108	4.15	-0.159	-0.010	0.009	0.055	0.014	0.091	-7.95
2. Consideration	0.019	0.915	0.035	0.017	0.001	0.011	11.81	0	0.769	0.048	0.058	0.079	0.047	4.32	-0.019	-0.147	0.012	0.040	0.078	0.035	-7.49
3. Committed	0.014	0.022	0.658	0.282	0.002	0.023	2.92	0	0	0.559	0.395	0.041	0.006	2.27	-0.014	-0.022	-0.099	0.113	0.038	-0.017	-0.65
4. Construction	0.001	0.008	0.001	0.898	0.091	0.001	9.82	0	0	0	0.818	0.175	0.006	5.50	-0.001	-0.008	-0.001	-0.080	0.084	0.005	-4.32
	Count, $\boldsymbol{P}_c^A$							Count, $\boldsymbol{P}_c^B$							Count, $\boldsymbol{P}_c^B - \boldsymbol{P}_c^A$						
1. Possible	0.944	0.024	0.003	0.008	0.004	0.017	17.75	0.798	0.021	0.012	0.036	0.015	0.118	4.96	-0.145	-0.003	0.009	0.028	0.011	0.101	-12.79
2. Consideration	0.011	0.926	0.020	0.023	0.008	0.012	13.55	0	0.758	0.033	0.062	0.108	0.039	4.13	-0.011	-0.169	0.013	0.039	0.100	0.027	-9.42
3. Committed	0.008	0.030	0.667	0.264	0.013	0.018	3.01	0	0	0.531	0.429	0.032	0.008	2.13	-0.008	-0.030	-0.136	0.164	0.019	-0.010	-0.87
4. Construction	0.001	0.008	0.003	0.844	0.138	0.006	6.40	0	0	0	0.783	0.209	0.008	4.61	-0.001	-0.008	-0.003	-0.061	0.071	0.003	-1.79
	Value – Count $\boldsymbol{P}_v^A - \boldsymbol{P}_c^A$							Value – Count $\boldsymbol{P}_v^B - \boldsymbol{P}_c^B$							Grand Difference $(\boldsymbol{P}_v^B - \boldsymbol{P}_c^B) - (\boldsymbol{P}_v^A - \boldsymbol{P}_c^A) = (\boldsymbol{P}_v^B - \boldsymbol{P}_v^A) - (\boldsymbol{P}_c^B - \boldsymbol{P}_c^A)$						
1. Possible	-0.026	0.032	0.001	-0.003	-0.003	0.000	-5.65	-0.040	0.025	0.001	0.023	0.000	-0.010	-0.81	-0.013	-0.007	0.000	0.026	0.003	-0.009	4.84
2. Consideration	0.008	-0.011	0.016	-0.006	-0.007	-0.001	-1.74	0.000	0.011	0.015	-0.005	-0.029	0.007	0.20	-0.008	0.022	-0.001	0.001	-0.022	0.008	1.93
3. Committed	0.006	-0.007	-0.010	0.017	-0.011	0.005	-0.09	0.000	0.000	0.028	-0.034	0.008	-0.002	0.13	-0.006	0.007	0.038	-0.052	0.019	-0.007	0.22
4. Construction	0.000	-0.001	-0.003	0.055	-0.047	-0.005	3.43	0.000	0.000	0.000	0.035	-0.034	-0.002	0.90	0.000	0.001	0.003	-0.019	0.013	0.003	-2.53

Notes: 1. "Mean" is short for "mean occupancy time occupancy", the expected number of quarters a project spends a given state. For state *i*, this defined as the reciprocal of $1 - p_{ii}$, where p_{ii} is the one-quarter probability of remaining in that state.

2. Transition matrices are from Tables 6, 7, 8 and 9.

FIGURE 9
THE TIME-VALUE OF PROJECTS
(Project Set B)



Note: To interpret this table, consider the entry for the second column, the column headed "1. Possible". The height of the rectangle here represents the mean time a project spends in state 1 (possible), whilst the width represents the mean value of all projects during their time in this state. The arrows and corresponding p_{1j}'s ($j = 2,\ldots,6$) show the probabilities of one-period transitions to other states. The probability of remaining in state 1 is give below the rectangle as $p_{11} = 0.798$. The probabilities are from the transition matrix given in the middle part of panel B of Table 12. The mean times are from the middle part of column 15 of Table 12. The average values by state are from the last six entries of the last row of Table 10.

TABLE 13
HITTING TIMES
(Quarters)

Initial state *i*	Final state *j*			
	2	3	4	5, 6
(1)	(2)	(3)	(4)	(5)
1. Possible	4.960	5.385	5.540	6.800
2. Consideration	-	4.126	4.415	6.168
3. Committed	-	-	2.133	6.346
4. Construction	-	-	-	4.607

Note: To interpret this table consider the first entry in column 4, 5.540. This indicates that we would expect a project starting in state 1 (*possible*) to take almost one and a half years until it enters state 4 (under *construction*).

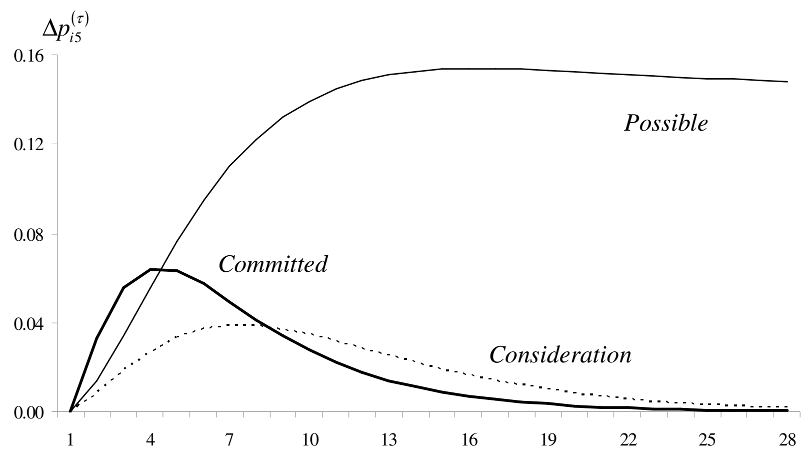
FIGURE 10
SPEEDING UP APPROVALS

A. Two transition probabilities matrices

State i in period t	*First matrix* State j in period t+1						*Second matrix* State j in period t+1					
	1	2	3	4	5	6	1	2	3	4	5	6
1. Possible	0.798	0	0	0.084	0	0.118	0.731	0	0	0.151	0	0.118
2. Consideration	0	0.758	0	0.134	0.108	0	0	0.677	0	0.215	0.108	0
3. Committed	0	0	0.531	0.469	0	0	0	0	0.375	0.625	0	0
4. Construction	0	0	0	0.791	0.209	0	0	0	0	0.791	0.209	0
5. Completed	0	0	0	0	1	0	0	0	0	0	1	0
6. Deleted	0	0	0	0	0	1	0	0	0	0	0	1

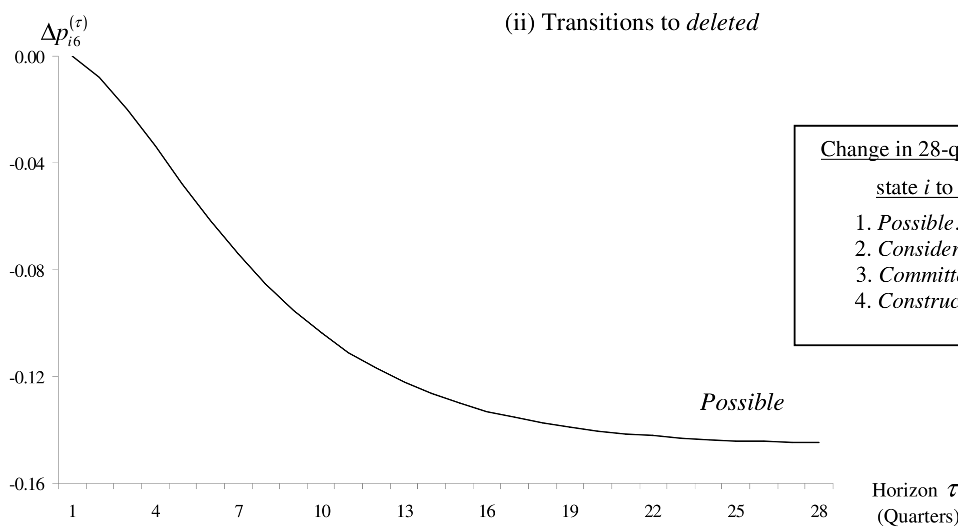
B. Changes in multi-period transition probabilities

(i) Transitions to *completed*



Change in 28-quarter probabilities, state i to *completed* $p_{i5}^{(28)}$
1. *Possible*…………0.148
2. *Consideration* …..0.002
3. *Committed*………0.000
4. *Construction*…….0.000

(ii) Transitions to *deleted*



Change in 28-quarter probabilities, state i to deleted $p_{i6}^{(28)}$
1. *Possible*…………-0.145
2. *Consideration* ...…0.000
3. *Committed*……..…0.000
4. *Construction*…..…0.000

Notes: 1. The first transitional probability matrix on the left-hand side of panel A is derived as follows. We start with the count data transition probability matrix from Table 8 and employ the following steps. (i) Set the $(i, j)^{th}$ probability to zero if $p_{ij} \le 0.05$ for $j \ne 4$. (ii) Enforce the condition that each row has a unit sum by changing the corresponding elements of state 4 (construction).

2. The second transitional probability matrix given on the right-hand side of panel A is derived from the first matrix as follows. Let the mean occupancy time for state i be $r_i = 1/(1-p_{ii})$. For states 1 to 3, we set the own-state probability such that r_i falls by 25 percent. Then, we increase the entries corresponding to state 4, so that the row sums of the second matrix are all unity.

FIGURE 11
SPEEDING UP AND THE DISTRIBUTION OF PROJECTS

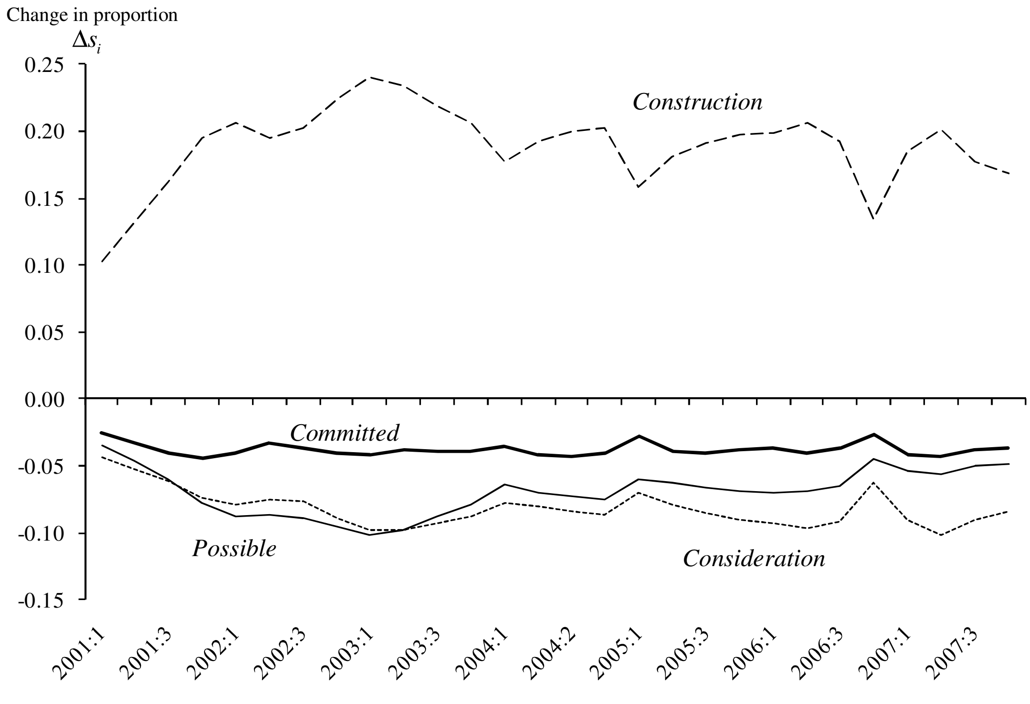
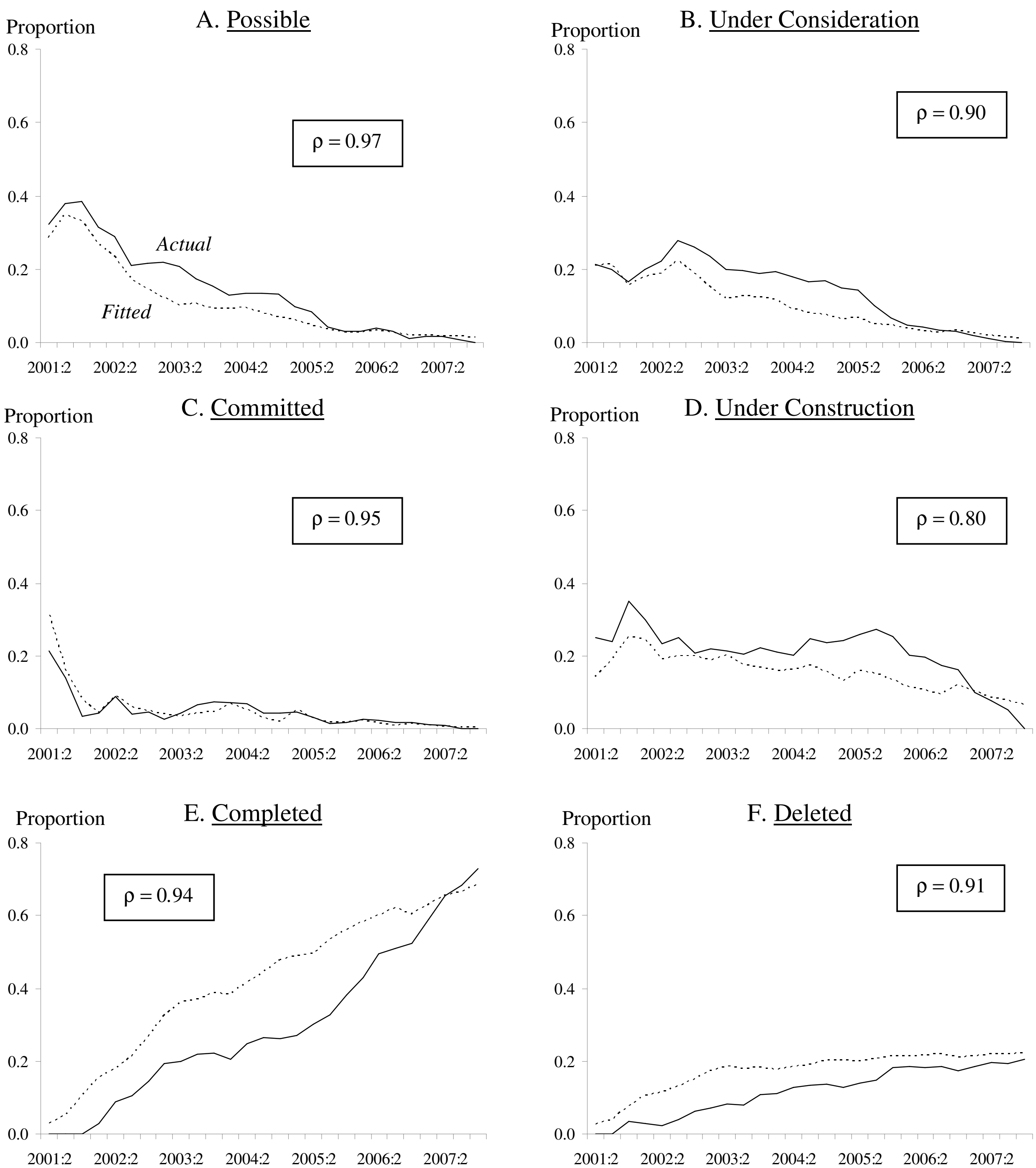


TABLE 14
OBSERVED AND IMPLIED OCCUPANCY TIMES

State *i*	Observed			Mean occupancy time derived from transition matrix (quarters)
	Total		Mean occupancy time (quarters)	
	Number of projects	Length (quarters)		
(1)	(2)	(3)	(4)	(5)
		A. Project Set *A*		
1. Possible	452	5,133	11.36	17.75
2. Consideration	524	4,837	9.23	13.55
3. Committed	211	581	2.75	3.01
4. Construction	417	2,286	5.48	6.40
Total	1,604	12,837	8.00	-
		B. Project Set *B*		
1. Possible	67	433	6.46	4.96
2. Consideration	88	497	5.65	4.13
3. Committed	74	155	2.09	2.13
4. Construction	173	856	4.95	4.61
Total	402	1,941	4.83	-

Notes:
1. Column 2 indicates the total number of projects entering state *i* during their lifetime.
2. Column 3 indicates the total number of quarters spent by projects in state *i*.
3. Column 4 =column 3/column 2.
4. Columns 5 refers to the average transition matrix based on the count data, from columns 8 and 15 of Table 12.

FIGURE 12
ACTUAL AND FITTED DISTRIBUTION OF PROJECTS
(Project proportions, *Project Set B*)



Note: ρ is the correlation coefficient between actual and fitted.

FIGURE 13
SUMMARY OF PREDICTION ERRORS
(Weighted average of logarithmic ratios of actual to fitted shares)

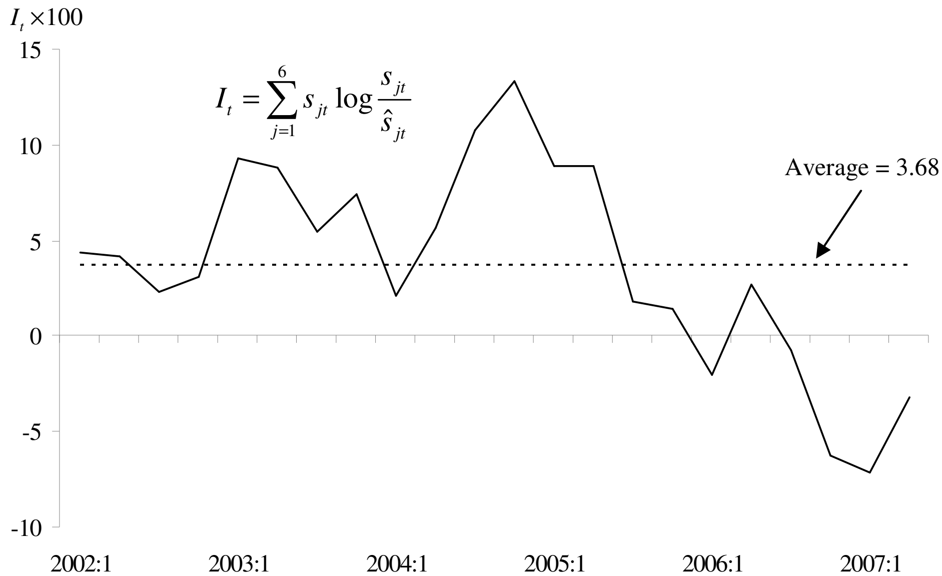
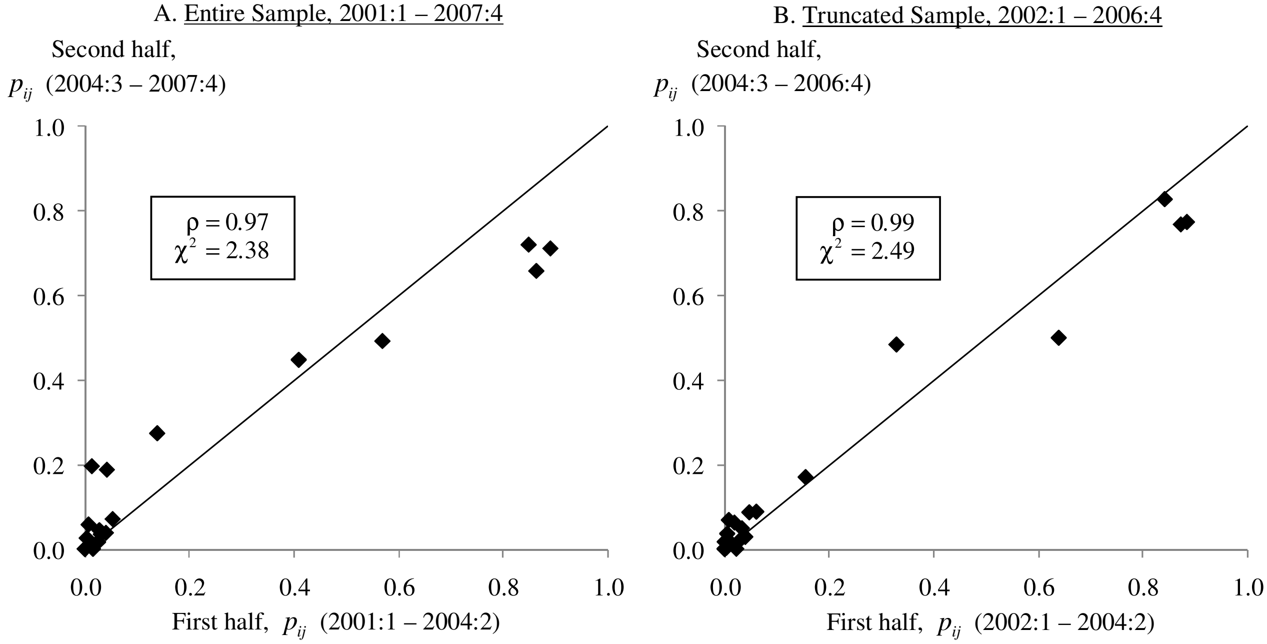


TABLE 15
SIX TRANSITION MATRICES (Project Set B)

State i in quarter t	A. Entire Sample, 2001:1 – 2007:4						B. Truncated Sample, 2002:1 – 2006:4					
	State j in quarter t+1						State j in quarter t+1					
	1	2	3	4	5	6	1	2	3	4	5	6
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	1. Whole period, 2001:1 – 2007:4						4. Whole period, 2002:1 – 2006:4					
1. Possible	0.798	0.021	0.012	0.036	0.015	0.118	0.826	0.027	0.009	0.042	0.021	0.075
2. Consideration	0.000	0.758	0.033	0.062	0.108	0.039	0.000	0.817	0.041	0.068	0.040	0.034
3. Committed	0.000	0.000	0.531	0.429	0.032	0.008	0.000	0.000	0.566	0.410	0.014	0.011
4. Construction	0.000	0.000	0.000	0.783	0.209	0.008	0.000	0.000	0.000	0.834	0.163	0.003
	2. First half, 2001:1 – 2004:2						5. First half, 2002:1 – 2004:2					
1. Possible	0.890	0.025	0.012	0.028	0.003	0.042	0.884	0.032	0.000	0.019	0.005	0.061
2. Consideration	0.000	0.863	0.030	0.053	0.013	0.040	0.000	0.873	0.033	0.047	0.008	0.039
3. Committed	0.000	0.000	0.569	0.409	0.007	0.015	0.000	0.000	0.639	0.329	0.010	0.022
4. Construction	0.000	0.000	0.000	0.848	0.138	0.013	0.000	0.000	0.000	0.842	0.155	0.003
	3. Second half, 2004:3 – 2007:4						6. Second half, 2004:3 – 2006:4					
1. Possible	0.713	0.017	0.012	0.044	0.026	0.188	0.774	0.023	0.017	0.062	0.036	0.088
2. Consideration	0.000	0.660	0.035	0.071	0.196	0.038	0.000	0.768	0.049	0.087	0.068	0.028
3. Committed	0.000	0.000	0.493	0.449	0.058	0.000	0.000	0.000	0.500	0.484	0.017	0.000
4. Construction	0.000	0.000	0.000	0.722	0.274	0.004	0.000	0.000	0.000	0.828	0.170	0.003

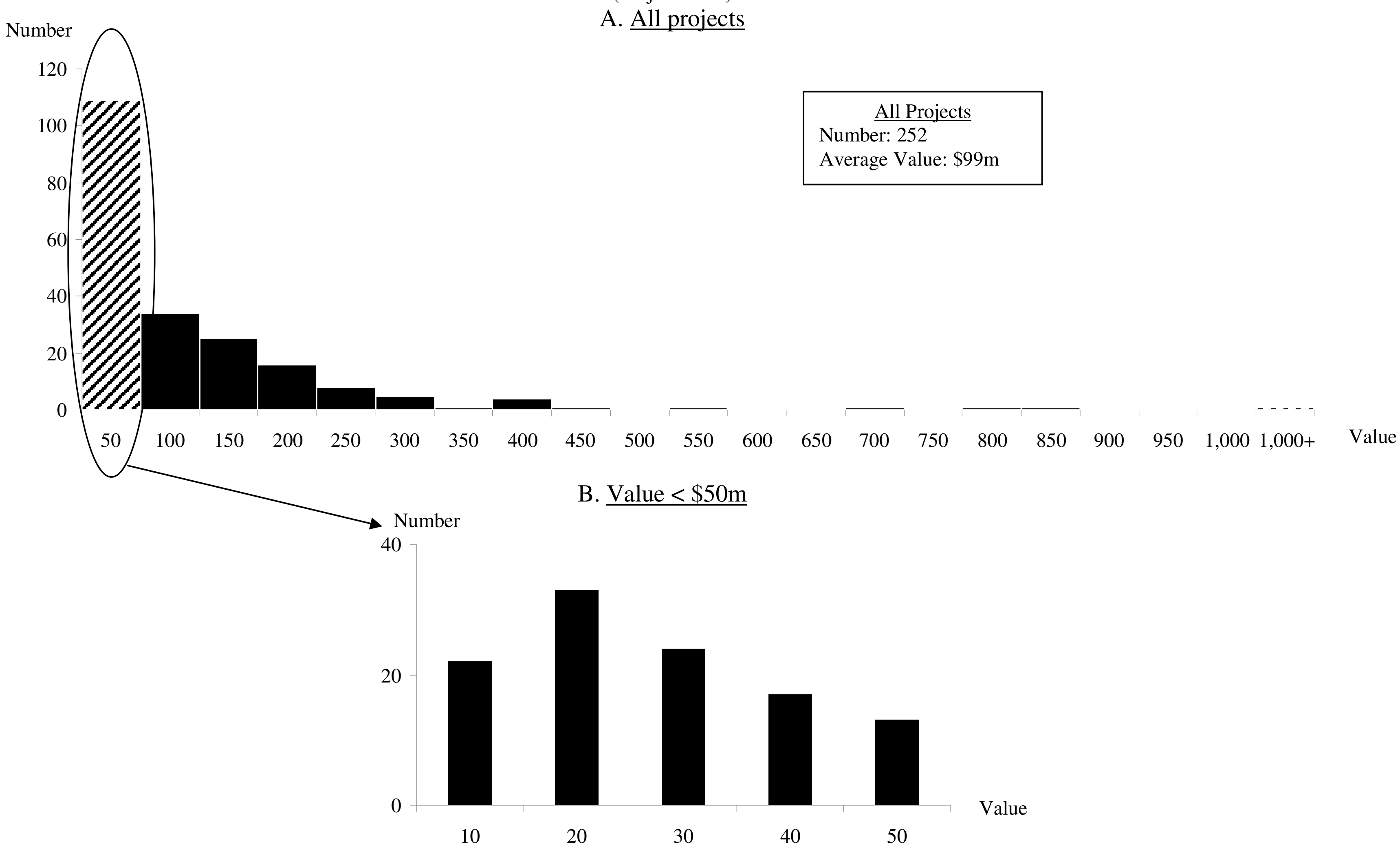
FIGURE 14
COMPARING TRANSITION PROBABILITIES

A. Entire Sample, 2001:1 – 2007:4 B. Truncated Sample, 2002:1 – 2006:4



Note: ρ is the correlation coefficient between the first half and second half transition probabilities; χ^2 is the chi-squared statistic for testing the equality of the transition probabilities.

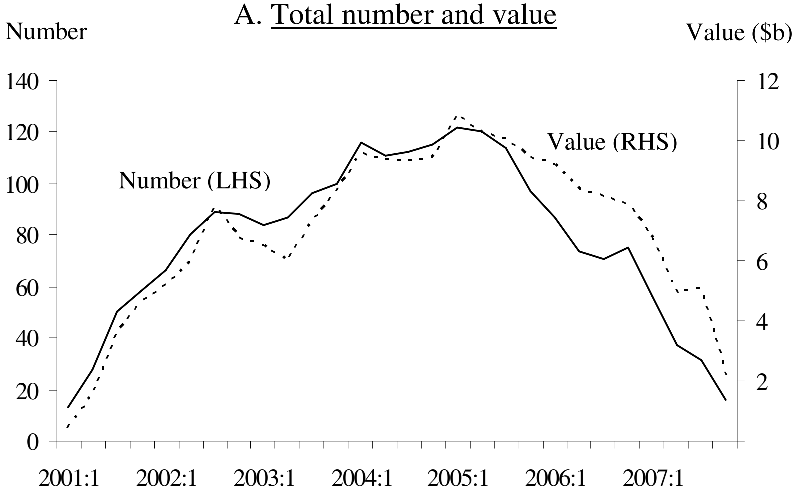
FIGURE A1
PROJECT VALUES, 2001:1 – 2007:4
(Project Set *B*)



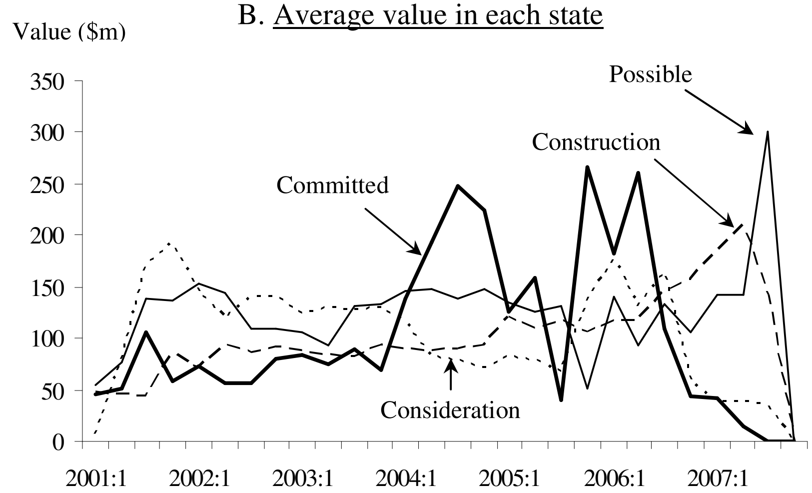
Note: See notes to Figure 1.

FIGURE A2
LIVE PROJECTS, 2001:1 – 2007:4
(Project Set *B*)

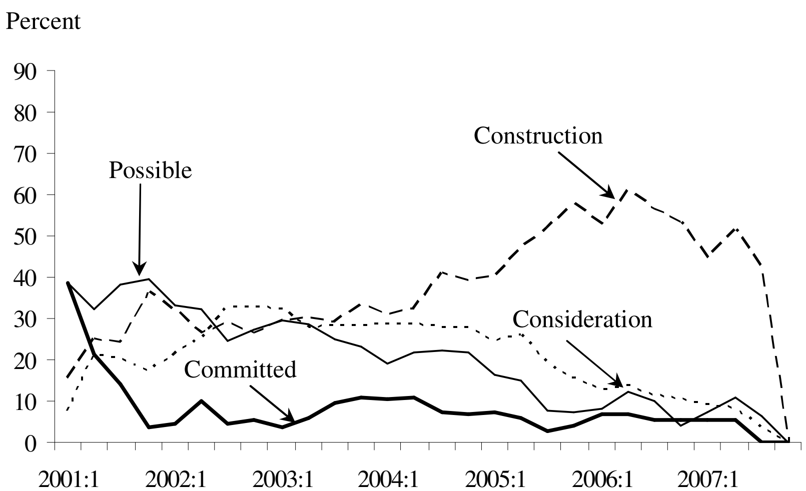
A. Total number and value



B. Average value in each state



C. Percent of total number in each state



D. Percent of total value in each state

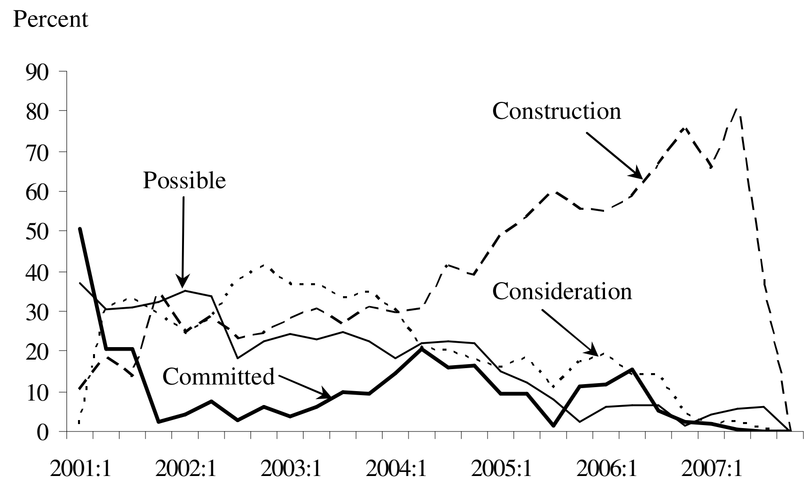
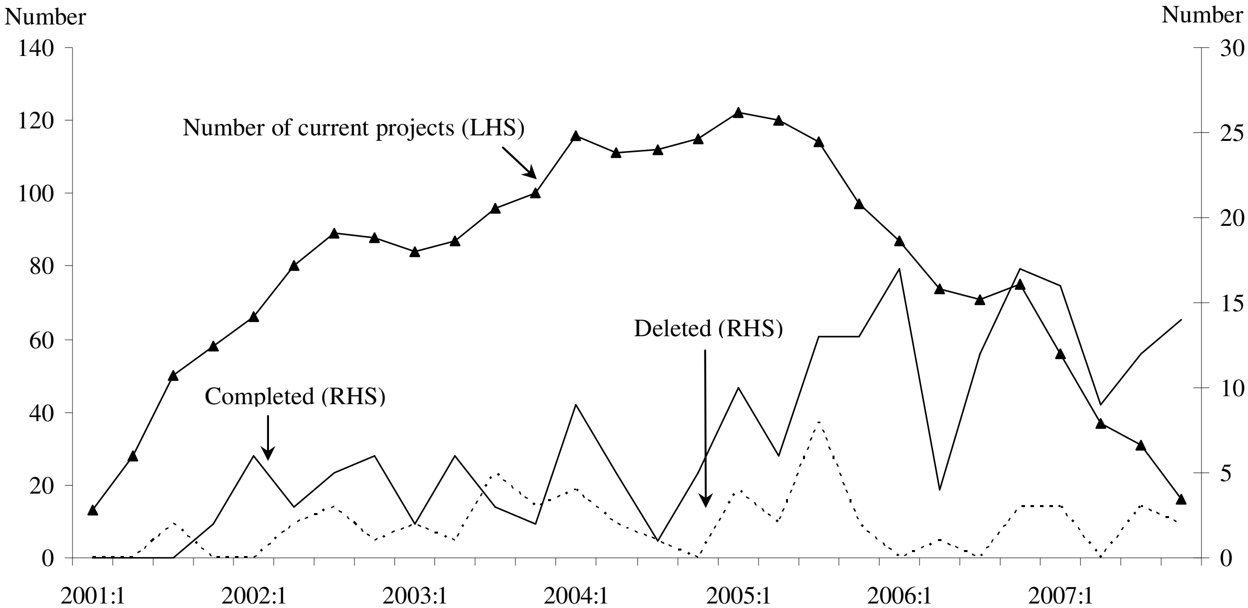


FIGURE A3
PROJECT SEPERATIONS, 2001:1 – 2007:4
(*Project Set B*)

A. Count



B. Value

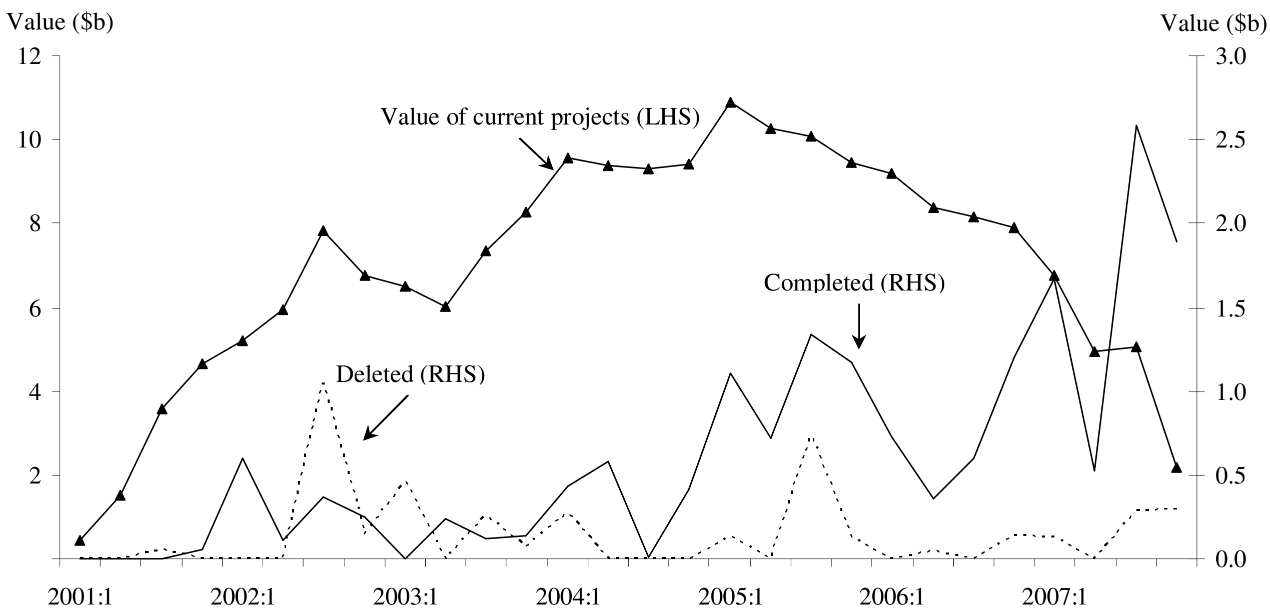
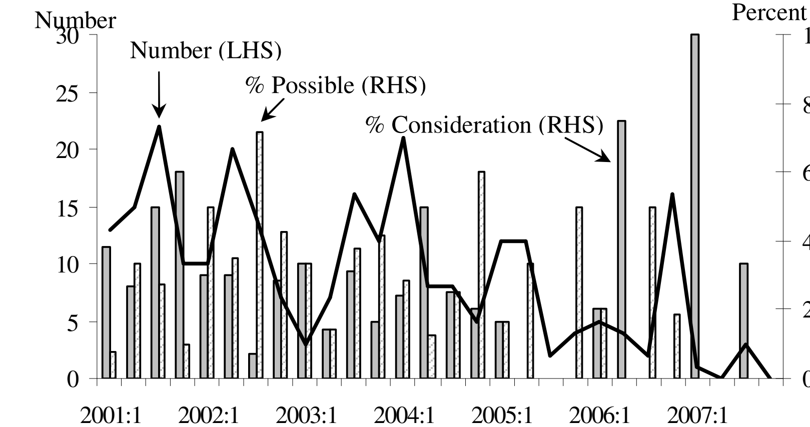
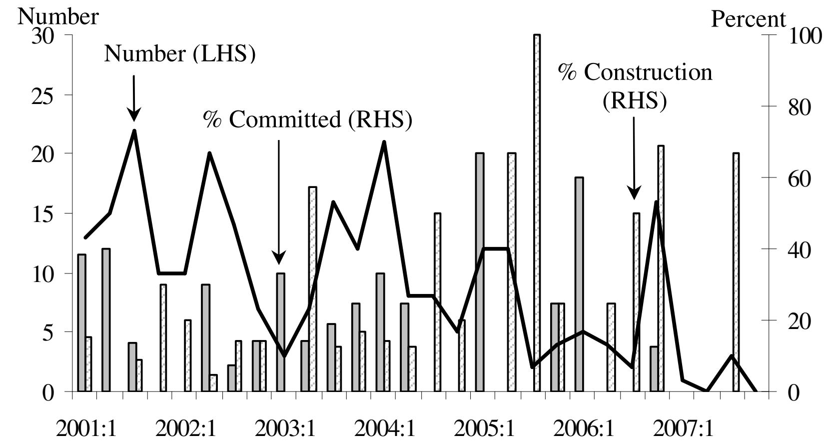


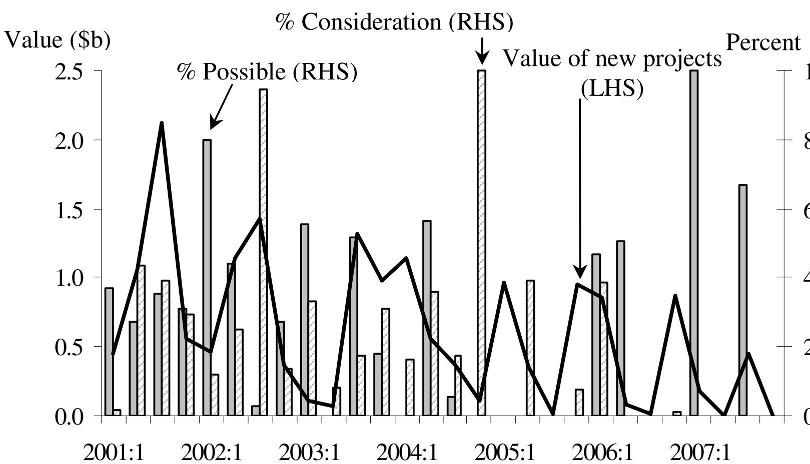
FIGURE A4
NEW PROJECTS, 2001:1 – 2007:4
(*Project Set B*)

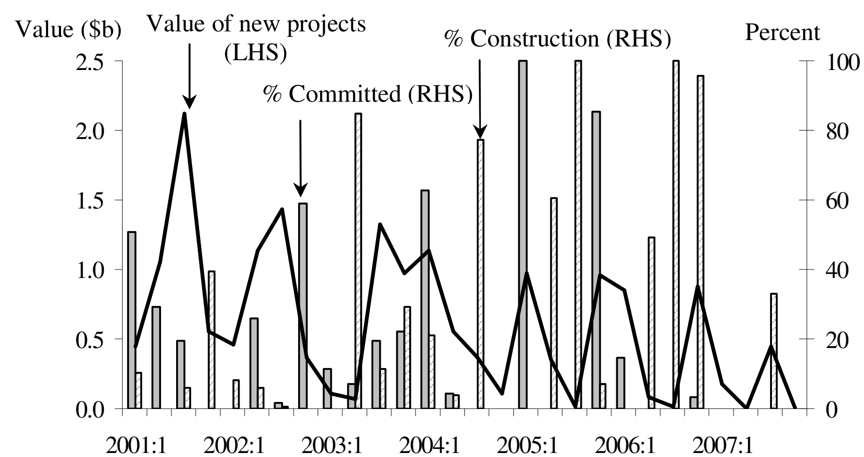
A. Count





B. Value





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