

Estimating the fiscal risks and costs of output-based payments

An overview

By Glenn Boyle and Timothy Irwin

Output-based payments are an important tool of government policy. Sometimes governments offer “output-based aid” to subsidize services sold to households. Guatemala and Mozambique, for example, subsidize new electricity connections, while Paraguay is piloting a program to subsidize new water connections. At other times governments are the sole source of revenue for a private infrastructure firm. Many governments enter into “public-private partnerships” in which they pay a private firm for making available such facilities as roads, schools, prisons, or hospitals. Dozens of developing countries buy wholesale electricity from independent power providers under similar arrangements. A few countries, such as Portugal and the United Kingdom, pay “shadow tolls” to privately financed roads. In all cases the government pays only when the firm delivers a service (such as when a connection is made, a car uses a road, or power is made available).

Because output-based payments are tied to the delivery of outputs, they have an obvious advantage over input-based payments. In agreeing to make such payments, however, governments assume a liability not unlike that created by taking on debt. Moreover, in some cases the payment amounts are subject to considerable uncertainty. As a result governments may benefit from estimating both the costs of these commitments and the new fiscal risks they create—and comparing these costs and risks with those of alternative policies. (Output-based payments also create risk for the private companies providing the outputs, including, in many developing countries, the risk of the government’s failing to make required payments. See von Klaudy and Goswami 2004 for ways of reducing payment risk.)

When a government commits itself to making payments for only a year, allowing itself the opportunity to decide at the end of the year whether to renew the payments, the fiscal risks are likely to be small. This is the safest option for governments and may be adequate

for efficiently encouraging investment in many cases. But if the payments are to encourage service providers to make long-term investments, the government may have to commit itself in advance to offering the payments for many years—perhaps for as long as the life of the assets used to provide the service. Even in this case, if the payment amounts are not subject to much risk (as in the case of many contracts with availability payments), there may be little need for carefully measuring the fiscal risks the government is taking. But when the subsidies represent long-term commitments of potentially large and uncertain amounts, the government would be wise to understand the costs and risks associated with the decisions it is making.

Output-based payments come in many forms, as do the risks they present (table 1). The payment structure associated with output-based schemes also varies. In some schemes, such as connection subsidies, the payment in any year depends only on output in that year; in others, such as access subsidies, the payment reflects not only this year’s output but also the cumulative result of previous years’ outputs. In addition, subsidy expenditure can be capped or uncapped. Under a capped scheme the government places a ceiling on the number of outputs it will subsidize. The cap can apply to either annual or cumulative output.

Measuring the risks and costs of output-based schemes is feasible but also, inevitably, mathematical. Quantifying risk necessarily involves some knowledge

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Table 1. Output-based schemes

Type	Applications	Source of fiscal risk
Consumption subsidies	Water, electricity	Consumption per subsidized customer, number of eligible customers
Vouchers	Education, health care	Number of eligible customers, propensity to enroll
Connection subsidies	Water, electricity, gas, telecommunications	Demand for new connections, supply of new connections, number of eligible customers
Access subsidies	Water, electricity, gas, telecommunications	Propensity of customers to maintain access (as well as factors for connection subsidies)
Availability payments	Wholesale water and electricity; roads; school, hospital, and prison facilities	Supply of capacity
Shadow tolls	Roads	Traffic flows

and application of probability and statistics; estimating the cost of uncertain payments that occur at different points in time requires asset pricing techniques from modern finance theory. Nevertheless, most of the important issues are conceptual rather than technical.

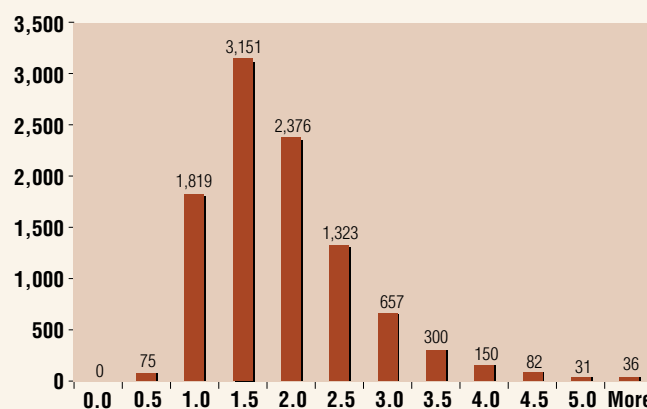
Measuring the risks

At its simplest, the risk associated with output-based schemes can be thought of as the potential volatility of required payments mandated by these schemes. But surprises can be pleasant as well as unpleasant, and volatility measures do not distinguish between the two. Measures that explicitly focus on the potential for unpleasant surprises, or so-called downside risk, are therefore more useful. One such measure, known as the excess-payment probability, calculates the probability of payments exceeding some prespecified level (table 2). Another measure, known as cash flow at risk, estimates the maximum payment likely under normal conditions. Both measures are particularly useful if a government’s fiscal position is threatened primarily by particularly high payments. To get a full picture of the fiscal risks of an output-based scheme, governments can also estimate the probabilities that payments will fall in each of several intervals (figure 1).

All risk measures require estimating some part of the underlying probability distribution. The best procedure for doing so will vary from case to case, and advice may well be required from such experts as statisticians and economic forecasters. In many cases the only realistic option is to assume that the future will look much like the past and, accordingly, attempt to build up a picture of the distribution implied by historical data. In some cases there may be reasonable grounds for assuming that the annual payment comes from a well-understood

distribution, and the desired risk measure can then be calculated using a simple formula. In other cases, particularly where payments depend on cumulative output or are capped, the distribution can be inferred only from a numerical technique such as Monte Carlo simulation. In simple terms, this technique works by using a random-number generator to create many alternative realizations of output, each of which is consistent with historical information about the output distribution. This approach makes it possible to build up a picture of the entire probability distribution of output and therefore of output-based payments. (With appropriate modification, each technique can be applied to portfolios of output-based schemes as well as to individual schemes.)

Figure 1. Estimated frequency distribution for a hypothetical output-based payment



Note: The bin on the far left, labeled 0, shows the estimated frequency out of 10,000 of payments of 0 or less (0). The next, labeled 0.5, shows the frequency of payments between 0 and 0.5 million (75). The bin on the far right, labeled More, shows the frequency of payments greater than 5 million (36).
Source: Boyle and Irwin 2005.

Table 2. Risk measures for output-based subsidy schemes

Measure	Description	Advantages	Disadvantages
Volatility of payments	Standard deviation of annual change in payments	Provides a single number summarizing the variability of payments	Doesn't distinguish between upside and downside risk
Excess-payment probability	Probability that subsidy payments exceed X	Provides a single number that helps determine whether risk to government's fiscal position is significant	Doesn't offer much information on the probabilities of other payments
Cash flow at risk	Maximum payment with α % probability	Provides a single number that helps determine whether risk to government's fiscal position is significant	Doesn't offer much information on other possible payments; may be mistaken for maximum possible payment
Frequency distribution of payments	Probability of payments in each of several intervals	Provides a picture of the entire range of possible payments	Requires a graph or table to convey the information; is not succinct

Valuing the obligations

A simple way of approximately valuing the obligations created by output-based schemes is to estimate the expected payments in each of the years for which the government has committed itself to making payments and then to discount those expected payments at the riskless rate of interest. This approach is good enough for some purposes. But it ignores the price of bearing risk and may generate a poor estimate of the value of some obligations. For large, risky commitments the government may want to use a valuation approach that incorporates the price of bearing risk.

Such an approach raises complex issues. One relates to the appropriate model for pricing risk. In general, a subsidy that mandates low payments when the government is flush and high payments when the government is constrained is costlier than one that offers the opposite payment pattern. The standard approach for quantifying this insight, the capital asset pricing model (CAPM), has at its core the result that everyone (including governments) holds a perfectly diversified portfolio, so what matters for the government's fiscal position is simply the return on the overall market of assets. To the extent that governments hold imperfectly diversified portfolios, however, the market return is only a proxy for the appropriate pricing factor.

A second valuation issue relates to the best way of incorporating risk pricing in the calculation of a subsidy's cost. The standard approach estimates the expected payment for each year, discounts each of these payments at a rate adjusted for risk (using, for example, the CAPM), and then adds all the discounted payments together. However, the frequent complexity of output-based schemes means that the second step poses technical difficulties that render it infeasible. An

alternative approach that bypasses this problem estimates the certainty-equivalent payment for each year (the expected payment less a risk adjustment), discounts each of these at a riskless rate of interest, and then adds all the discounted payments together.

For some schemes this alternative approach yields a complicated-looking formula for cost that is in fact simply an application of the growing-annuity formula. In most cases, however, no such formula exists, and Monte Carlo simulation must be used to estimate the certainty-equivalent payments before proceeding to the last two steps. The estimated cost should be fairly accurate for a sufficiently large number of simulations (given, of course, accurate input information about the underlying distribution and the appropriate adjustment for risk). Box 1 gives an overview of how a government might go about estimating both the fiscal risks and the liability created by a particular long-term commitment to make output-based payments.

So, quantifying the risks and costs of an output-based scheme is no simple task. But when the scheme involves long-term commitments of large and uncertain amounts, the effort is well worth it: making good decisions about such commitments is difficult for a government unless it understands the size of the liability and the nature of the risks.

References

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Box 1 How a government might estimate the risks and costs of output-based payments

Suppose a government is planning a privately financed shadow toll road. It has forecast the initial volume of traffic at 1 million vehicles a year and the growth in volume at 5 percent a year (continuously compounded), with volatility of 10 percent a year. It plans to pay the private company a shadow toll whose level depends on the volume of traffic as follows:

For $X_t \leq 1.5$, $s_1 = \$1$

For $1.5 < X_t < 2.0$, $s_2 = \$0.5$

For $X_t \geq 2$, $s_3 = 0$

where X_t is the volume of traffic in millions in year t , s_1 is the shadow toll in the first band, s_2 is the shadow toll in the second band, and s_3 is the shadow toll in the third band. That is, the shadow toll is \$1 a vehicle for the first 1.5 million vehicles, 50 cents a vehicle for the next 500,000 vehicles, and zero thereafter. With this schedule of shadow tolls, government expenditure on the scheme is effectively capped at \$1.75 million a year ($= 1.5(1) + (2 - 1.5)(0.5)$).

The government will commit itself to paying this schedule of shadow tolls for 20 years in order to give the privately financed toll road a reasonable chance of recovering its costs, including the cost of capital. Given the initial traffic volume (1 million vehicles in year 1) and its forecast growth rate (5 percent), the government can forecast the traffic volume in years 2–20 and thus the shadow toll payments in those years. The

forecast payment in year 2, for example, is about \$1.05 million ($\approx 1,000,000 \times \exp(0.05 \times 1) \times \1). By year 15 the forecast payment will hit the cap of \$1.75 million ($1,000,000 \times \exp(0.05 \times 14) \approx 2,000,000$).

To understand the fiscal risks of the scheme, the government could use Monte Carlo simulation to estimate the frequency distribution of the payments it will make in each year (as explained in Boyle and Irwin 2005). From the frequency distribution it could extract the risk measures discussed in the text. For example, it could estimate the probability in each year of payments greater than, say, \$1.5 million (or another threshold of interest to the government) and the cash flow at risk at, say, the 95 percent level by year. It could also produce a histogram of payments (such as that in figure 1) for each year.

To estimate the total liability created by its commitment to pay shadow tolls, the government could use the Monte Carlo simulation to estimate the expected payments by year and then discount each expected payment at the riskless rate. But to take account of the price of risk, the government would have to use a model of the price of risk bearing, such as the capital asset pricing model (CAPM). In particular, it could use the CAPM to estimate the certainty-equivalent payments and then discount them at the riskless rate to get an estimate of its liability (as explained in Boyle and Irwin 2005).

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