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Model Representations of Japanese Monetary Policy

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This paper reviews the issues that researchers encounter when specifying "reaction functions" to represent monetary-policy behavior in an empirical model. These issues arise not only for Japanese monetary policy, but for the behavior of any national monetary authority. The paper suggests a general approach, and then illustrates the ideas by developing reaction functions for the two main instruments of Japanese domestic monetary policy (the interbank call rate and the Bank of Japan's discount rate). As background for its main sections, the paper also gives an overview of how the Bank of Japan implements monetary policy in actual practice.

I. Introduction and Background

My research in recent years has been especially concerned with macroeconomic interactions among national economies. In collaboration with others, I have compared and evaluated macroeconometric models, especially those multi-country models concerned with interdependence among national economies. The ultimate motive has been to improve understanding of how the world economy functions and to refine views about the appropriate types of intergovernmental policy cooperation.[1]

In this paper, I focus on how to improve analytical treatments of Japanese monetary policy and the Japanese financial system. After this introductory section, section II of this paper summarizes the basic elements of the actual operating procedures of the Bank of Japan (BOJ). Section III outlines my approach to the model specification of "reaction functions" for monetary policy. Section IV contains empirical illustrations of this

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Numerous members of the staff of the Bank of Japan, and many other Japanese economists, helped the author learn about Japanese monetary policy. He refrains from acknowledging these persons individually because the list of names is very long and because he wants to avoid even a mistaken inference that those who helped him can be held accountable for errors in his analysis.

[1]See, for example, Bryant, Helliwell, and Hooper (1989); Bryant, Henderson, and others (1988).

approach to Japanese monetary policy. Section V contains brief concluding remarks.

Almost more than any other type of economic actor, a national monetary authority requires an analytical understanding of the financial system and its international linkages.[2] To formulate alternative courses of action in a coherent manner and to clarify the likely costs and benefits associated with them, policymakers must rely on an analytical framework that connects their actions to expected outcomes. Models can be explicit and systematic. Or models can be carelessly devised, even implicitly presumed. Modeling attempts can be more or less successful. The true economic structure of a national economy, not to speak of its macroeconomic interactions with other parts of the global economy, cannot be fully or reliably known by any of the decisionmaking units in the economic system. Yet a model of *some* sort is a logical prerequisite for decisions by policymakers on what to do with their instruments. A major premise underlying this paper, therefore, is that monetary authorities especially, but also numerous other analysts, require a model, or models, that incorporate the financial behavior of the private sector, in both its domestic and cross-border manifestations.

The paper also rests on a second, related premise. I believe it has become increasingly important in financial-sector models to include explicit equations that attempt to summarize the behavior of the monetary authority itself. The need for such representations stems from the fact that the causation between monetary-policy instruments and the economy operates in both directions. The actions of policymakers influence the financial system and the real economy, but policymakers react to movements in the economy when choosing their actions. Policymakers' behavior is "endogenous" in this very fundamental sense.

From the perspective of an outside analyst whose objective is to describe the evolution of the economic system as a whole, the decision procedures of the policymakers as they react to the economy are no less endogenous than the behavior of private-sector agents. In principle, the outside analyst has no obvious reason for treating policymakers in a conceptually different way than private agents. Summary representations of the behavior of the policymakers merely constitute another set of equations in the analytical model.

When the perspective is that of the policymaker, to be sure, matters are more complicated. Policymakers cannot adopt the perspective of the outside analyst looking into the economic system; policymakers are part of the system, attempting to influence it. Their job is to decide, somehow, how to vary over time the dial settings for their policy

[2]When I use the phrase "monetary authority," I am of course thinking especially of central banks. But the degree of political autonomy of the central bank varies from country to country. In no nation does the central bank conduct monetary policy without extensive and fairly frequent consultation with the finance ministry and the rest of the national government. When referring generically to monetary-policy decisions, it is thus sometimes more accurate to refer to "the monetary authority." The plural "policymakers" alludes implicitly to the likelihood that something less than full consensus exists within the monetary authority.

instruments. Seen from their own chair, from the context of the decision problem they face, their policy actions are "exogenous" in an *ex ante*, conceptual sense. When they use one or another analytical model of the economy to try to aid their decisions, they necessarily must treat their own actions as conceptually exogenous.

But how should policymakers and their staffs construct the model(s) of the economy that are used to aid their decisions? During the construction process, the policymakers and their staffs have to be careful to take account of the fundamental endogeneity of policy actions. The only empirical data about the evolution of the economy that exist are inevitably "contaminated" by the behavior of the policymakers and their predecessors. The more successful policy has been in promoting macroeconomic stability, the greater the degree of (favorable) contamination! If inappropriate allowance is made in constructing a model for the past interactions between the policymakers and the rest of the economic system, the resulting model can be seriously misspecified. To state this point another way: policymakers and their advisers have to be careful not to confuse the conceptual exogeneity of their decisions *ex ante* with *statistical exogeneity* of their actions in *ex post* data. The behavior of policymakers is definitely not exogenous in the latter, statistical sense.[3]

For three classes of reason, it can be helpful to include equations for the behavior of the monetary authority in macroeconomic models. Such equations, rather than treating policy instruments as mechanically exogenous, treat instrument variation over time as explicitly modeled. It has become conventional to use a shorthand expression — "reaction functions" — as a label for such equations.[4]

The first rationale for incorporating reaction functions in a model is implicit in the preceding discussion. When one tries initially to specify and empirically estimate a model, one needs some way of allowing for the endogeneity of policy. If policy instruments are treated mechanically in estimation, as though statistically exogenous, the resulting models will contain faulty estimates of private-sector behavior and will be much less informative than required (and at worst will be seriously misleading).

The second rationale turns on the importance of expectations. Agents in the private sector, as they form forward-looking views about events in the future that will affect them, pay particular attention to macroeconomic policy. How can they form these expectations of policy, and how can analysts try to include the expectations in macroeconomic models? Unless an analytical framework can provide some sort of explicit anchor for

[3]This distinction, and the lack of policy exogeneity in the statistical data, have been emphasized in the past by, among others, Goldfeld and Blinder (1972), Blinder and Solow (1974), and Crotty (1973). The more emphasis given to forward-looking expectations and the more the model tries to incorporate private-sector expectations of the behavior of policymakers, the more important it becomes to take into account the statistical endogeneity of policy behavior.

[4]In the literature on the United States, important earlier studies include Goldfeld and Blinder (1972) and Anderson and Enzler (1987). Recent studies include Reinhart (1989), Whitesell (1989), and Bernanke and Blinder (1989).

such expectations, the analysis of *private* behavior may fall short of what it should be. If the main features of the conduct of monetary policy can be represented in the model and can be taken as "known" by private agents, the agents can correctly form expectations of what policy will be. This second rationale, like the first, could be quite important even if a model is to be used exclusively by the monetary authority to help formulate its own decisions.[5]

The final rationale for trying explicitly to model the behavior of monetary policy is even more compelling. If the length of the analytical horizon is medium or longer run, and if the monetary authority wants to analyze the consequences of a variety of nonpolicy or fiscal-policy shocks, it will be important to incorporate in the analytical framework some explicit summary of how monetary policy is conducted over time. In real life, the central bank does condition its behavior endogenously on what is happening in the economy; the central bank's notion of a "neutral" or "sound" policy will require responsiveness to the economy's evolution. If the analytical world of the model cannot mimic this endogenous responsiveness of policy, the usefulness of the analytical model to the policymaker can be much reduced. Old fashioned treatment of policy instruments as mechanically exogenous is not satisfactory.[6]

In this regard, it is well to remember that some models do not simulate well for longer horizons if the "exogenous" policy variables are set on rigidly predetermined paths. Yet such models may well be more plausible characterizations of economic behavior than models which do not have such sensitive properties.[7]

The third rationale for reaction functions can be brought home expositionally by imagining a two-country model of the world economy. In each country the government makes policy decisions; the government of country A, when it carries out simulations of either its own policy actions or of various nonpolicy shocks, will want to summarize the expected behavior of the government of country B by including in the model some reaction functions for the B government. From the analytical perspective of the A gov-

[5]The literature on "dynamic inconsistency" of policies and the relative merits of rules and discretionary activism has recently given great emphasis to private-sector expectations of policy and the need to incorporate them in analytical models. See Kydland and Prescott (1977) for an early, influential statement and Fischer (1987) for a recent survey. To believe that this second rationale carries force, one does not have to adopt the strongest versions of the rational expectations perspective.

[6]Analogous points apply about the modeling of fiscal policy. When a modeler wishes to study the consequences of nonpolicy or monetary-policy shocks over a medium or longer run, the model should contain reaction functions for the instruments of fiscal policy that capture the main endogenous aspects of fiscal policy through time (including satisfaction of the government's intertemporal budget constraint).

[7]The MPS model of the Federal Reserve staff is an example. The MPS model, for well documented reasons, will not simulate well with predetermined paths for the instruments or for the monetary aggregates. Moreover, the MPS is a much more carefully researched model than many other macroeconometric models of the U.S. economy. See Enzler and Johnson (1981) and Anderson and Enzler (1987) for an explanation of why the MPS model cycles when, for example, the money stock is set on a simple constant-growth-rate path. Other references on the MPS model include Brayton and Mauskopf (1985, 1987).

ernment, it is as essential to represent "endogenously" the behavior of the *B* government as it is to represent endogenously the behavior of private-sector agents. Similarly, the *B* government will want to try to model the behavior of the *A* government. By extension, the *A* and *B* governments may need an endogenous representation of their own policies. For multi-country models, therefore, it is especially important to try to model the policy behavior of central banks and governments.

The insertion of reaction functions for monetary policy into macroeconomic models by itself has no implications, one way or the other, for the vexed policy issues of "rules versus discretion" or the appropriate degree of activism for monetary policy. In particular, trying to summarize policy behavior *for the purposes of analytical modeling* does not imply that discretionary elements should be absent from the actual conduct of policy.[8]

II. Basic Elements of the Operating Procedures of the Bank of Japan

The broad outlines of the implementation of monetary policy by the Bank of Japan have been described in a number of publications. The most authoritative accounts are by members of the staff of the BOJ itself.[9] Several descriptions by outside analysts are also available.[10]

The institutional and regulatory environments in the Japanese financial system have changed significantly over time. Some of these changes have been of first-order importance — for example, changes in the government bond market in April 1977; regulatory changes in 1980, especially governing foreign-exchange and international transactions; liberalization of the terms on large deposits during the period 1985-90; and reforms of the interbank market in November 1988 and early 1989.[11]

In this section, I discuss only the dominant features of the conduct of Japanese monetary policy. I omit numerous details and do not describe the extensive changes in the institutional and regulatory environments. Rather, I merely present an overview of monetary-policy instruments and operating procedures as of the first half of 1990.

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[8]For a more extended discussion, see the unabridged version of the paper.

[9]For English-language sources about the decades prior to the 1980s, see in particular Suzuki (1980) and OECD (1972, 1975); Kumiharu Shigehara of the Bank of Japan was instrumental in the preparation of the latter two studies. Important contributions done in the 1980s include Fukui (1986), Suzuki and the Institute for Monetary and Economic Studies of the Bank of Japan (1987), and Suzuki, Kuroda, and Shirakawa (1988). Recent papers include Okabe (1990), Shigehara (1990), Osugi (1990), and Shikano (1990a, 1990b). On external monetary policy and the linkages of the Japanese economy to the rest of the world, see Fukao (1989, 1990), Fukao and Hanazaki (1987), Fukao and Okina (1989), Nambara and Fukao (1988), and Nakao (1989).

[10]References by authors outside the Bank of Japan include Hamada and Hayashi (1985), Hamada and Horiuchi (1987), Ito (1989a, 1989b), Takagi (1989), Cargill and Royama (1988), Dotsey (1986), Cargill (1985), and Horne (1985).

[11]Useful chronologies of the many regulatory and institutional changes, covering different periods and with differing emphases, may be found in Shigehara (1990), Suzuki and Institute staff (1987), Fukui (1986), Frankel (1984), Osugi (1990), and Cargill (1985), among others. Fukao (1990) has the most complete account of changes affecting cross-border and foreign-exchange transactions.

A. Chief Features of the Operating Regime

When an analyst stands close to the implementation of Japanese domestic monetary policy, his description would have to identify multiple "basic" instruments. A complete list includes the reserve ratios in the reserve-requirement system; extension or withdrawals of discount-window lending to banks; the official discount rate; market purchases and sales of a variety of financial instruments; and window guidance. When an observer stands back to take a broad overview, however, it is legitimate to abstract from many details and to focus only on the essential features of the operating regime.

Much the largest portion of hour-to-hour and day-to-day operations are directed at influencing the short-term interest rates in the call and bill markets (see, for example, Fukui (1986)). Especially by 1990, therefore, one can plausibly take the unconditional interest rate in the call money market as the chief fulcrum for the thrust of policy. It is "as if " the BOJ, from one month to the next, uses the call rate as its primary operating instrument. One can imagine the Executive Directors of the Bank giving instructions to the Market Operations Department to try to attain, over the period of the next few weeks, a given range for the call rate. Within a margin of error that is small from the perspective of the monthly average of call rates (and certainly the quarterly average), the actual call rate corresponds closely to the value specified by the Executive Directors.[12]

If one examines developments day to day (and *a fortiori* within a day), it is not accurate to treat the call rate as an actual instrument. From such a perspective, the reserve-requirement ratios, the discount rate, sales and purchases of various securities, and the reserve-progress ratio are the genuine instruments. For some analytical purposes, one must take that basic-detailed perspective. For example, one could not intelligently discuss defensive open-market operations and the smoothing of very short-term money-market fluctuations without adopting the detailed perspective.

This paper adopts a broad-overview perspective, and accordingly focuses primary attention on the call rate. Figure 1 is a schematic diagram showing the main outlines of the Bank of Japan's operating procedures, with emphasis on the central role of the call rate.

Changes in the discount rate and in direct lendings to the commercial banks are now less central to the execution of Japanese monetary policy than in former times.[13] The processes of liberalization of financial regulations, the internationalization of Japanese

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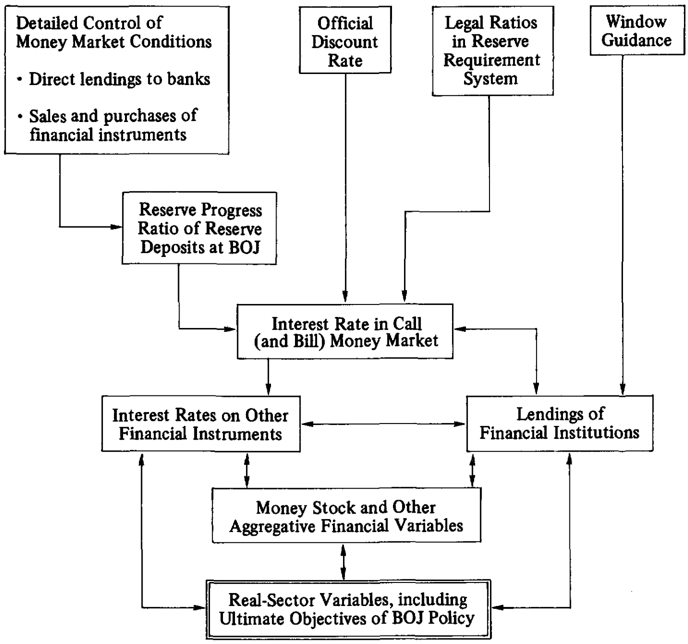
[12]In several official accounts, for example Fukui (1986) and Suzuki, Kuroda, and Shirakawa (1988), some ambiguity remains about whether the short-term rate that is the primary focus of money-market operations is the unconditional call rate, the interest rate on short-maturity bills, or perhaps some weighted average of the call rate and bill rate. (The two rates move fairly closely together over time, but there is a margin between them and they do not change identically, especially in the very short run.) From conversations with the Bank of Japan staff, I have formed the impression that the call rate is the more important of the two for the conduct of policy.

[13]The contrast between earlier policy and the situation in 1990 is sharply evident when one compares official summaries, for example Bank of Japan (1973, pp. 16-20) and Suzuki, Kuroda, and Shirakawa (1988, p. 7).

Figure 1
Schematic Diagram of the Conduct of Japanese Monetary Policy



financial markets, and the consequent restructuring of financial institutions will probably lead to an even further diminution in the relative importance of the discount rate.

Japanese policy with respect to the discount rate, and to the relationship of the discount rate to interbank market rates, is moving toward a status similar to that prevailing in the United States. In the United States since 1982, the federal funds rate — interacting with Federal Reserve operating objectives for the quantity of discount-window borrowing — has been the primary operating fulcrum for monetary policy. The discount rate is moved more sluggishly — and, when it is moved, is changed by larger amounts — than the federal funds rate. When the funds rate has moved sufficiently to widen the spread between the funds rate and the discount rate beyond a threshold level, the size of the spread becomes an important inducement for the Federal Reserve to consider changes in the discount rate. Changes in the discount rate are perceived as having political and "announcement" effects for the general public that are more salient than changes in the federal funds rate. Such considerations largely explain why the discount rate is moved more sluggishly and why, in periods of monetary stringency, the spread widens to abnormal levels. Nonetheless, despite the political and announcement effects, changes in the discount rate more often than not follow behind, and in part respresent adjustments to, earlier changes in the funds rate.

As the interest rate on call money has become more important to the BOJ as the cutting edge of its policy, a somewhat analogous situation has evolved in the Japanese interbank market. Unexpected new developments in the Japanese or world economies, especially when reacted to by the BOJ with "dynamic" policy initiatives, tend to show up in the first instance as changes in money-market conditions and in the call interest rate. As the spread between the call rate and the discount rate widens (in periods of rising interest rates) or narrows (in periods of falling rates), tensions start to accumulate. An abnormally large or small spread, if sustained for an extended period, triggers consideration of the possibility of a change in the discount rate. When a discount-rate change has been made in recent years, it has often had a dimension of "adjusting the discount rate to the current levels of market interest rates." The changing relationship between the call rate and the discount rate is reflected in the financial community's new use of the phrase "*tsuizui*" (roughly translated, "following in the wake of") to discuss recent changes in the discount rate.

Decisionmaking about the discount rate in Japan is even more complex than that in the United States because of the role in Japanese monetary policy played by the Ministry of Finance. I will not venture any broad generalizations here about the degree of political independence of the Bank of Japan or about the many subtleties of consultations between the Bank and the Ministry of Finance about the overall stance of monetary policy. Nonetheless, I do think it is clear that the Ministry has traditionally taken an especially strong interest in decisions about discount-rate changes. More so than in the United States, actions to change the discount rate in Japan are thus significantly complicated by the need to consult and obtain consensus within the wider government as a whole.

The amount of foreign-exchange market intervention is also an explicit instrument of Japanese monetary policy. Like the discount rate, it is an aspect of monetary policy in which the Ministry of Finance takes a strong interest.

Economic theory demonstrates that changes in the relative supplies of imperfectly substitutable assets denominated in different currencies can alter exchange rates and interest rates. If interest-bearing assets denominated in different currencies are perfect substitutes in the portfolios of a sufficiently important class of investors, however, changes in the stocks of those assets unaccompanied by changes in the stocks of central-bank reserve-money liabilities — *sterilized* intervention — cannot have significant, non-transitory effects on exchange rates and interest rates. The degree of substitutability among assets denominated in different currencies is thus a critical issue for the efficacy of exchange-market intervention.[14]

In the academic literature and in central banking circles, the view is now widely accepted that sterilized intervention has only very small and typically transitory effects on

[14]Henderson (1984) provides a survey of the applicable theory.

exchange rates. This view was cautiously incorporated in the official "Jurgensen Report" in the spring of 1983. Numerous academic articles on the subject have been published, with a majority also taking that view.[15]

The Bank of Japan and the Japanese Ministry of Finance behave as though they believe that exchange-market intervention, including sterilized intervention, can be a useful supplementary instrument of Japanese monetary policy (especially if the intervention is internationally coordinated). It is not feasible to say more here about Japanese exchange-market intervention or to attempt to describe a reaction function that models it. The ideas outlined below, however, could readily be extended to exchange-market intervention.[16]

B. Policy Objectives

As a device for identifying the most important of the ultimate objectives of the monetary authority in Japan, it is helpful to examine Table 1.[17] This table indicates the date of each discount-rate change since October 1970, the size of the change, and the factors cited in the BOJ press release explaining the change. The table is closely modeled after a table prepared within the BOJ itself.

Six types of explanatory factors are shown in the final columns of the table. The first two are the status of effective aggregate demand and of inflation. The remaining columns pertain to the balance of payments, the exchange value of the yen, the stock of money, and the adjustment of the discount rate to market interest rates. Mentions of these variables in the press release are classified according to whether the variable is indicated as an objective of policy (the symbol Φ), whether it is indicated in the analysis of the then-current economic and financial situation (the symbol O), and whether it is indicated as having a "proviso" status (the symbol Δ).[18]

This table pertains to discount-rate changes, not of course to changes in the call rate. Moreover, due allowance must be made for the fact that press releases announcing a discount-rate change contain language that is crafted to foster a desired private-sector

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[15]For the official view, see Working Group on Exchange Market Intervention (1983). Important studies inlcude Henderson and Sampson (1983), Obstfeld (1982, 1988), Rogoff (1984), and Boothe and others (1985).

[16]References on exchange-market intervention with particular relevance to the Japanese case include Fukao (1985, 1987, 1989), Ito (1987, 1989c), and Takagi (1989).

[17]As is common in analytical discussions, I postulate that policymakers have preferences defined over the time paths of "ultimate-target variables," which are macroeconomic magnitudes assumed to affect the well-being of individuals or the social well-being of the nation directly (or else, for the purposes of policy decisions, are believed to be satisfactory proxies for still more remote and fundamental goals).

[18]A table of this type was first published in a 1984 document of the Economic Planning Agency, *Economic Survey of Japan*. The most recent update with which I am familiar is in Okabe (1990), who added the rows for 1989 and the columns for money supply and market interest rates. At the time of its announcement of a discount-rate change, the Bank of Japan issues a short press release of a few sentences. Shortly thereafter, in the monthly bulletin of the Research and Statistics Department, a fuller explanation of several pages is published.

Table 1
Statements by the Chairman of the Policy Board of the Bank of Japan Announcing Changes in the Official Discount Rate*

Date (year/month/date)	Old and New Discount Rate		Size of Change	Factors Cited in Explanation: Effective Demand	Inflation	Balance of Payments	Exchange Value of the Yen	Money Supply	Market Interest Rates
1970/10/28	6.25	6.00	−0.25	O	O	–	–	–	–
1971/01/20	6.00	5.75	−0.25	O	–	O	–	–	–
05/08	5.75	5.50	−0.25	Φ	–	O	–	–	–
07/28	5.50	5.25	−0.25	Φ	–	Φ	–	–	–
12/29	5.25	4.75	−0.50	Φ	–	Φ	–	–	–
1972/06/24	4.75	4.25	−0.50	Φ	–	Φ	–	–	–
1973/04/02	4.25	5.00	0.75	Φ	O	–	O	–	–
05/30	5.00	5.50	0.50	Φ	O	–	–	–	–
07/02	5.50	6.00	0.50	Φ	Φ	–	–	–	–
08/29	6.00	7.00	1.00	O	O	–	–	–	–
12/22	7.00	9.00	2.00	–	O	–	–	–	–
1975/04/16	9.00	8.50	−0.50	O	Φ	–	–	–	–
06/07	8.50	8.00	−0.50	O	O Δ	–	–	–	–
08/13	8.00	7.50	−0.50	Φ	O Δ	–	–	–	–
10/24	7.50	6.50	−1.00	Φ	O Δ	–	–	–	–
1977/03/12	6.50	6.00	−0.50	Φ	O Δ	O	–	–	–
04/19	6.00	5.00	−1.00	Φ	O Δ	–	–	–	–
09/05	5.00	4.25	−0.75	Φ	O Δ	–	–	–	–
1978/03/16	4.25	3.50	−0.75	Φ	–	Φ	Φ	–	–
1979/04/17	3.50	4.25	0.75	Φ	Φ	O	Φ	–	–
07/24	4.25	5.25	1.00	O	Φ	–	–	O	–
11/02	5.25	6.25	1.00	O	Φ	–	Φ	O	–
1980/02/19	6.25	7.25	1.00	O	Φ	O	Φ	–	–
03/19	7.25	9.00	1.75	O	Φ	–	Φ	–	–
08/20	9.00	8.25	−0.75	Φ	Φ	–	O	–	–
11/06	8.25	7.25	−1.00	O	O Δ	–	O	–	–
1981/03/18	7.25	6.25	−1.00	O	O Δ	–	O	–	–
12/11	6.25	5.50	−0.75	O	O Δ	O	O	O Δ	–
1983/10/22	5.50	5.00	−0.50	Φ	O Δ	–	O Δ	–	–
1986/01/30	5.00	4.50	−0.50	Φ	O Δ	Φ	O Δ	–	–
03/10	4.50	4.00	−0.50	Φ	O Δ	Φ	Φ	–	–
04/21	4.00	3.50	−0.50	Φ	–	Φ	Φ	–	–
11/01	3.50	3.00	−0.50	Φ	O Δ	–	Φ	O Δ	–
1987/02/23	3.00	2.50	−0.50	Φ	–	–	Φ	O Δ	–
1989/05/31	2.50	3.25	0.75	Φ	Φ	Φ	O	–	O
10/11	3.25	3.75	0.50	Φ	Φ	–	O	O	O
12/25	3.75	4.25	0.50	Φ	Φ	–	O	O	O

*See text for further explanation.
Symbols: Φ indicates a factor identified as a policy objective.
O indicates a factor mentioned in the assessment of the current economic and financial situation.
Δ indicates a factor mentioned with a proviso clause.
Source: Okabe (1990) and Economic Planning Agency, *Economic Survey of Japan* (August 1984, 1987).

reaction. (The language, moreover, emerges from a process of intense consultation within the BOJ and, presumably, also with the Ministry of Finance.) At best, the table provides only a rough guide. Nevertheless, the classification in the table provides some meaningful clues to the likely status of variables as objectives and constraints.[19]

The status of inflation as a goal variable for Japanese monetary policy is unambiguous. A great variety of statements from the BOJ and other parts of the government forthrightly assert that control of inflation is a central if not paramount objective. In general terms, the avoidance of pronounced cyclical swings in output and aggregate demand also appears to be an important objective of policy. If one tries to go beyond generalities to identify details about desired time paths for inflation and output, however, the public record is less clear.

The press releases announcing discount-rate changes frequently have mentioned the balance of payments, the exchange value of the yen, or both — sometimes even indicating these variables as objectives of policy. For any nation, not least Japan, many subtle issues arise about the status of external-sector variables as goals of policy, including which such variables are appropriate as goals and whether such variables should be regarded as ultimate or intermediate goals. I cannot take up these difficult issues in this paper. For the purposes of the analysis below, I presume that both the exchange value of the yen and the balance of payments are ultimate goal variables for Japanese monetary policy.[20]

III. Reaction Functions for Monetary Policy: General Considerations

In this section I identify some conceptual issues about reaction functions and summarize my general approach to them. These general points apply to the modeling of reaction functions not only for Japanese monetary policy, but for any national monetary authority.[21] Section IV then illustrates the approach by applying it empirically to reaction functions for the two key domestic instruments of Japanese monetary policy.

A point sometimes forgotten needs to be made at the outset: the specification of reaction functions for monetary policy in an empirical model should be conditioned by who will be using the model, and for what purpose. A central-bank policymaker using a model to help shape policy decisions has a different perspective and different analytical needs than an outsider using a model to evaluate the consequences for the economy of policy actions and shocks. Furthermore, the analytical assumptions about expectations formation and the analytical time horizon for model simulations should also influence

[19]Asako and Kanoh (1988) analyze the objectives of Japanese monetary and fiscal policies.

[20]The unabridged version of the paper contains a discussion of the status of the money stock as a possible *intermediate* objective of Japanese monetary policy.

[21]The unabridged version of the paper contains a more extended discussion.

how the model specifies monetary policy.[22]

A. General Issues

Reaction functions intended to summarize the behavior of policymakers must somehow embody (be derived from) the goals and priorities of the policymakers. Modelers typically have only limited information about policymakers' preferences. It is therefore often difficult, or impossible, to specify an explicit "loss function" that accurately summarizes the policymakers' preferences.[23]

My approach avoids the specification of an explicit loss function, but it does presume that policymakers have systematic preferences. Thus I assume that modeling analysts can legitimately attribute to policymakers a clearly defined set of goals and priorities. In particular, I presume that policymakers in the monetary authority identify a limited number of variables that are "ultimate goals" of policy and that they have systematic (though possibly time varying) priorities about their relative importance. I also presume that, with the aid of staff members and the models used by the staff, the policymakers can develop rough approximations for particular time paths for the ultimate-goal variables that purport to be mutually consistent with each other.

What level of attention to policy decisions should an empirical model embody? There is inevitably a tradeoff between simplicity and disaggregation. The objective of making the model analytically transparent tends to clash, often seriously, with the objective of adequately summarizing the complexity of actual behavior.

When the research objective is to construct reaction functions for the behavior of a monetary authority for use in a macroeconometric model, the appropriate approach will usually take the "broad overview" perspective. The lower the frequency of the data in the model, the greater the force of this presumption. In a quarterly model, and even more so in an annual model, it is perhaps impossible and in any case undesirable to try to model the fine details of money-market transactions and policy actions.

For quarterly or annual models of Japan's economy in the 1990s, for example, the preferred approach is to treat the unconditional call rate as the primary instrument of Japanese monetary policy. For the illustrations of reaction functions in this paper, I concentrate the most attention on the call rate. The BOJ's discount rate, increasingly subsidiary but still very important, is also modeled.

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[22]My analysis draws extensively on research done at the Federal Reserve Board, including an underappreciated essay by Anderson and Enzler (1987), which in turn was stimulated by the work of Peter Tinsley and Peter von zur Muehlen. The approach I take to reaction functions is different from this research, but my ideas have been significantly shaped by it.

[23]If an explicit loss function could be specified, that function could be used in conjunction with the macroeconometric model(s) and well developed mathematical techniques for "optimization" to derive particular forms for policy reaction functions that would, given the model(s), best promote the policymakers' objectives.

Sensible reaction functions for policy behavior cannot be divorced from the analytical model or models with which they are to be used. Inevitably, therefore, reaction functions will be model specific. In the remainder of this section, I discuss the general specification of reaction functions that could be incorporated in a variety of models. To make this approach applicable and helpful in a specific modeling situation requires joining reaction functions of this general form to one or more specific analytical models, and then "tuning" the reaction functions to those models.

B. Essential Components for a Reaction Function

It is useful to distinguish three different elements of a reaction function. First, it should specify a target path for the level of the policy instrument; the target path ought to be consistent with that particular long-run, equilibrium evolution of the national economy judged by the monetary authority to be most desirable (among those evolutions that are feasible). Second, the reaction function should specify how the monetary authority alters the policy instrument in response to deviations of the economy from the desired long-run, equilibrium evolution. Third, the reaction function should acknowledge that some aspects of policy behavior cannot be readily summarized in simplified model equations and will therefore have to be represented in the model by an "everything else," residual element.

The phrase "long-run, equilibrium evolution of the national economy" refers to the analytical concept of steady-state growth paths in long-run growth theory. This concept, though full of difficulties, is nonetheless vital for systematic thinking about macroeconomic developments. The key premise of the concept is that, given appropriately stable government policies and given an absence of new disequilibrating nonpolicy shocks, the main macroeconomic variables in an economy could (after a period of adjustment to past shocks) evolve along smooth, sustainable growth paths. Actual economies presumably never settle onto such long-run equilibrium paths, because no substantial period of time is ever free from new disequilibrating shocks and/or because policymakers may make mistakes in their policy actions. The absence of such paths in the real world, however, does not vitiate the analytical importance of the concept.

A variety of shock-free, long-run equilibrium evolutions of the economy can be imagined (for any given analytical framework describing the economy). Some evolutions, for example, might have high saving rates and rapid accumulation of capital, and hence higher paths for the level of output, than evolutions associated with lower rates for saving and capital accumulation. Logically, therefore, a variety of time paths may exist for the long-run, equilibrium level of the policy instrument that would be consistent with these various shock-free equilibrium evolutions of the economy. Choosing a path for the equilibrium level of the policy instrument thus involves *both* "positive economics" (analyzing alternative paths the economy could conceivably follow) and "normative choices" (making value judgments about which path ought to be followed).

If the economy were ever to experience an extended period of absence of nonpolicy shocks, the reaction function for policy should cause the actual time path of the policy instrument to move toward and then settle on its long-run equilibrium path. In practice, some of the goal variables of policy will always be away from their long-run equilibrium paths, with corresponding incentives for the policymakers to consider adjustments in their policy instrument. Thus the second main component of a reaction function is its specification of policy responses to deviations of goal variables from their equilibrium paths. The shorter-run dynamics of movements in the policy instrument stem largely from this component. The specification of this disequilibrium component, like that of the long-run equilibrium component, involves both positive and normative elements. The policymakers' preferences, in particular the priorities they assign to the various goal variables, will determine the strength of their responses to the various disequilibrium deviations (hence the obvious normative element). Positive analysis is also required, however, because the responses to the deviations for particular goal variables need to be conditioned by (analytical, positive judgments about) the actual behavior of the goal variables.

In principle, a reaction function should make the *level* of the policy instrument a function of the size of the disequilibrium deviations of goal variables. Hence *changes* in the policy instrument will be induced by changes in the size of the disequilibrium deviations of goal variables.

An analyst can aspire to summarize some of the most important features of the conduct of monetary policy in the first two components of the reaction function. But, inescapably, some nuances — some of the "bells and whistles" — will be overlooked. Such things as differences of view within the monetary authority (e.g., between the central bank and the finance ministry; the influence of individual personalities) and certain types of one-time nonpolicy shocks (e.g., political scandals; unexpected failure of a large financial institution) impinge on policy decisions but usually cannot be modeled without more information than is available to analysts. Furthermore, even if enough information were available, it might nonetheless be preferable to omit such factors from the usual analysis done with the model.[24]

The non-modeled, "everything else" component of the reaction function is a residual in one sense of that word. But it will probably bear little resemblance to the nicely behaved statistical error term that econometricians hope to find in their regression equations. Most notably, there is a strong presumption that "everything else" will be autocorrelated through time. Usually, it seems reasonable to presume, the non-modeled influences on policy will be associated with, and involve responses to, the disequilibrium

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[24]There is an analogy here with the issue of how detailed to be in the modeling of the conduct of monetary policy. Just as it is not always necessary or desirable to take the basic-detailed perspective when describing the implementation of monetary policy, it may not be necessary or desirable to try to model explicitly all the considerations that lead to non-zero values of the third component of the reaction function.

behavior of the economy. Thus one can probably assume that these influences would converge to zero if all the policy goal variables themselves were ever to settle on their shock-free equilibrium paths.

The preceding ideas can be summarized in symbolic form, for a particular policy instrument X_t and a vector of different goal variables G_t :

X_t	$=$	X_t^{U*}	$+$	$f(G_t - G_t^{U*})$	$+$	Zeta_t.	(1)
actual value of policy instrument		"ultimate" target value of instrument		responses to disequilibrium deviations of goal variables		non-modeled residual elements of policy	

The superscript notation "$U*$" is used to indicate the shock-free, equilibrium values of variables selected as targets by the policymakers. It will be convenient to use the short-hand label "ultimate target" to distinguish these values from the actual values of the variables (without superscript) and from values that will be labeled "interim target" (denoted with a superscript "$I*$" — see below).

C. Long-run Equilibrium Paths

How can policymakers, helped by their staff analysts, develop estimates for the time paths G_t^{U*}, and then the associated estimate for X_t^{U*}? Alternatively, how should outside analysts proceed in trying to develop such paths, given publicly available information about policymakers' preferences and the functioning of the economy? I cannot do more here than sketch some general points about this difficult topic and, in the next section, provide tentative illustrations.

Consider the example of the short-term nominal interest rate, R_t, used as the primary instrument of a central bank's policy. To obtain an ultimate-target path R_t^{U*}, an analyst would first focus attention on the real (inflation-adjusted) interest rate that corresponds to R_t. A long-run, ultimate-target path for this real rate, denoted here r_t^{U*}, would be derived in conjunction with derivation of ultimate-target paths for goal variables such as inflation, output, and the exchange rate. The most appropriate way to derive such paths is with the aid of the model or models into which the reaction function will be incorporated. Because a variety of conceivable shock-free evolutions of the economy exist, even within the context of a single model, the policymakers and their analysts must select from among the evolutions judged to be feasible that particular one that corresponds best to the policymakers' preferences. Many hypothetical simulations of the model are likely to be performed as part of this process of preparing alternative equilibrium evolutions and choosing among them.

The outcome of this analytical process will be a set of time paths for goal variables — for example, inflation ($P\text{dot}_t^{U*}$) and output (Y_t^{U*}) — and a path for the inflation-adjusted short interest rate (r_t^{U*}); all of these ultimate-target paths will be, to the best of the analysts' ability, mutually consistent. Finally, the paths for r_t^{U*} and $P\text{dot}_t^{U*}$ can be combined to generate an ultimate-target path for the nominal short rate that is the actual instrument of monetary policy ($R_t^{U*}=r_t^{U*}+P\text{dot}_t^{U*}$).[25]

D. Responses to Disequilibrium

I hypothesize that, when setting policy in the shorter run, policymakers do not respond directly to the deviations ("gaps") between the actual paths and the ultimate-target paths for their goal variables. Rather, they are assumed to make adjustments to these gaps and then to calibrate their response in proportion to the adjusted gaps.

Consider the example of a particular goal variable A. Rather than focus directly on the ultimate gap ($A_t - A_t^{U*}$), the policymakers are deemed to focus on an adjusted or "interim" gap measured as

$$\underline{\text{“Interim, adjusted” gap:}} \quad A_t - [A_t^{U*} + \sum_i (A\text{adj}_{it})], \quad i=1, \ldots, k. \tag{2}$$

The k adjustment terms, $A\text{adj}_{it}$, constitute temporary adjustments to the target path at which policy aims. In practice these terms may be complex. For example, there is no presumption that the adjustments should be modeled as linearly proportional to the ultimate gap; they might be nonlinear in a complex way. Similarly, the responses need not be symmetric to deviations of the goal variable above its ultimate target value and to deviations below. One ideally wants to work with a specification of the reaction function that readily permits nonlinear and asymmetric responses to be modeled but retains simplicity. Such a specification is suggested below. The complex adjustment terms condition the adjusted, interim gap in (2). Given these adjustments, policymakers may be thought of as aiming at an interim-target rather than directly at an ultimate-target path for the goal variable A:

$$\underline{\text{“Interim target path”:}} \quad A_t^{I*} = A_t^{U*} + \sum_i (A\text{adj}_{it}), \quad i=1, \ldots, k. \tag{2a}$$

With A the only goal variable, the reaction function (1) might take the specific form:

$$X_t = X_t^{U*} + \Psi[A_t - (A_t^{U*} + \sum_i (A\text{adj}_{it}))] + \text{Zeta}_t, \quad i=1, \ldots, k, \tag{3}$$

where the size of the coefficient Ψ ($\Psi > 0$) embodies the strength of the response to the adjusted, interim gap.

When the adjustments in equation (2) are positive, the result is to algebraically *reduce* the size of the interim gap to which policy responds in the short run. Positive adjustments to a positive ultimate-target gap, in other words, dampen policy action (induce more cautious responses). Conversely, when the net adjustments are negative to an otherwise positive gap, the result is to *increase* the interim gap to which policy re-

[25]The formidable difficulties associated with such analytical calculations are discussed further in the unabridged version of the paper.

sponds, thereby inducing a more aggressive response.[26]

From the perspective of a modeler looking backwards at *ex post* data, one can by definition obtain the value of the non-modeled factors Zeta_t by subtracting the sum of the long-run, equilibrium value of the instrument and the short-run dynamic adjustments from the actual value of the instrument. In the single-goal-variable case of (3), for example, the non-modeled factors would be defined as:

$$\text{Zeta}_t = X_t - \{X_t^{U*} - \Psi[A_t-(A_t^{U*}+\sum_i(A\text{adj}_{it}))]\}\,, \quad i=1, \ldots, k. \tag{4}$$

In logic and practice, policymakers look forward into the future. Hence, in principle, the disequilibrium deviations in a reaction function ought to be expressed as forward-looking, not merely as current-period and backward-looking. For the example of the goal variable A, the policymakers will make forecasts $\hat{A}_{t+1}$ (perhaps even $\hat{A}_{t+2}$ and $\hat{A}_{t+3}$), as well as looking at the current-period value A_t.[27] Policymakers will also have developed a projection $\hat{A}_{t+1}^{U*}$ for the ultimate-target path. When making their target adjustments for this period, which in turn determine the strength of their policy response in the current period, they will thus examine and respond to a projection of the ultimate gap "tomorrow" as well as to its value "today." In effect, their interim target — instead of merely (2a) — incorporates forward-looking as well as current and backward-looking adjustments:

$$A_t^{I*} = A_t^{U*} + \sum_i(\hat{A}\text{adj}_{i,t+1}) + \sum_i(A\text{adj}_{it}) + \sum_i(A\text{adj}_{i,t-1}), \quad i=1, \ldots, \text{k}. \tag{5}$$

The need for reaction functions to look forward, emulating the behavior of policymakers and their staffs in real life, is crucially important. In the empirical illustrations below, I have unfortunately not had a practical, model-based way to generate forecasts for the goal variables. When one is working with an explicit macroeconomic model of the economy, it is feasible to generate such forecasts. And presumably this is what policymakers and their staffs actually do, judgmentally if not with the aid of an explicit model.

When policymakers in real life make dynamic adjustments in their instrument settings, they often do so in complex ways, with a richness of detail. The specification of the adjustment terms in reaction functions — equation (5) — cannot of course capture all this richness. Some nuances will inevitably fall into the Zeta component. Nevertheless, if the modeled part of policy behavior is to capture the dominant features of the dynamic adjustments, the adjustment terms must allow for non-linear, differentiated responses to the gaps between actual and ultimate-target values of the goal variables.

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[26]When an ultimate-target gap has an algebraically negative value — when an A_t is less than A_t^{U*} — a positive value for an adjustment term $A\text{adj}_{it}$ has the effect of strengthening policy action (reducing X_t by a larger amount than would otherwise occur).

[27]Depending on time lags in the collection of statistics, it may be necessary even to make a forecast for the current-period value of A. In addition to formulating current-period and future-period forecasts, policymakers and their analysts will of course be constantly "looking in their rear-view mirror" at past values of the goal variables and other variables that provide information about where the economy has been and is heading.

The approach I follow is to include several types of adjustment terms, with some or perhaps all allowed to take a nonlinear form. Four types — the "shock-absorption," the "proportional," the "derivative," and the "integral" responses — may be pertinent for each identified goal variable. The ideas stimulating these suggestions come from control theory, especially as applied in engineering applications.

When policymakers receive new information about the economy showing that a goal variable has moved away from its ultimate-target path, they recognize that the deviation could be transitory. If they were to react immediately and strongly to the deviation, there is a chance that, seen in retrospect, their instrument change would have constituted an over-reaction. Moreover, policymakers have an understandable aversion, other things being equal, to high volatility in the settings for their instruments. Various implicit costs may be associated with instrument variations, and in any case volatile instrument changes could have adverse effects on private-sector expectations. Hence, in the short run, policymakers may wish to "accept" some of the newly identified deviation, pending further information to be received in subsequent periods. This "shock-absorption" response, algebraically increasing the interim-target value of the goal variable relative to its ultimate-target path, has the effect of dampening any current-period change in the policy instrument.

Although policymakers may be prepared temporarily to absorb unexpected shocks as they occur, their more lasting response is in the opposite direction — to lean against the wind. Consider first the policy response to an observed or projected discrepancy between the actual and ultimate-target values of a goal variable. The larger this gap, the greater the degree of concern and — presumably — the harder will the policymaker want to lean against the deviation. An adjustment term responding to the level of the gap may be labeled "proportional," in the sense that the policymaker calibrates his adjustment in proportion to the size of the ultimate-target gap itself (though not necessarily in a linear way).

Policymakers presumably pay attention not only to the level of a discrepancy between the actual and ultimate-target values of a goal variable but also to the rate of change of that discrepancy. Suppose a discrepancy, though still not large in absolute size, is growing at a rapid pace; the high rate of change may be a signal that things are threatening to get out of hand. Policymakers may therefore want to supplement their proportional response with a "derivative" response: other things equal, the faster a discrepancy between actual and ultimate-target values is emerging, the more aggressively they may wish to change their policy instrument to offset the emerging discrepancy. The derivative response also works in the opposite direction: if a deviation between actual and ultimate-target values is closing rapidly, the policymakers would take this rapid rate of change into account by, other things equal, dampening their leaning against the wind.

Decisionmakers typically try to learn from their past mistakes. This idea leads to the suggestion for an "integral" adjustment term. Policymakers are hypothesized to look in their rear-view mirrors at the *cumulative* discrepancy, for some representative longish past period, between the actual and ultimate-target values of their goal variable. If this cumulative discrepancy (in effect, the integral of the period-by-period values of the discrepancy) is observed to become larger, policymakers are presumed, other things equal, to make a negative adjustment to offset the growing cumulative discrepancy of the past. Like the proportional and derivative responses, therefore, the integral response increases the current-period assertiveness of policy when goal variables deviate further from their ultimate-target values.

E. Summary Specification

In summary, one can write the specification of the reaction function for an instrument X as follows (presuming the consideration of q different goal variables):

$$X_t = X_t^{U^*} + \theta_1\mu\,(\text{adjusted } G_1 \text{ gap})_t + \theta_2\mu\,(\text{adjusted } G_2 \text{ gap})_t + \ldots + \theta_q\mu\,(\text{adjusted } G_q \text{ gap})_t + \text{Zeta}_t. \qquad (6)$$

The "adjusted gap" for each goal variable — (2) above — would in a general treatment embody adjustment terms for future as well as current and past-periods. If desired for expositional purposes, interim-target values for goal variables can be defined as in (2a) or (5).

The coefficient on each adjusted goal-variable gap may for expositional purposes be construed as the product of two coefficients. A general response coefficient, μ, applicable to all types of goal variable, measures the aggressiveness or weakness of policy behavior to all the gaps. The other coefficients, the θ_i, are weights which by assumption add up to unity. Thus in principle this specification, given judgments about the θ_i, permits the interpretation of empirical priorities among the goal variables. As with the disequilibrium adjustments themselves, there is no presumption that the coefficients μ and θ_i remain invariant over time.

F. Reaction Functions for Fiscal Policy

For some purposes and circumstances, it may be feasible to simulate a macroeconomic model that incorporates reaction functions for monetary policy but does not incorporate reaction functions for fiscal policy. In the Federal Reserve MPS model, for example, staff analysts can successfully simulate the model over shorter horizons using only reaction functions for monetary policy. In general, however, it will be crucially important to model reaction functions for fiscal policy as well. Simulation experiments conducted over longer-run horizons in any model (certainly including the MPS model) tend not to give sensible and stable analytical results without intertemporal restrictions governing the behavior of the government's expenditures and its tax policies.

Macroeconomic theory in the last decade has clarified the reason for this fact. Along a steady-state growth path, the surplus or deficit in the government's budget and the outstanding stock of government debt will be constant proportions of GNP. Moreover, if there is a difference between the steady-state growth rate of output and the real interest rate on government debt (sometimes stated as a difference between the rate of growth of nominal GNP and the nominal interest rate on debt), the government budget position net of interest payments will have to be adjusted to reflect this difference if the stock of government debt relative to the economy is not to grow or decline explosively.

Accordingly, macroeconomic models simulated over long horizons, especially those that incorporate forward-looking expectations, now contain as an essential element a reaction function for fiscal policy. A common formulation is to suppose that the fiscal authority selects a target ratio for the level of government debt to GNP. A reaction function for the average tax rate then induces changes in the tax rate in such a way that the simulated ratio of actual debt to GNP gradually converges to the target ratio. Many variations exist for how the tax-rate instrument is adjusted in the shorter run.[28]

The common sense of this necessity for reaction functions for fiscal as well as monetary policy is that, in real life as in the models, a stable, desirable evolution of the economy requires sensible monetary policy *and* sensible fiscal policy. The world would be tidier if God had made it such that monetary policy only had to be concerned with nominal variables while fiscal policy had only to focus on the real economy and the allocation of resources between the government and private sectors. But God in his wisdom, or pique, created a world in which such a compartmentalization is not valid. Macroeconomic modelers ignore the inevitable interrelationships between monetary and fiscal policies at their peril.

IV. Reaction Functions for Japanese Domestic Monetary Policy

This section illustrates the previous ideas by building up the components required for a reaction function for the Japanese call rate. I use quarterly data for those components and the call-rate function itself. A reaction function for the discount rate, using data with a monthly frequency, is presented at the end of the section.

A. Long-run Equilibrium Paths for the Ultimate-Goal Variables

Long-run equilibrium paths for goal variables should be derived in conjunction with the model(s) into which a reaction function will be embedded (section III). When preparing the empirical illustrations here, it was impractical to derive those G_t^{U*} and the X_t^{U*} time paths from an explicit model.

Four goal variables — inflation, real output, the exchange value of the yen, and the

[28]Examples of multi-country models containing a tax-rate reaction function for fiscal policy include Masson and others (1988, 1990), Helliwell, Meredith, and others (1988), Meredith (1989), Taylor (1989), McKibbin and Sachs (1989a, 1989b), and Gagnon (1989).

balance of payments — are included in the reaction function for the call rate to be described below. The Bank of Japan has never published target paths for the levels of these or other goal variables, and even internally may never have formulated such paths in the manner conjectured here. Self evidently, my conjectures have no official status or endorsement.[29]

Which price series should be used to generate an ultimate-target path for inflation? The three main candidates are an index of domestic wholesale prices, an index of consumer prices, and a broadly based deflator series from the national income and product accounts. Consumer prices and the GNP deflator behave in roughly similar ways, both differing significantly from the behavior of domestic wholesale prices. The GNP deflator is the most comprehensive of the candidate indexes.

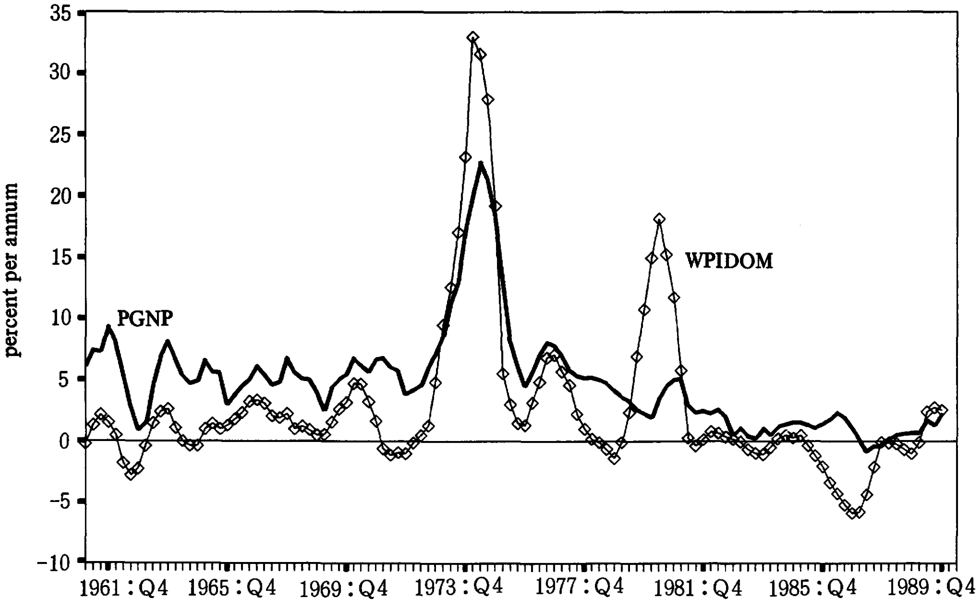
Figure 2 shows inflation rates for both the GNP deflator (PGNP) and the domestic wholesale price index (WPIDOM). The average inflation rate for PGNP has been higher than that for WPIDOM. One possible explanation for this difference in trends, often cited, is a faster growth of productivity for traded goods than for non-traded goods (with the former having a much higher relative weight in WPIDOM than in PGNP). The inflation rate for the index of domestic wholesale prices also shows higher short-run variability than PGNP inflation, rising more in periods of upward pressure (such as the two oil shocks) and falling more in periods of low pressure (such as the yen appreciation of 1985-88).

The BOJ has paid close attention to all three types of price indexes. I was unable to discern a consensus, however, whether one of the indexes has priority as the dominant measure of inflation. Because new observations for WPIDOM are available sooner than for PGNP and because the former is measured at a monthly frequency, BOJ judgments about current or very recent inflation are conditioned more by WPIDOM than by PGNP. Some BOJ staff members prefer to focus on the GNP deflator because of its comprehensive coverage of the economy. I finally chose to use PGNP in my illustrative calculations, though I also brought in WPIDOM in a subsidiary role when constructing the adjustment terms (as explained below).

The inflation rates shown in Figure 2 are calculated on an *ex post*, 4-quarter basis (current-quarter price level versus the price level 4 quarters previously). I have used this year-over-year basis throughout, primarily because that method of calculation appears to be commonly used within the BOJ. Quarter-to-quarter inflation rates are considerably more volatile. In principle, one might want to use an inflation rate that was partly or

[29]While preparing the following illustrations, I read a variety of official documents and had numerous conversations with individuals informed about Japanese monetary policy, including many BOJ staff members. I shaped my conjectures using the information gleaned from those readings and conversations. I therefore hope that my illustrations are consistent in a rough, broad sense with the reality of Japanese monetary policy. But even when a source or a conversation seemed to corroborate my conjectures, that corroboration was only in qualitative terms. At best, my illustrations are a highly preliminary pass at identifying ultimate-target paths.

Figure 2
Inflation Rates for GNP Deflator and Domestic Wholesale Prices



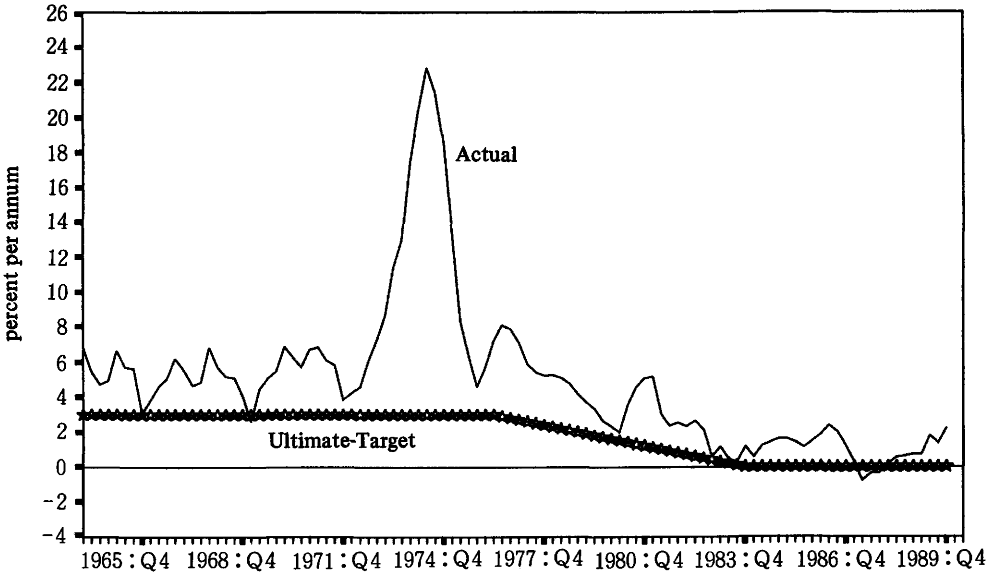
Note: Quarterly data calculated as current quarter price level versus price level 4 quarters previously.

wholly forward-looking, since for many purposes it is inflation *expectations* as well as inflation itself that are relevant for policy decisions.

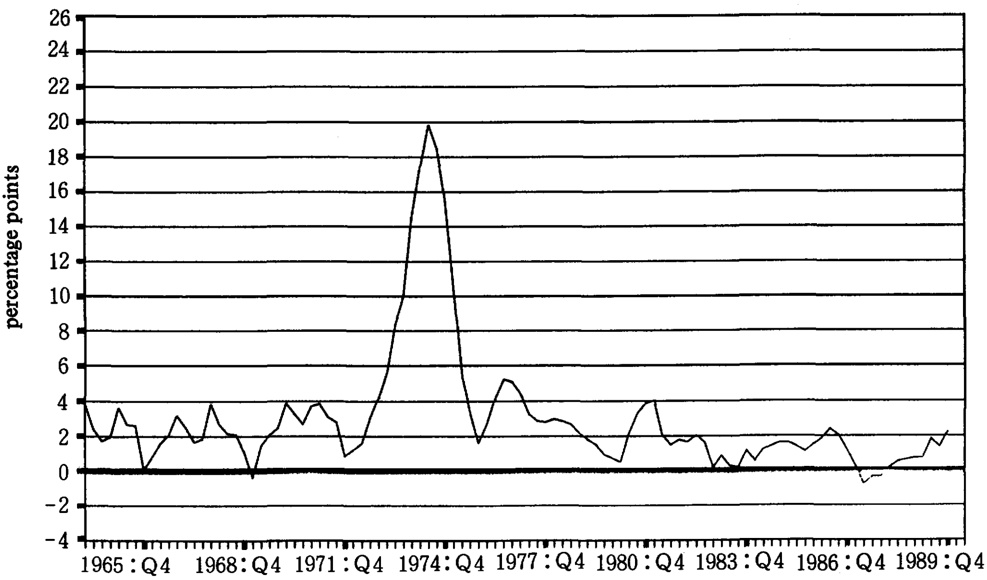
The top panel of Figure 3 repeats the series for the actual inflation rate for PGNP and shows in addition an illustrative ultimate-target path ($Pdot_t^{U^*}$). My working assumption is that Japanese policymakers were prepared to tolerate a modest rate of inflation in the period of high growth in the 1960s and early 1970s, but then gradually lowered their tolerance for inflation after the outburst of high inflation associated with the first oil crisis. The ultimate-target path that illustrates this presumption postulates a 3 percent rate prior to 1976 and a rate of zero for 1984 and subsequent years; between 1976 and 1984, the ultimate-target rate declines monotonically from the 3 percent rate to zero. The bottom panel of Figure 3 plots the deviation between actual inflation and the hypothesized ultimate-target path (to be referred to as the "ultimate gap").

To develop an ultimate-target path for real output, one requires an estimate of potential output for the Japanese economy as a place to start. Preferably, such an estimate would be derived in conjunction with an explicit model. Model-specific estimates were not available to me, and I accordingly searched for a next-best substitute. For the illustrations here, I have used estimates implied by the research of Munehisa Kasuya on

Figure 3
PGNP Inflation: Actual and Illustrative Ultimate-Target Path



Inflation Ultimate Gap



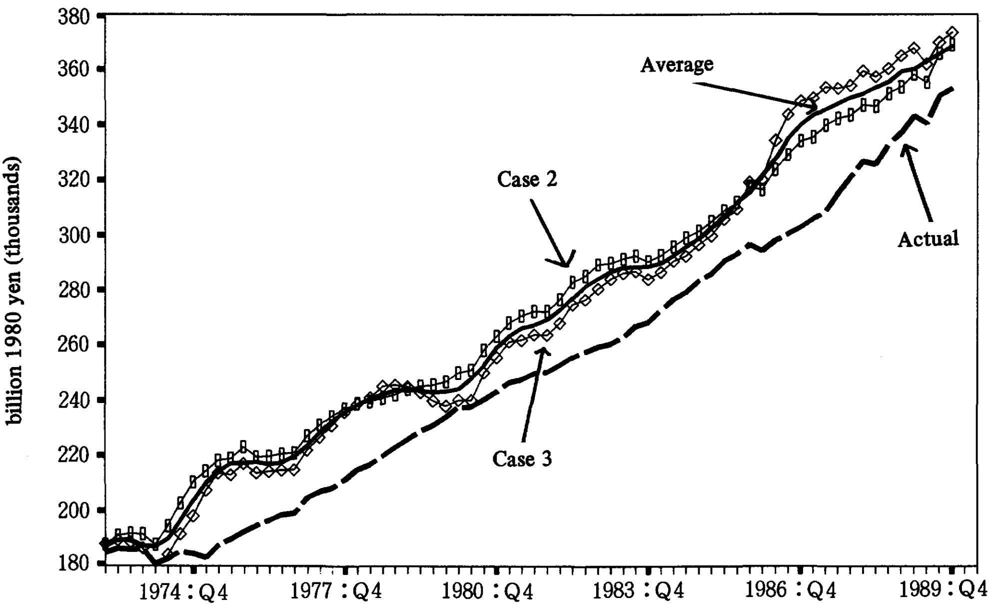
macroeconomic supply-demand gaps for the Japanese economy (1989, 1990).

Kasuya (1989) pursues a production-function approach that attempts to allow not only for traditional factors of production such as capital and labor but also for imports as intermediate inputs. He is concerned especially with the stabilizing influence on domestic prices and output of lower costs attributable to the appreciation of the yen and to declines in oil prices. He reports "output gaps" (the percentage shortfall of actual output from maximum attainable output) calculated by three different methods. His "case 2" assumes capital and labor inputs at maximum values (full utilization), with actual input volumes for imports; his "case 3" assumes that capital, labor, and import inputs are all at "maximum" values.

Given Kasuya's output-gap measurements and given the series for actual real GNP, I derived series for the level of "maximum attainable output" implied by the Kasuya estimates. These levels for Kasuya's cases 2 and 3, together with actual real GNP, are plotted in Figure 4. For the illustrations here, I have taken a simple average of the levels from Kasuya's cases 2 and 3 (also plotted in Figure 4) as a rough estimate of maximum attainable output.

Some features of the maximum-output estimates in Figure 4 are problematic. One

Figure 4
Alternative Estimates of Maximum Attainable Output



Note: Derived from output gaps presented in Kasuya (1989). See text for explanation.

typically thinks of potential ("maximum") output as being a more stable, smoothly growing series than actual output. The estimates derived from Kasuya's output gaps reverse this presumption, especially when the production function explicitly includes intermediate imported inputs (case 3). The difficulties with the Kasuya series and the estimates in Figure 4 stem especially from drawbacks in the underlying data for production capacity (the index for which is published by MITI).

Policymakers concerned about inflation seem unlikely to aim directly at "maximum attainable" output. Doing so could expose the economy to high inflationary risks in the event of unexpected expansionary shocks or expansionary mistakes in policy. When specifying the illustrative ultimate-target path for output, therefore, I assumed that policymakers built in a margin for error, with that margin increasing somewhat after the first oil shock in the mid-1970s. Specifically, the target path is assumed to be 2 percentage points below (the averaged estimate of) maximum attainable output prior to 1976 and 3 percentage points below after 1980; in the interval from the first quarter of 1976 through the fourth quarter of 1980, the margin-for-error factor is assumed to increase monotonically from 2 to 3 percentage points.

The top panel of Figure 5 shows the illustrative target path for real output, Y_t^{U*}, that results from these assumptions. The bottom panel plots the ultimate gap, the difference between actual real output and this ultimate-target path. According to these calculations, except for the late 1960s and brief periods in 1973 and 1980, Japanese output was below — often substantially below — a desired level even taking into account the hypothesized margin-for-error factor. Refinements of these calculations could well change this inference significantly.

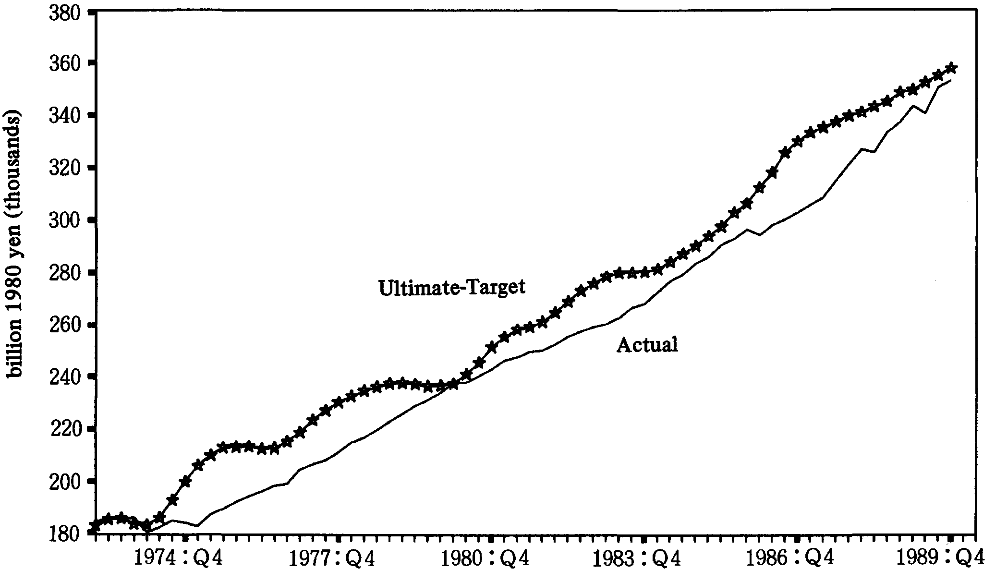
In principle, a long-run, shock-free equilibrium path for the exchange value of the Japanese yen should pertain to an *effective* (weighted-average) exchange value rather than to a bilateral rate against any single currency. The ultimate-target path should probably refer to an inflation-adjusted ("real") exchange value. And it should be derived in conjunction with an explicit multi-country macroeconomic model. The illustration here is deficient on all three of those counts. I focus only on the nominal bilateral exchange rate of the yen against the U.S. dollar.

The U.S. dollar is typically the primary focus of attention when the Japanese monetary authority considers exchange markets and exchange-market intervention. The U.S. dollar, without any near challengers, accounts for the largest single share of Japanese transactions denominated in foreign currencies. In the shorter run, movements in the nominal and inflation-adjusted ("real") exchange rates of the yen against the dollar are highly correlated. Nonetheless, a more careful treatment should begin with an inflation-adjusted index of the weighted-average value of the yen against all important foreign currencies.[30]

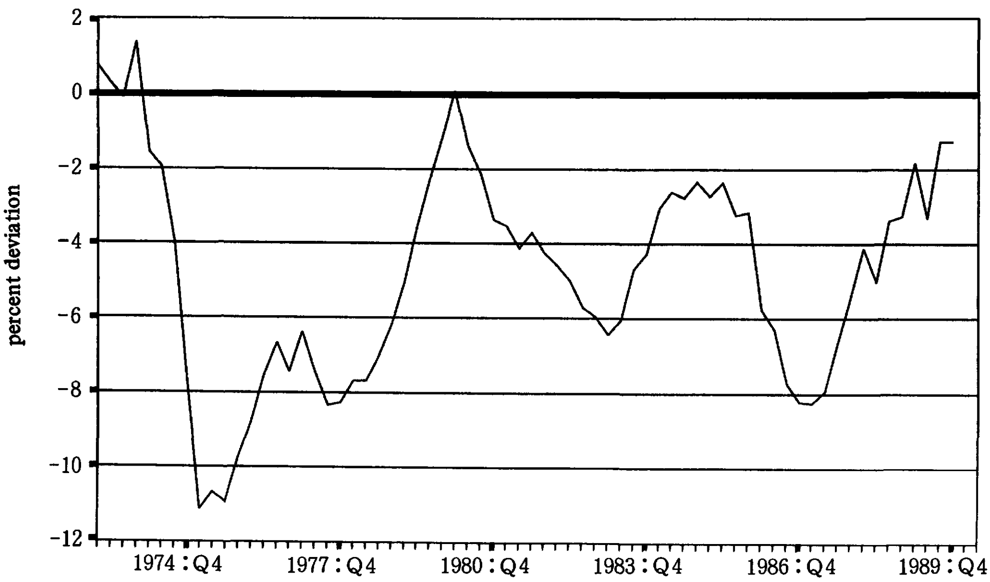
[30]The unabridged version of the paper contains a chart comparing indexes of the nominal and real value of the yen-dollar exchange rate.

Figure 5

Real GNP: Actual and Illustrative Ultimate-Target Path



Real GNP Ultimate Gap



The top panel of Figure 6 presents an illustrative ultimate-target path for the nominal yen-dollar rate. When constructing this path, I drew on various official statements and public sources of commentary about the desirable range for yen-dollar exchange rates. For example, for the period 1985-88 I made use of Funabashi (1988) and Ito (1989c). My identification of the target path is, at best, rough and ready. As most readers will be well aware, moreover, the public record is incomplete and often ambiguous. The bottom panel of the figure plots the percentage deviation of the actual spot rate from the ultimate-target path.

Figure 6 shows not only an illustrative target path but also variable-width bands around that path. The band widths vary from as little as plus and minus 0.75 percent (e.g., in the early 1970s) to as much as plus and minus 4 percent (e.g., in the early 1980s when the major governments had no cooperative understanding about intervention in exchange markets). These illustrations of band widths are even more speculative than the illustration of the ultimate-target path.[31]

The top panel of Figure 7 plots the ratio of the current account of the Japanese balance of payments to the value of aggregate Japanese exports (both numerator and denominator measured in current U.S. dollars). Possibly — I feel especially unsure of the ground here — this ratio may embody in summary form the concern of the Japanese monetary authority with the balance of payments as a goal variable.[32]

To serve as a proxy for an ultimate-target path for this ratio, I arbitrarily chose an unchanged value of 7 percent. This assumption is surely not an accurate summary of historical preferences about the balance of payments; on *a priori* grounds, it is unlikely that any target ratio would have been constant over time. Nor can I make a strong case for 7 percent as a presumptive value for the target ratio as of 1990. I have not had time to undertake a careful reading of official statements about the balance of payments, from the BOJ or from other government sources. Such an effort might suggest a substantial refinement of the illustrative path in Figure 7.[33]

B. A Derived Ultimate-Target Path for the Call Rate

In Figure 8, I present the illustrative assumptions made about the ultimate-target path for the call rate itself. The preferred procedure is to try to generate a feasible path

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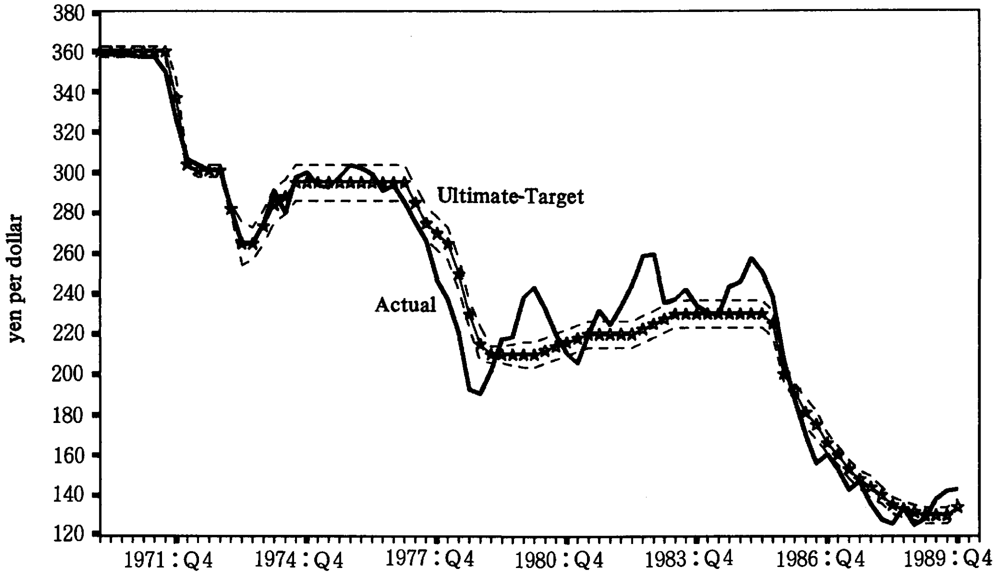
[31]In concept, Figure 6 refers to the exchange-rate goals of the Japanese monetary authority. Those goals will be influenced by the presence or absence of cooperative understandings with other governments, but are not the same things as any such understandings.

[32]The purpose of the denominator of the ratio is to scale the nominal magnitude in the numerator. I examined the ratio of the current account to nominal GNP as well as to the aggregate value of exports; it made little practical difference which scaling variable I chose for the denominator.

[33]As a practical matter, as can be seen from a comparison of the top and bottom panels in Figure 10, it makes only a small difference — once the arbitrary assumption is made that the target ratio was constant over the recent historical past — what the particular unchanged value is. Any constant value within a fairly wide range tends to give qualitatively similar results.

Figure 6
Yen/Dollar Exchange Rate: Actual and Illustrative Ultimate-Target Path



Exchange-Rate Ultimate Gap

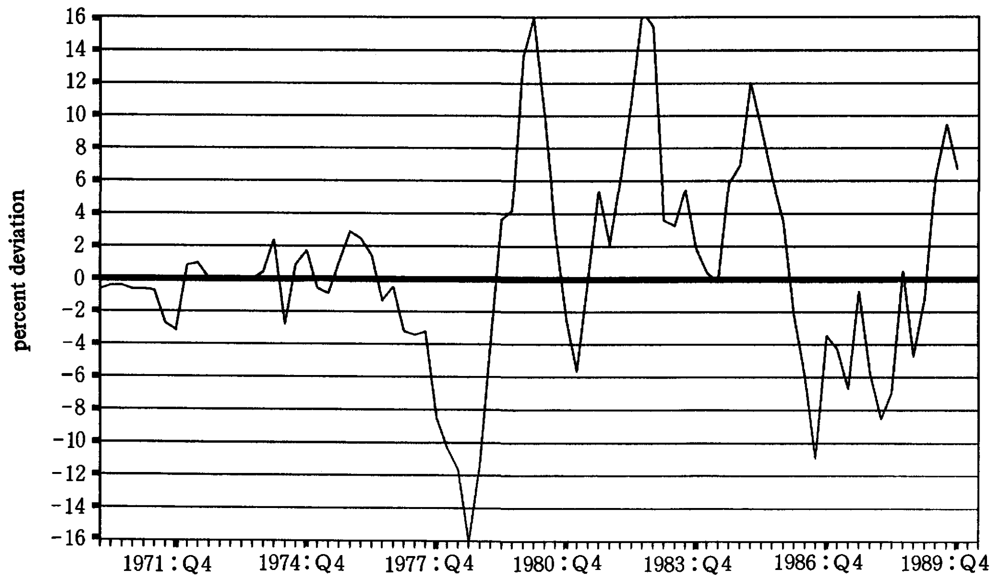
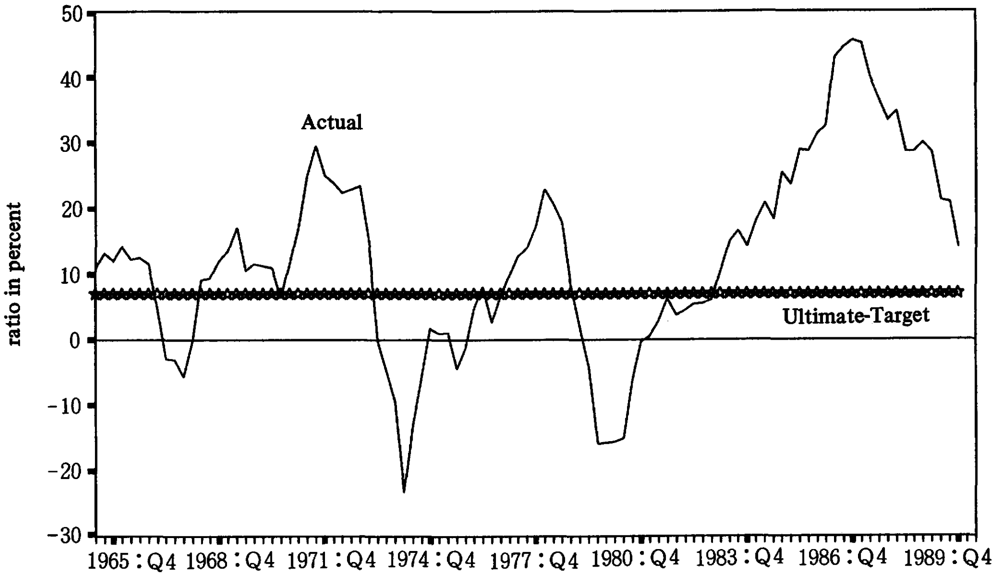
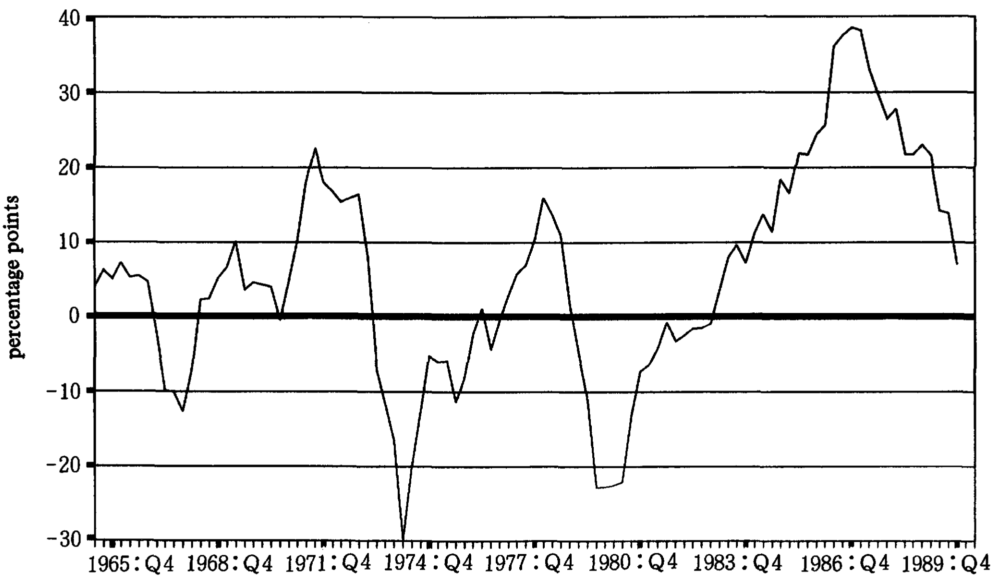


Figure 7

Balance of Payments Ratio: Actual and Illustrative Ultimate-Target Path



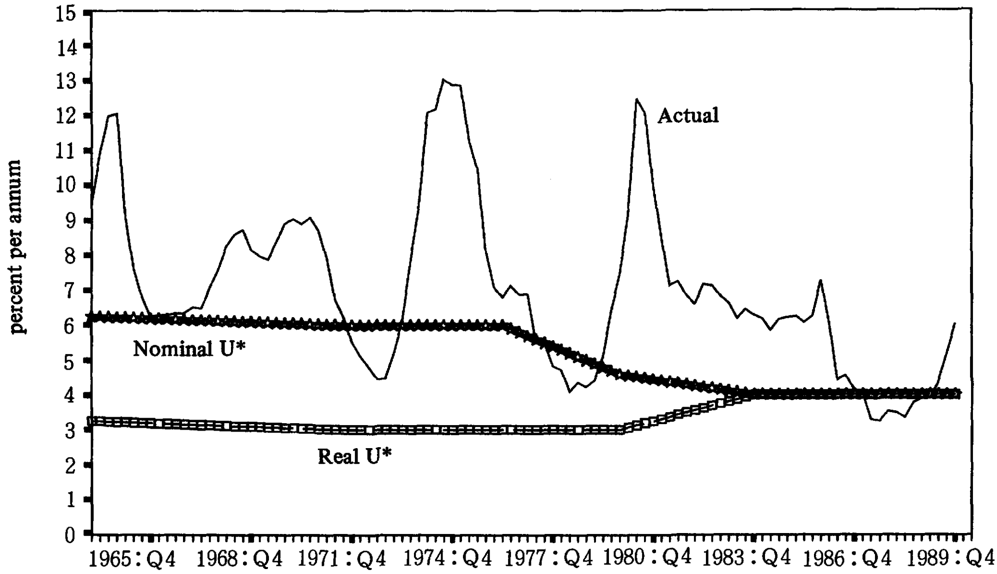
Balance of Payments Ultimate Gap



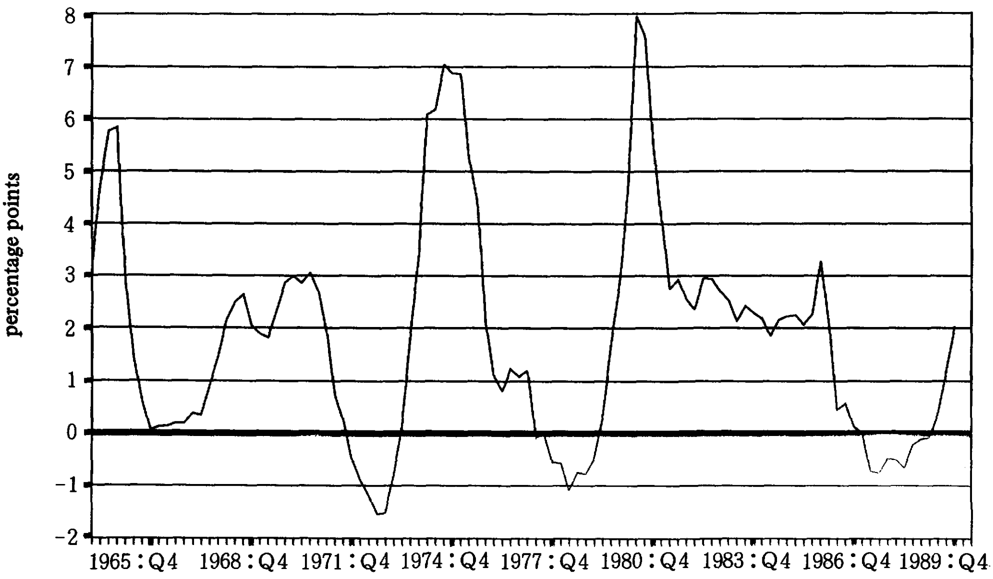
Note: Balance of payments ratio: current account divided by value of aggregate exports (dollar basis).

Figure 8

RCAU: Actual and Illustrative Ultimate-Target Paths (Real & Nominal)



RCAU minus Nominal Ultimate-Target Call Rate



for an inflation-adjusted call rate (r_t^{U*}) that will be mutually consistent with the ultimate-target paths for the goal variables ($Pdot_t^{U*}$, Y_t^{U*}, E_t^{U*}, and BOP_t^{U*}). The best hope for achieving this consistency is, again, to make all of the estimates jointly in conjunction with the model into which the call-rate reaction function is to be incorporated.

As a substitute for the first-best procedure, I examined alternative inflation-adjusted series for Japanese and U.S. interest rates. Then I hazarded a crude guesstimate for r_t^{U*}, the ultimate-target real call rate. This conjectured path for r_t^{U*} is not quite constant, but nearly so. It declines very slightly from a rate a bit above 3 percent in the 1960s to 3 percent in the early 1970s; then it stays at 3 percent until the second oil shock. In 1979 it starts to increase at the same time as real interest rates in the rest of the world are rising. After moving up to 4 percent by mid-1983, the target rate thereafter remains at that level through 1989.

To generate an estimate for the ultimate-target *nominal* call rate, R_t^{U*}, I added the ultimate-target inflation rate ($Pdot_t^{U*}$, top panel of Figure 3) to the path for r_t^{U*}. This series is also plotted in the top panel of Figure 8. Given these illustrative estimates for the last several decades, the bottom panel of Figure 8 shows the deviations of the actual call rate from this nominal ultimate-target path.

C. An Illustrative Reaction Function for the Call Rate

The next stage in the illustrations is to specify the shorter-run dynamics of monetary policy — how the policymakers respond to deviations of the goal variables from the target paths. This amounts to specifying the "adjustment terms" that define the "interim gap" in equation (2).[34] For these illustrations, I always include terms for the shock-absorption, proportional, derivative, and integral responses. For the inflation and exchange-rate goal variables, I have also added a fifth adjustment term.

I experimented with several alternatives for the functional forms of the adjustment terms. In the end, because of the appealing flexibility it provides, I resorted to the hyperbolic tangent. This function, illustrated in Figure 9, has the convenient property of placing limits on the variation in a variable Y that occurs when the variable X changes. These limits can be adjusted (including even relaxing them to a point where they are not binding) by changing a single parameter. The shape of the function, and hence the degree of responsiveness within the limits, can also be controlled with a single parameter.

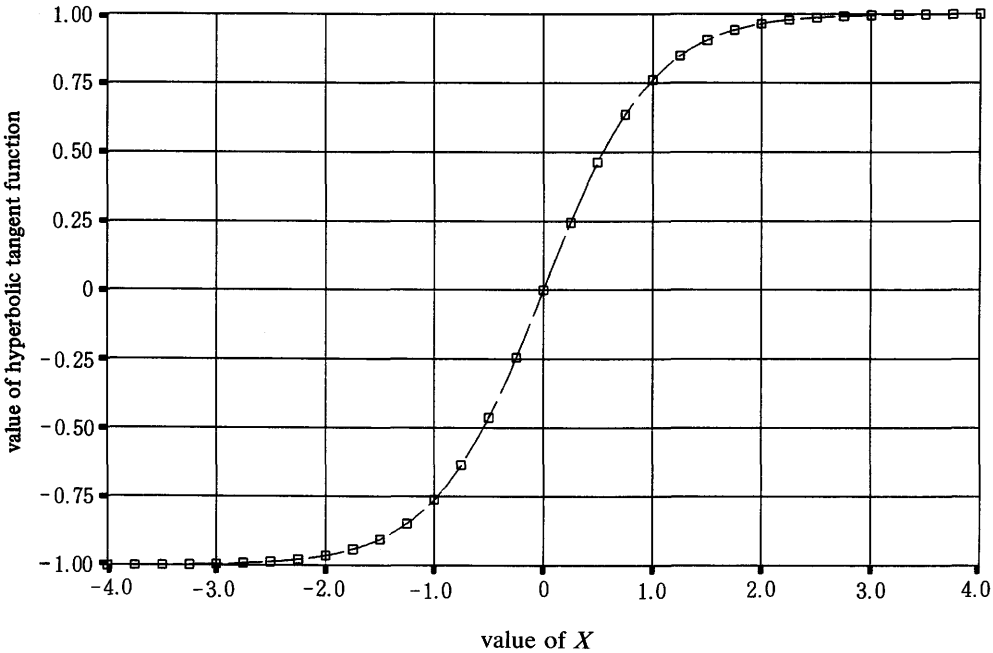
Specifically, the function plotted in Figure 9 is of the form

$$Y = a_0 + a_1 [\tanh (a_2 X)] \tag{7}$$

where a_0 has the value zero, and a_1 and a_2 are both equal to unity. For this case, the function crosses the origin (Y=0, X=0) and has the limits of -1 and $+1$. More generally,

[34] It has not been practical in these illustrations to generate forward-looking forecasts for the goal variables even though, in actual policymaking, the responses of the monetary authority to disequilibrium gaps are in part anticipatory, not based merely on current-period and past-period data (section III).

Figure 9
Hyperbolic Tangent Function



Note: See text for explanation.

the parameter a_0 shifts the function up or down the Y axis, a_1 expands or contracts the distance between the lower and upper limits, while a_2 adjusts the slope of the curve between the limits. For example, to constrain the variation of Y within the limits -3 to $+3$, one could specify the function as

$$Y = a_0 + 3.0 \, [\tanh \, (a_2 X)].$$

The hyperbolic tangent function itself is defined as

$$\tanh \, (X) = (e^X - e^{-X}) \, / \, (e^X + e^{-X}). \tag{8}$$

Note that if one does not want the variation in the function tanh(X) to be constrained within bounded limits (for any given range of variation for X), the desired effect can be obtained by choosing a sufficiently large value for the coefficient a_1.

For the inflation goal variable, policymakers are assumed to set an interim target path (equation (2a)) according to

$$Pdot_t^{I*} = Pdot_t^{U*} + \text{five adjustment terms.} \tag{9}$$

The first four adjustment terms are direct functions of the ultimate inflation gap itself

($UP_t = Pdot_t - Pdot_t^{U*}$). The fifth term is a function of the differential between the inflation rates for PGNP and WPIDOM. For the situations in which inflation is above its ultimate-target path, adjustment terms with positive (negative) coefficients have the effect of raising (lowering) the path for $Pdot_t^{I*}$, which algebraically reduces (increases) the interim gap ($Pdot_t - Pdot_t^{I*}$) relative to the ultimate gap and hence dampens (augments) the size of upward changes in the call-rate policy instrument. I use the hyperbolic tangent function for each of the adjustment terms.

The shock-absorption term, causing policy temporarily to tolerate a deviation of inflation, depends only on the current-period value of UP. It is modeled as:

$$\underline{\text{shock-absorption:}}\quad 2.0 \tanh\left[1.0\,(UP_t)\right] \tag{9a}$$

which permits the interim-target value to increase, but by no more than 200 basis points, in response to the current-period size of the ultimate gap.

The proportional term is modeled as depending on the average of the ultimate gap in the current quarter and the preceding quarter, with of course a response in the opposite direction so as to lean against the deviation of inflation from its ultimate-target value:

$$\underline{\text{proportional:}}\quad -8.0 \tanh\left[0.15\,((UP_t + UP_{t-1}) \,/\, 2.0)\right]. \tag{9b}$$

It is presumed that the strength of the proportional response (the coefficient of −8.0) is substantially greater than the shock-absorption response (+2.0). Thus if a shock causing inflation to increase is persistent beyond a single quarter, the proportional term will dominate the shock absorption term.[35]

The derivative term depends on the change in the ultimate gap between the previous and the current period. It is modeled as:

$$\underline{\text{derivative:}}\quad -3.0 \tanh\left[0.5\,(UP_t - UP_{t-1})\right]. \tag{9c}$$

The integral adjustment term responds to the cumulative deviations of the ultimate gap over a longer past period. For the illustrations here, I take this past period to be three years (12 quarters). Thus the integral term is modeled as:

$$\underline{\text{integral:}}\quad -3.0 \tanh\left[0.35\,(\sum_i (UP_{t-i} / 12))\right] \tag{9d}$$

where the index i runs from 0 to 11.

In a more careful treatment than is possible in these illustrations, model forecasts of the ultimate gap ($\hat{UP}_{t+1}$) as well as UP_t would be used as inputs into adjustment terms.

[35]The shock-absorption term needs to be bounded at some relatively low magnitude to reflect the fact that the policymakers, even temporarily, are prepared to accept only a limited deviation of $Pdot_t$ from its ultimate-target value. The amount of the adjustment due to the proportional term, on the other hand, should perhaps not be bounded at all, or at least should be bounded at a much higher magnitude; to reflect this requirement, the hyperbolic tangent function in (9b) must have a coefficient value for a_1 — see equation (7) — that is large in relation to the variation in UP.

As an inferior substitute in the illustration here, I postulate that the policymakers examine the differential between inflation rates for the GNP deflator and the domestic component of wholesale prices ($\text{PGNPdot}_t - \text{WPIDOMdot}_t$) and treat deviations of that differential from a long-run average value as if they were a leading indicator of future PGNP inflation. The average differential between these two price series over a long run is a small positive number, roughly 2 percentage points in recent decades (see Figure 2). If this differential falls below the long-run average value of 2 and especially if it becomes negative (as for example during the high inflation following the oil shocks of 1973-74 and 1979-80), I presume that this development leads the policymakers to react more strongly by raising the call rate more than otherwise. Conversely, if the differential becomes more positive than normal (as in the yen appreciation of 1986-88, when WPIDOM showed actual declines), the adjustment to the interim target has a positive value, implying that monetary policy as embodied in the call rate becomes easier than it would otherwise be. Thus this adjustment term is:

$$\underline{\text{WPI differential:}}\quad 8.0 \tanh [0.15 (\text{PGNPdot}_t - \text{WPIDOMdot}_t - 2.0)]. \qquad (9e)$$

The pattern of effects attributable to the different adjustment terms can be complex. The net consequences of combining the five adjustment terms together are shown in Figure 10.[36] The top panel plots the value of the interim adjusted gap together with the ultimate-target gap (repeated from Figure 3). The bottom panel shows the same information in a different way: it plots the interim-target and the ultimate-target paths for inflation, together with the actual inflation rate. Remember that, when inflation is above its long-run desired path, negative values of the adjustment terms increase the size of the effective ("interim") gap to which policy responds (and *vice versa*). The more positive is the interim gap, the greater the incentive to take policy action to raise the call rate. As Figure 10 shows, the net effect of the five adjustment terms taken together is to make the interim gap larger in absolute size, and hence to increase the pressure for policy changes (relative to what it would be if policymakers merely reacted to the size of the ultimate gap).

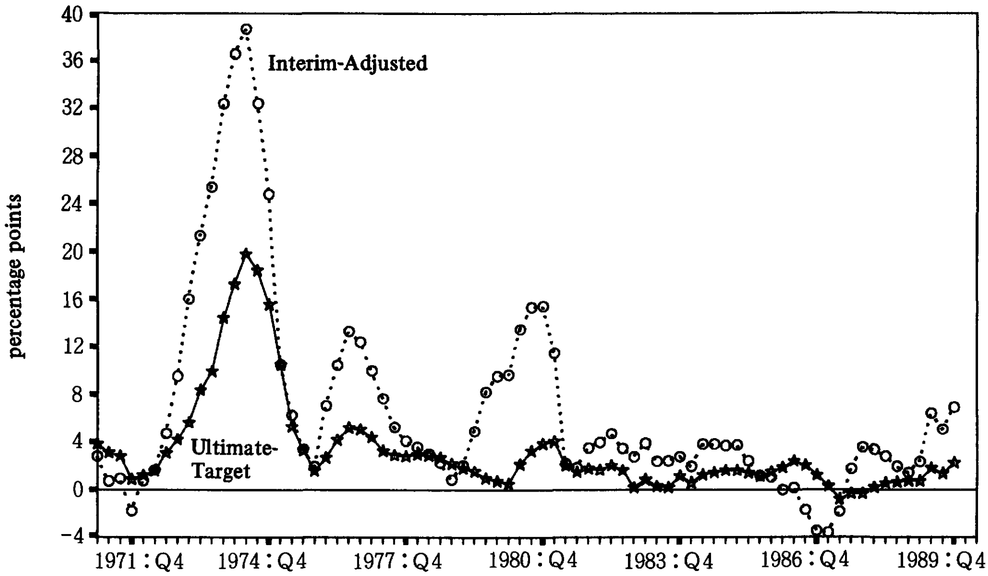
Given the preceding description of the adjustment terms for inflation, the adjustment terms for the other three goal variables, which follow a similar pattern, can be described briefly.

The adjustment terms for the output goal variable are functions of a transformation of the ultimate output gap, defined in percentage terms as $UY_t = 100\ (Y_t - Y_t^{U*})/Y_t^{U*}$ where Y_t is the actual path of real GNP and Y_t^{U*} is the ultimate-target path shown in

[36]The unabridged version of the paper contains a chart showing the five adjustment terms separately.

Figure 10

Inflation: Interim-Adjusted and Ultimate-Target Gaps



Inflation: Actual, Interim-Target, and Ultimate-Target Paths

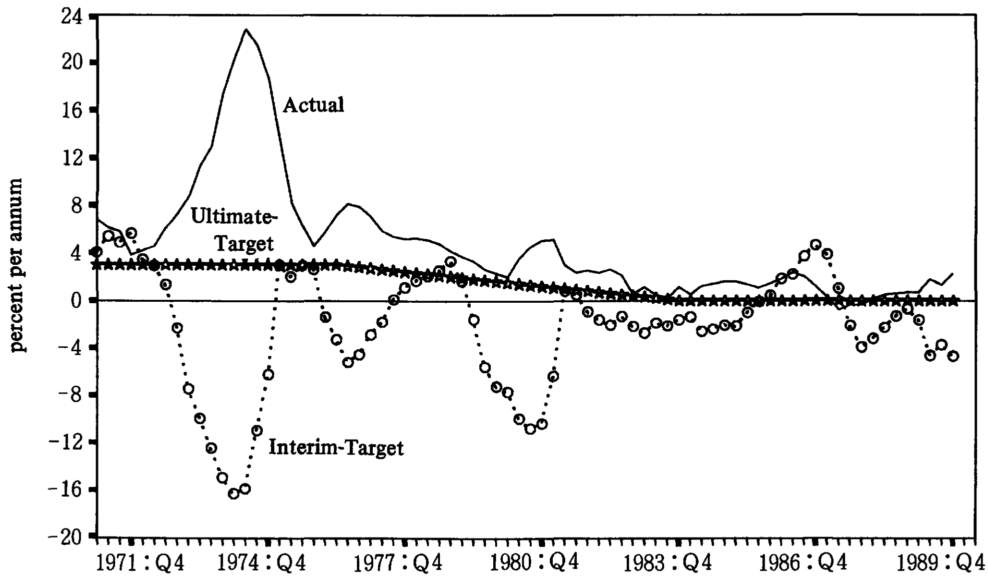


Figure 11
Real GNP: Interim-Adjusted and Ultimate-Target Gaps

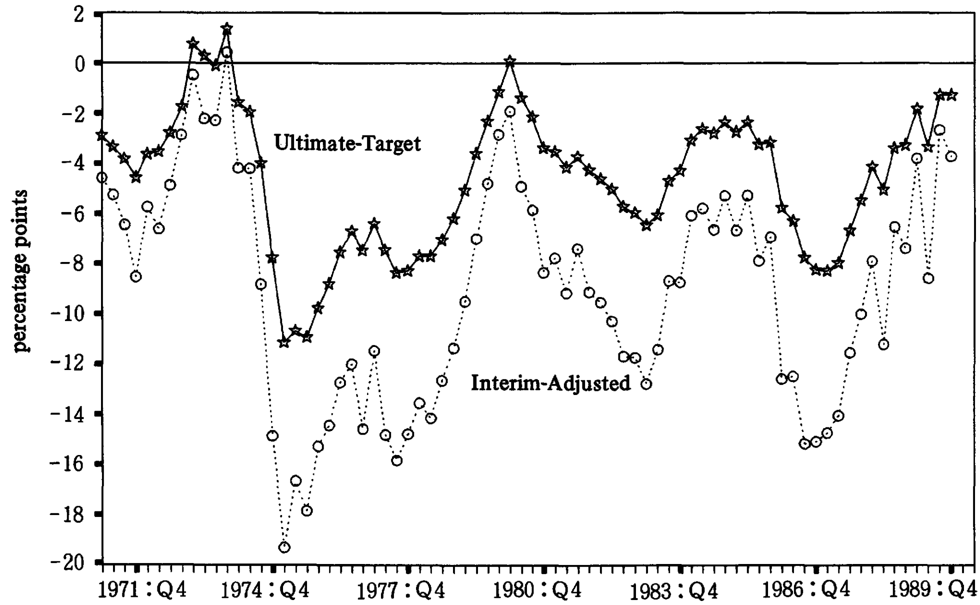


Figure 5. Each term is specified as a hyperbolic tangent function:

shock-absorption:	$2.0 \tanh [1.0\,(UY_t)]$,	(10a)
proportional:	$-8.0 \tanh [0.15\,((UY_t + UY_{t-1}) / 2.0)]$,	(10b)
derivative:	$-3.0 \tanh [0.5\,(UY_t - UY_{t-1})]$,	(10c)
integral:	$-3.0 \tanh [\,0.35\,(\sum_i (UY_{t-i} / 12))]$, i=0 to 11.	(10d)

The reasoning underlying the specification of the terms and choice of coefficients is analogous to that given for the inflation adjustment terms.

Figure 11 summarizes the net consequences of combining the adjustment terms. Analogously to the top panel in Figure 10, the curves plotted are the adjusted interim gap for real output and the ultimate gap (repeated from the bottom panel of Figure 5). Here, too, the net effects of the adjustments augment, but by varying amounts, the pressure for policy changes (relative to what it would be if policymakers reacted to the ultimate gap alone).

Four of the adjustment terms for the exchange-rate goal variable are a function of the ultimate gap itself, defined in percentage terms as $UE_t = 100\,(E_t - E_t^{U*}) / E_t^{U*}$ where E_t is the actual path of the nominal yen-dollar rate and E_t^{U*} is the ultimate-target path. The specifications and coefficients are:

shock-absorption: $2.0\,(BW_t)\tanh[1.0\,(UE_t)]$, (11a)
proportional: $-8.0\,(BW_t)\tanh[0.15\,((UE_t+UE_{t-1})/2.0)]$, (11b)
derivative: $-3.0\,(BW_t)\tanh[0.5\,(UE_t-UE_{t-1})]$, (11c)
integral: $-3.0\,(BW_t)\tanh[0.35\,(\sum_i(UE_{t-i}/12))]$, i=0 to 11. (11d)

In (11a) through (11d), BW_t represents the time-varying width of the band around the ultimate-target path for the exchange rate (see top panel of Figure 6). Use of the band widths in the adjustment terms indicates another way in which flexibility can be introduced into the specification of the adjustment terms.[37]

To illustrate still another way that adjustment terms can be incorporated in this approach, I have included a fifth term for the exchange-rate goal variable. It is based on a proxy series for the amount of foreign-exchange intervention conducted by the Japanese monetary authority (the Bank of Japan and the Ministry of Finance together). While not a fully accurate measurement of the amount of intervention and while measured in yen not in dollars, this proxy series for intervention nonetheless can be used as a reasonably faithful indication of broad trends in intervention activity.[38] The proxy data as published are measured in units of 100 million yen, with positive amounts corresponding to purchases of foreign currencies (a gain in international reserves) and negative amounts corresponding to sales of foreign currencies. As I have used the data here, the series — FXI_t — is quarterly (a cumulative sum of the monthly flows during a quarter). The adjustment term I postulate takes the form:

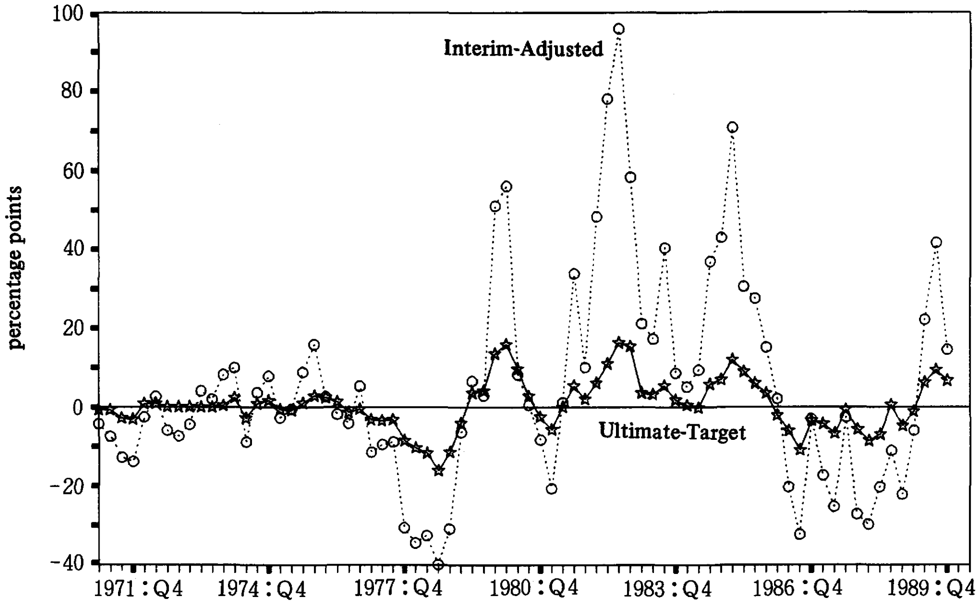
intervention: $10.0\tanh[0.10\,(FXI_t/1000)]$. (11e)

The rationale for this adjustment turns on the fact that exchange-rate movements and intervention are partial substitutes from the perspective of the monetary authority (provided that sterilized intervention can have significant effects). Suppose that the yen is weak in exchange markets, with E (the yen per dollar spot rate) threatening to rise well above the ultimate-target path E_t^{U*}. If large intervention sales of U.S. dollars occur, that intervention may mitigate the upward movement of E relative to E_t^{U*}; at the extreme, with heavy intervention the Japanese monetary authority may be able to prevent E from deviating from E_t^{U*}. If so, however, international reserves may decline by a large amount, which in itself may be taken as an indication that domestic monetary policy may need to be tightened. The opposite forces may be at work when the yen is threatening to appreci-

[37] BW_t is the symmetrical distance between each band and the ultimate-target path, measured as a percent of the ultimate-target path. BW_t in the illustration here varies between 3/4 of 1 percent and 4 percent. The total width of the band around the target path is twice the size of BW_t.

[38] A large part of the outstanding stock of international reserves (and hence the booking of foreign exchange intervention) appears on the accounts of the Ministry of Finance rather than the balance sheet of the BOJ. The series for intervention used in my illustration is published by the Bank of Japan in its *Economic Statistics Monthly* and *Economic Statistics Annual*. The English translation for the series is "Foreign Exchange Treasury Funds." The data appear in the table for the supply of and demand for funds in money markets.

Figure 12
Yen/Dollar Exchange Rate: Interim-Adjusted and Ultimate-Target Gaps



ate excessively and foreign exchange intervention is used to purchase foreign currencies. The adjustment term in (11e) has the effect, other things being equal, of inducing a fall (increase) in the call rate when Japanese policymakers are purchasing (selling) dollars.

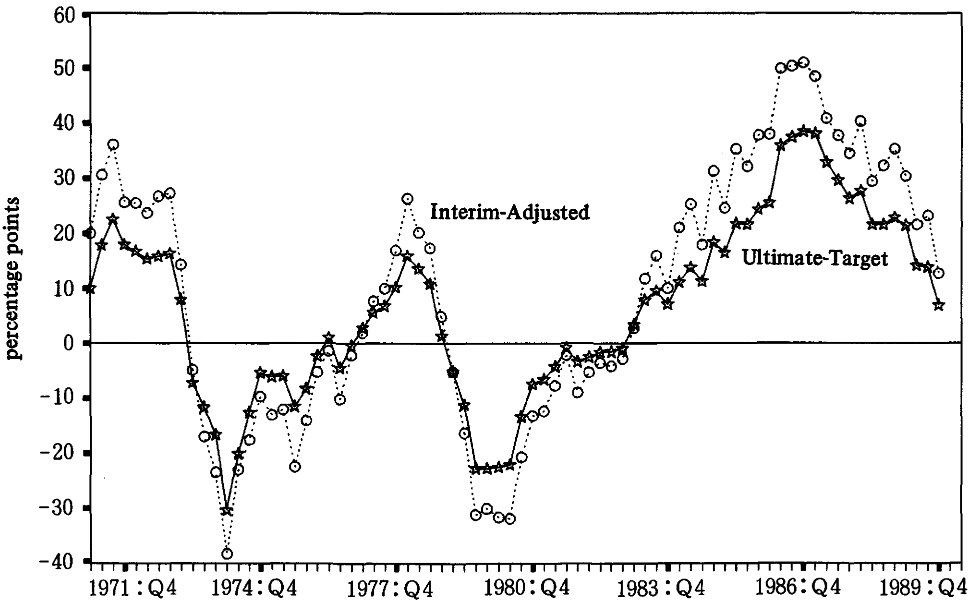
Figure 12 is the counterpart summary for the exchange-rate goal variable analogous to Figures 10 and 11. Even more than for the cases of inflation and output, the interim gap shows a higher variance than the ultimate-target gap. Policy is thus modeled as responding more aggressively than if attention were focused merely on the deviation of the exchange rate from its ultimate-target path.

The adjustment terms for the balance-of-payments goal variable are hypothesized responses to the ultimate balance-of-payments gap. That gap is defined as $UB_t = BOP\text{ratio}_t - BOP\text{ratio}_t^{U*}$, the series in the bottom panel of Figure 7. The adjustment terms are specified as:

<u>shock-absorption:</u>	$2.0 \tanh [1.0\,(UB_t)]$,	(12a)
<u>proportional:</u>	$-10.0 \tanh [0.10\,((UB_t + UB_{t-1}) / 2.0)]$,	(12b)
<u>derivative:</u>	$-3.0 \tanh [0.5\,(UB_t - UB_{t-1})]$,	(12c)
<u>integral:</u>	$-3.0 \tanh [0.35\,(\sum_i (UB_{t-i} / 12))]$, i=0 to 11.	(12d)

The curves plotted in Figure 13 are the analogue of those in earlier figures. The ultimate gap and the interim-adjusted gap differ less for the balance of payments than for the other three goal variables.

Figure 13
Balance of Payments Ratio: Interim-Adjusted and Ultimate-Target Gaps



To include the various goal variables and their disequilibrium adjustments in a reaction function together, one must hypothesize some pattern of coefficients for combining them — for example, the μ and the θ_i of equation (6). For my illustrations, the main option was to examine recent-period historical correlations among the modeled parts of the reaction function. Such a focus on historical correlations is potentially misleading; my inclination is to believe that reaction functions of the monetary authority, including the relative weights on goal variables, are unlikely to remain unchanged over long periods. Nevertheless, to complete the illustration, I have included in Table 2 some information from simple least-squares regressions.

The dependent variable in these regressions is the actual quarterly-average call rate less the ultimate-target value $(RCAU_t - RCAU_t^{U^*})$. The regressors are the four adjusted interim gaps and a constant term.[39] If consistent with the earlier analysis, the coefficients on the adjusted gaps for inflation, output, and the yen-dollar exchange rate should have positive signs and the coefficient on the balance-of-payments gap should have a negative sign. The first regression in the table is for the period 1970:Q2 to 1989:Q4, the longest interval for which I had data for all the underlying variables. The remaining regressions

[39]If the non-modeled factors ($Zeta_t$) were known to be small with a mean of zero, one might want to suppress the constant term. Since I presume that the non-modeled factors may be large, it is preferable to include a constant term.

Table 2
Illustrative Regression Equations with "Interim" Adjusted Gaps
Dependent variable in rgressions is $RCAU_t - RCAU_t^{U*}$
(plotted in bottom panel of Figure 8)

Period of Estimation	Value of OLS Regression Coefficient (t-ratios in parentheses)					Explained Sum of Squares divided by Total Sum of Squares (R^2)
	Adjusted Inflation Gap	Adjusted Output Gap	Adjusted Exchange-Rate Gap	Adjusted BOP Gap	Constant Term	
1970:Q2 to 1989:Q4	0.090 (2.96)	−0.062 (−1.46)	0.024 (3.06)	−0.037 (−3.24)	0.872 (1.50)	0.518
1974:Q1 to 1989:Q4	0.142 (4.40)	−0.030 (−0.57)	0.024 (3.06)	−0.026 (−2.31)	0.906 (1.30)	0.594
1977:Q1 to 1989:Q4	0.244 (3.25)	0.049 (0.78)	0.023 (3.19)	−0.007 (−0.56)	0.971 (1.12)	0.585
1980:Q1 to 1989:Q4	0.204 (2.52)	−0.031 (−0.46)	0.008 (1.06)	−0.040 (−2.71)	1.573 (1.58)	0.719
1983:Q1 to 1989:Q4	−0.235 (−1.93)	0.058 (0.85)	0.029 (3.74)	−0.046 (−2.28)	3.297 (2.68)	0.632

successively cut off several years at the beginning of the estimation period.

The historical correlations in Table 2 are only mildly encouraging. For most of the different estimation periods, the coefficients on the inflation, exchange-rate, and balance-of-payments gaps are correctly signed and have relatively high *t*-ratios. The major historical ups and downs in the dependent variable are roughly captured by the regression. However, the estimates of the coefficients vary somewhat erratically across different time periods. The residuals from the regression are badly autocorrelated.[40] The most worrisome problem is that the coefficient on the output gap tends to have the incorrect sign (though it is not statistically significant for any estimation period). For the latter part of the 1980s (see the last regression in the table), the output-gap coefficient turns positive but at the expense of the inflation-gap coefficient (which incorrectly takes on a negative sign).[41] The regressions in Table 2 may be an indirect clue that I have misspecified the output or the inflation goal variables, or both. (As suggested earlier, the rough estimates for the ultimate-target path for output may be seriously inadequate; this possibility might account for the insignificance of the output-gap coefficient.)

[40]The Durbin-Watson (DW) statistic for the regression covering the whole period 1970:Q2 to 1989:Q4 has the miserably low value of 0.32, and the DW statistics for subperiods all tend to be below 1.0.

[41]A sample period such as 1983-89 excludes the major episodes when inflation became rapid (1973-75 and 1979-80), thereby severely undercutting the ability of a historical regression to estimate an inflation-gap coefficient.

Table 2 demonstrates that the historical correlations among *RCAU* and the adjusted gaps (as I have specified them) are not stable across time. The 1979-80 period causes particular problems. This fact can be seen in Figures 14 through 17, which provide another type of evidence about the unsatisfactory nature of the historical correlations. Figures 14 through 17, constructed from recursive least squares estimation of the regression, plot the successive values of each of the coefficients on the adjusted gaps, together with the band defined by plus and minus two standard errors.[42] These charts indicate the offsetting, probably incorrect relationship between the coefficients on the inflation and the output gaps. Figures 14 through 17 also show obvious, rather large "humps" around 1979-80, suggesting that atypically large shocks may have hit the Japanese economy at that time. 1979-80 was of course the period of the second oil shock with its inflation surge, output stagnation, and exchange-rate instability.

For illustrative purposes, I postulate the following values for response coefficients: 0.14 for the inflation gap, 0.03 for the output gap, 0.05 for the exchange-rate gap, and −0.02 for the balance-of-payments gap. In a loose sense, these values are extracted from the mixture of estimates in Table 2 and Figures 14 through 17, though all the chosen values were selected to have analytically correct signs.

Given these values, one can use the general specification assumed for equation (6) to infer estimates of the overall strength of monetary-policy responses to disequilibrium deviations for all variables (the coefficient μ) and the weights on the individual goal-variable gaps (the θ_i). In effect, there are five equations in five unknowns: $\theta_i=0.14/\mu$; $\theta_2=0.03/\mu$; $\theta_3=0.05/\mu$; $\theta_4=-0.02/\mu$; and $\theta_1+\theta_2+\theta_3+\theta_4=1.0$. In this illustration, therefore, the general response coefficient has a value of 0.20. The weights on the goal variables are 0.70 for inflation, 0.15 for real output, 0.25 for the yen-dollar exchange rate, and −0.10 for the balance-of-payments ratio.

From my different conversations at the Bank of Japan, inflation was typically mentioned most prominently as a goal variable. External-sector considerations, particularly the exchange value of the yen, were probably the second most important category to figure prominently in the discussions. My illustrative calculations are consistent with — or perhaps I should say reflect — these broad generalizations.

The end result of the preceding web of calculations for a call-rate reaction function, applied to the historical data for the 1970s and 1980s, is shown in Figure 18. The chart plots the actual call rate and the modeled component. The modeled portion captures some of the major historical fluctuations, enough to suggest that the approach may be broadly descriptive of actual policy behavior. Yet there are many ways in which the

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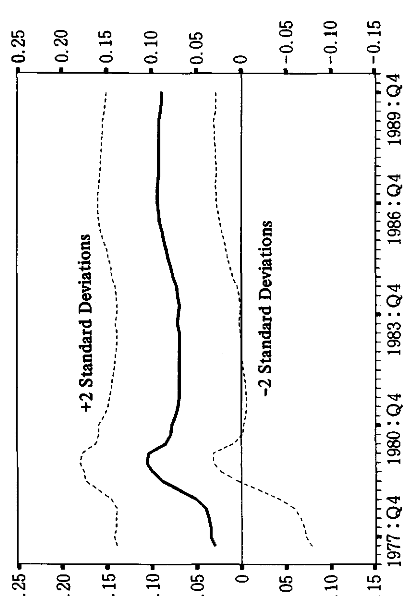
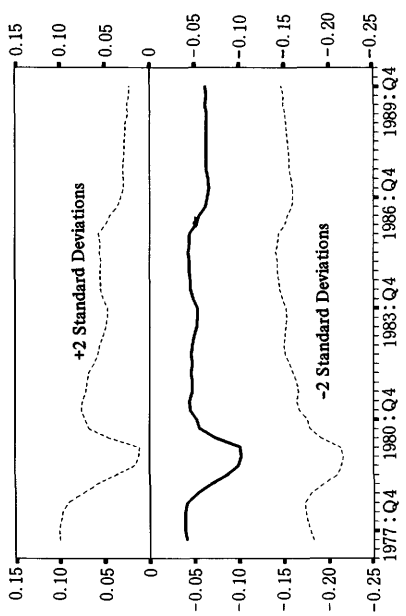
[42]The recursive least-squares estimates are obtained by first estimating the regression equation for the subperiod 1970:Q2 to 1977:Q3, then re-estimating with the observation for 1977:Q4 added, re-estimating again for the period 1970:Q2 to 1978:Q1, and so on with successive observations added one by one, until the final interaction where the estimation period is the full sample 1970:Q2 to 1989:Q4. The calculations were done with the PC-GIVE software written by David Hendry.

Figure 14
Coefficient on Adjusted Inflation Gap in Recursive Estimation



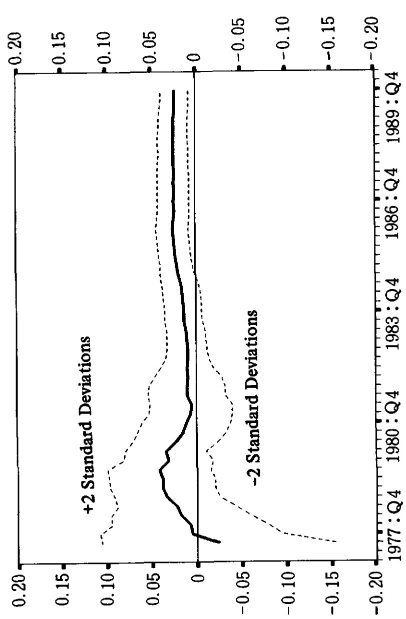
Note: See text for explanation.

Figure 15
Coefficient on Adjusted Output Gap in Recursive Estimation



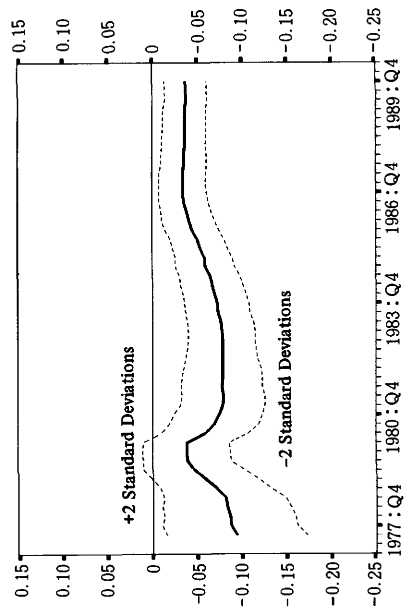
Note: See text for explanation.

Figure 16
Coefficient on Adjusted Exchange Rate Gap in Recursive Estimation



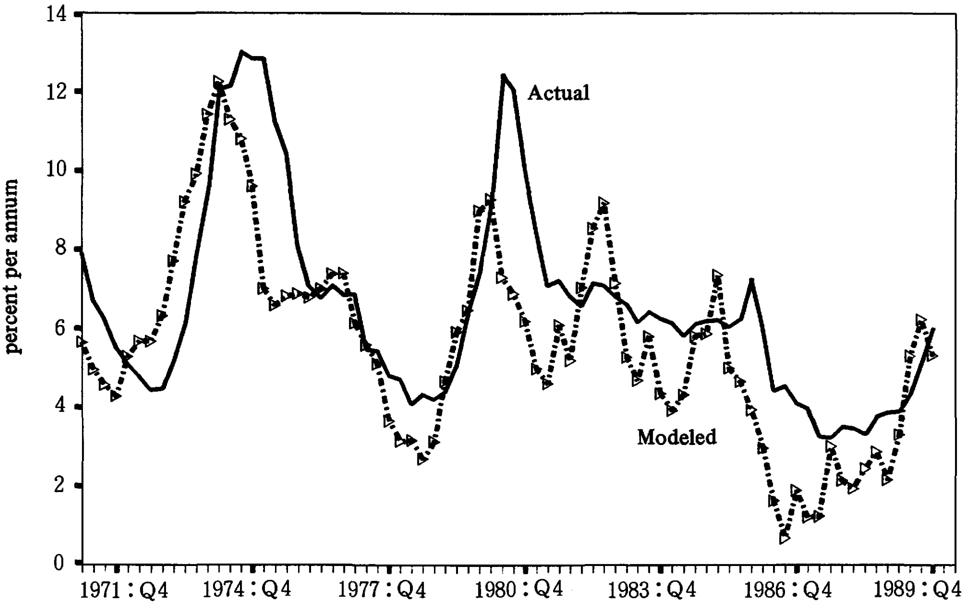
Note: See text for explanation.

Figure 17
Coefficient on Adjusted BOP Gap in Recursive Estimation



Note: See text for explanation.

Figure 18
Call Rate: Actual Path and Modeled Component



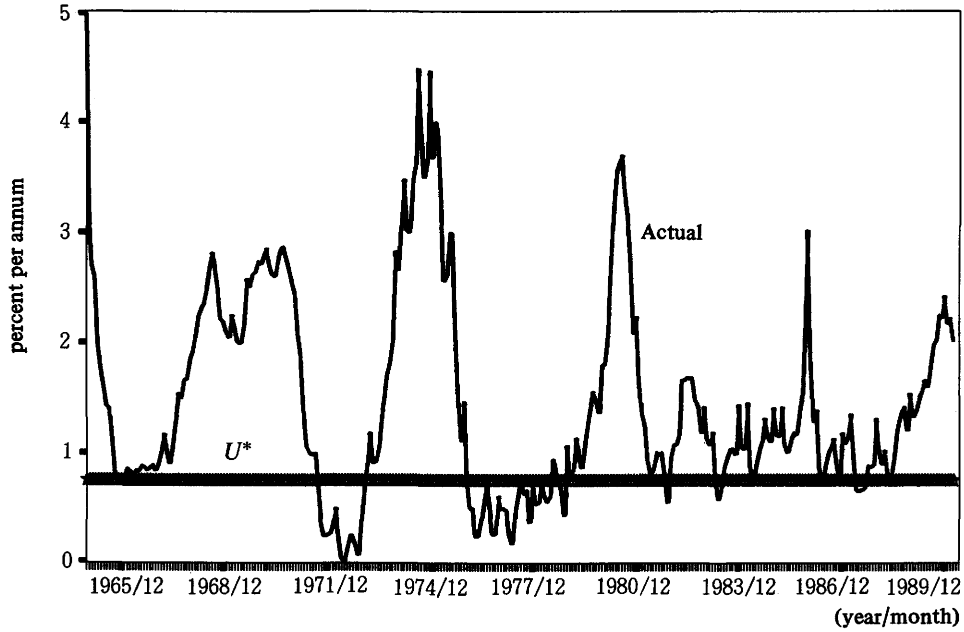
timing or the magnitude of the modeled changes matches poorly with history. For example, the 1979-80 oil-shock episode of policy tightening was much sharper than predicted by the modeled component, and the modeled component predicts a substantially greater easing of policy in 1986-87 than actually occurred.

D. Modeling the Bank of Japan's Discount Rate Process

I now turn briefly to an illustrative reaction function for the discount rate, which is done here with monthly data. The goal variables of inflation, real output, the exchange value of the yen, and the balance of payments are of course relevant for discount-rate decisions as well as for decisions about the call rate. Given the evolving relationship between the call rate and the discount rate, however, it may be feasible to simplify the modeling of the discount-rate process by postulating that the major goal variables exert their influences on the discount rate indirectly through the call rate. In other words, deviations of the goal variables from their ultimate-target paths will cause policy changes in the call rate, which in turn will initially lead to changes in the spread between the call rate and the discount rate. The simplifying modeling device is to pretend that the monetary authority focuses only on the spread, using it as an indirect proxy for the true goal variables.

Figure 19 shows the actual spread, $RCAU_t - RDIS_t$, together with an illustrative assumption for an ultimate-target value for the spread. My illustration simply postulates a

Figure 19
Spread of *RCAU* over *RDIS*: Actual and Illustrative U^* Path



Note: Monthly data, last observation March 1990

constant target value of 75 basis points.[43]

My approach presumes that the monetary authority changes the discount rate so that the actual spread converges toward the ultimate-target value, but with disequilibrium adjustments. The treatment of the adjustment terms is analogous to that used earlier for the call rate. In effect, the authority is presumed to aim at an interim-target spread ($\text{Spread}_t^{I*} = \text{Spread}_t^{U*}$ + adjustment terms), which in turn implies an interim-target value for the discount rate itself: $RDIS_t^{I*} = RCAU_t - \text{Spread}_t^{I*}$. Positive values of the adjustment terms, by increasing the interim-target spread, reduce the pressure for discount-rate increases when the call rate is above the discount rate. The interim-target path, $RDIS_t^{I*}$, is the "modeled" component of the discount rate. The actual discount rate is the sum of this modeled component and the residual component that cannot be successfully modeled ($RDIS_t = RDIS_t^{I*} + \text{Zeta}_t$).

I postulate that the policymakers are prepared to let unexpected events in the

[43]I cannot defend 75 basis points as more realistic than, say, 100 or 125 basis points. Nor do I believe that in practice any official presumption about the desirable value of the spread has been constant through time. Given the information available, however, it did not seem appropriate to try to specify a more refined ultimate-target path.

economy, while leading fairly promptly to changes in the call rate, work their way without causing as prompt an adjustment in the discount rate. This shock-absorption response is modeled as

$$\underline{\text{shock-absorption:}}\quad 2.0\tanh\left[0.5\,(US_t)\right], \tag{13a}$$

where the ultimate gap for the spread, the disequilibrium magnitude that is the argument for the hyperbolic tangent function, is defined as US_t=Spread$_t$−Spread$_t^{U*}$. The choice of coefficients for the tanh function in (13a) permits up to 200 basis points of adjustment in the interim-target spread, thereby (other things equal) delaying changes in the discount rate even when the spread deviates by a large amount from its preferred normal value.

After allowing for the temporary shock-absorption responses, policymakers are then presumed to respond so as to reduce any deviation of the spread from its ultimate-target value. The proportional, derivative, and integral responses are defined analogously to those presented before:

$$\underline{\text{proportional:}}\quad -1.0\tanh\left[0.35\,((US_t+US_{t-1})/2.0)\right], \tag{13b}$$

$$\underline{\text{derivative:}}\quad -1.0\tanh\left[0.5(US_t-US_{t-1})\right], \tag{13c}$$

$$\underline{\text{integral:}}\quad -1.5\tanh\left[0.5\,(\textstyle\sum_i(US_{t-i}/12))\right],\quad i=0\text{ to }11. \tag{13d}$$

The coefficients for these three terms cause negative adjustments that more than offset the positive adjustments due to the shock-absorption responses. These negative adjustments, however, lag behind the shock-absorption responses.

Figure 20 shows the combined effect of the adjustment terms for the interim-target value of the spread. As the spread initially starts to deviate upwards from the ultimate-target value of 75 basis points, the shock-absorption response temporarily dominates; the increases in the interim target dampen the pressure to raise the discount rate (relative to the situation where policy focuses on the ultimate target alone). Subsequently, the adjustments lower the interim target, often to a value below the ultimate-target path; other things being equal, policymakers then are under augmented pressure to raise the discount rate and thus bring the spread back to its preferred normal level.

Finally, Figure 21 presents the same story in terms of the discount rate itself. The heavy solid line is the actual historical path of the discount rate; the dashed line is the modeled component. Given the simplicity with which the reaction function is modeled, its ability to track the historical discount rate seems surprisingly good. Notable episodes have occurred, all of them periods of monetary stringency, when the reaction function predicts a much higher discount rate than was actually implemented. Alternatively stated, the variety of political and other factors embedded in the non-modeled component of policy have at these times acted to keep the discount rate abnormally below the call rate and other short-term interest rates. Such episodes have been followed by periods of monetary easing, however, in which the discount rate has been reduced by less than the decline in the call rate, which eventually has resulted in more normal levels of the spread.

Figure 20
Spread of *RCAU* over *RDIS*: Actual, Interim-Adjusted and U^* Paths

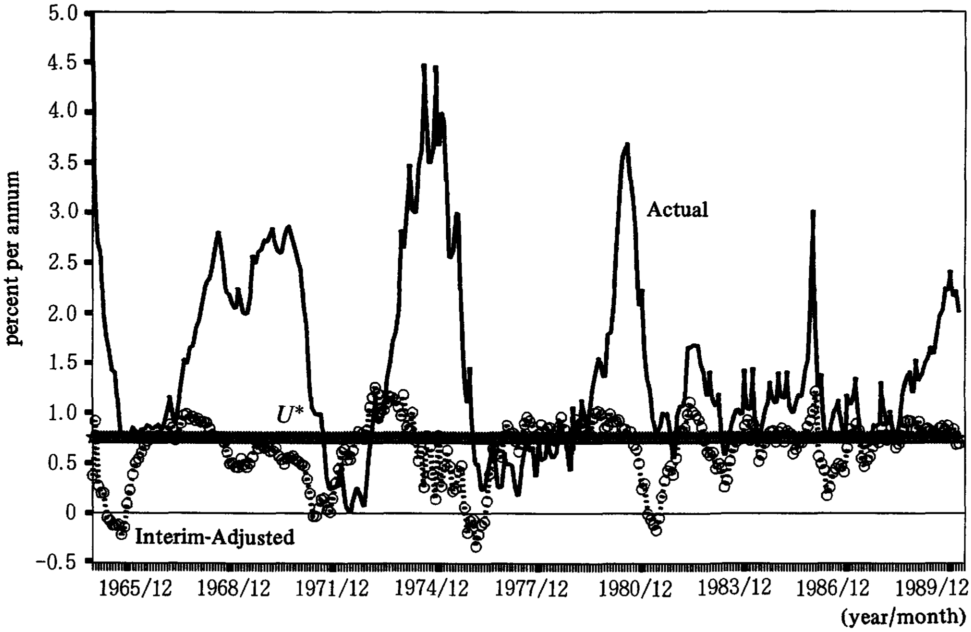
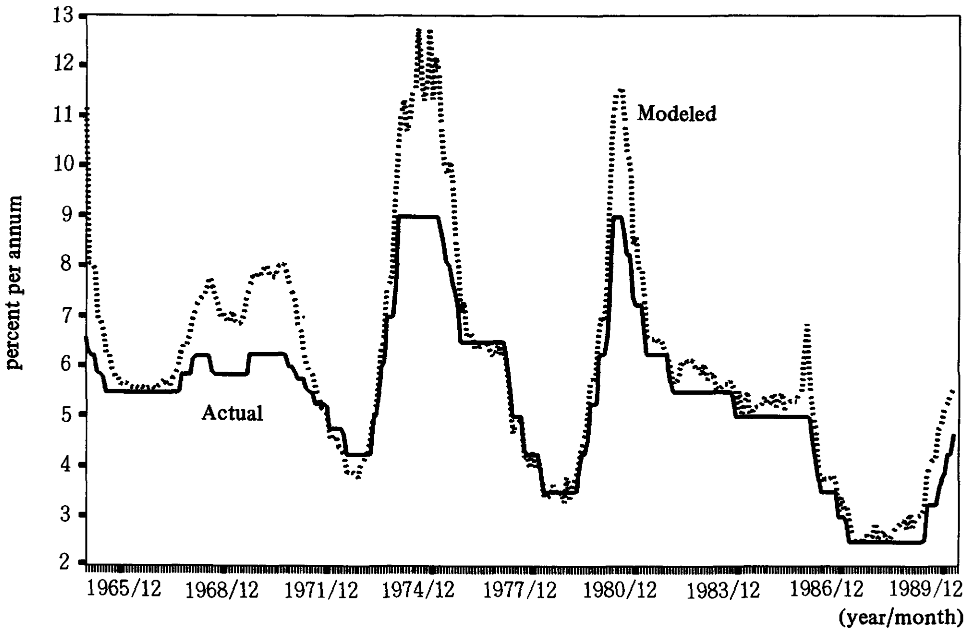


Figure 21
Discount Rate: Actual Path and Modeled Component



Given many of the analytic purposes for which a macroeconometric model is used and given the need to summarize the policy behavior of the discount rate in such a model, a simplified reaction function of the sort shown here might well prove satisfactory.

V. Concluding Remarks

The goal of the research summarized in this paper has been exploratory: to refine how economists try to model the conduct of monetary policy in macroeconomic models, in particular for Japan. The label "exploratory" applies especially to the empirical illustrations in section IV of the general ideas about reaction functions in section III.

The empirical calculations can be modified in several ways, and would be so modified in conjunction with their incorporation into a working macroeconomic model. For example, for use by the BOJ staff in a model of the Japanese economy, members of the BOJ staff itself — with their superior sources of information — would make substantially improved estimates of the target paths for goal variables and of the disequilibrium-adjustment responses.

The purpose of my illustrations has been to indicate with examples how the general concepts can be applied in empirical practice. The primary use of reaction functions, at least within a monetary authority, is to facilitate the appropriate implementation of forward-looking analytical simulations with a policy-oriented model. It can be misleading, therefore, to focus on historical data in the ways that I have done in this paper. The examination of historical data can nonetheless give concreteness to the ideas that would otherwise be lacking. It also imposes a constructive discipline that inhibits abstract analysis from straying away from policy relevance. I have thus included the historical illustrations despite some misgivings.

I strongly hope that the deficiencies in the empirical illustrations will not get in the way of the reader's evaluation of the basic ideas and their potential application in empirical representations of policy behavior in macroeconomic models. The general approach is promising. This paper shows that it is possible to specify relatively flexible forms of reaction functions that can summarize many of the dominant features of monetary policy. Such reaction functions are analytically tractable enough to be able to use them in manageable models helpful in the formulation of policy. Yet the functions need not be so limited or so time-invariant that they strain credulity as an analytical summary of how policy is actually conducted.

As noted at the outset, this paper's topic is just part of a broad agenda of research to improve the economics profession's empirical modeling of the economies of the major countries. Such improvement, if it can be attained, can in turn enhance our understanding of how the Japanese economy and other national economies actually work — and hence our understanding of the most appropriate ways of conducting national macroeconomic policies. The goal of adequate understanding is today well out of reach. If research progress can be accumulated in a series of small steps, however, little by little the eventual goal can be approached.

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