"Vintage Capital, Technology Adoption and Electricity Demand-Side Management"

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Executive Summary

Demand-side management (DSM) programs, designed to reduce electricity consumption by improving energy efficiency, are now widespread among North American electricity utilities. Proponents of DSM argue that due to imperfect information consumers and firms make sub-optimal decisions, which result in a large 'energy efficiency gap' between actual and optimal energy consumption. DSM programs seek to address this gap through information campaigns, financial incentives for replacing old appliances, product standards and more stringent building codes. Electricity utilities report substantial energy savings from such programs; however assessments of individual energy-efficiency programs find that the energy savings are much lower than promised, and that the costs of the programs far exceed the likely future benefits.

Central to the discussion is the manner in which anticipated DSM energy savings are measured. In this paper we draw upon a vintage capital model and the literature on technological adoption to provide a more intuitive and theoretically-compelling approach to evaluate the impact of DSM programs. Where energy-efficient technological change is embodied in new appliances, consumers must decide when to replace old vintages of appliances with new vintages. Consumers weigh the annual energy consumption associated with their current appliance against the amortized cost of purchasing a new appliance and the lower future energy consumption. The replacement decision also depends on expectations about the future with respect to the rate of improvement in energy efficiency.

Households in our model operate different vintages in the initial period. We allow for heterogeneity in the beliefs of households about the pace of future improvements in efficiency of the appliance. We show that consumers with beliefs of slower technological improvement delay the adoption of the new vintage and, relative to the case where all consumers have the correct belief, this results in higher energy consumption. Hence, if consumers are under-informed (hold unduly pessimistic forecasts) about future technological progress, a DSM program through subsidization of the adoption can address this 'energy efficiency gap' and reduce energy consumption.

There are three main advantages of our approach for evaluating DSM programs. First, it highlights the problem of insufficient appreciation of the manner in which new, more energy-efficient technology is adopted in the computation of energy use reduction through DSM. Second, it allows for the construction of a benchmark energy use in the absence of the program. This addresses the selection-bias problem with evaluation of DSM programs: reported energy savings of the programs include reduction in energy use of consumers who would have replaced

the appliance even in the absence of the program. Third, to measure the effectiveness of DSM programs, the approach allows for modelling not only a reason for the 'energy efficiency gap' but also its magnitude.

We parameterize the model using data on depreciation, energy use, retail price, and efficiency improvements for refrigerators in the U.S. over the period 1979-2007. Given our parameterizations, we compute the reduction in energy consumption for the case where all households have perfect information (correct belief) about the pace of efficiency improvements. We find the reduction in total energy consumption to be about 2 percent, which is the size of the energy efficiency gap implied by the parameterized model.

We then introduce a DSM program that provides a subsidy for adoption of energy-efficient refrigerators. We find that the DSM program generally produces small savings in aggregate energy use. For example, while a 5 percent subsidy results in aggregate energy savings of about 1 percent, the subsidy cost is about two times the generated energy savings. These findings are robust to different parameter values.

We argue that the reason why empirical studies fail to verify the energy savings reported by utilities from DSM programs is because of the inherently static view of technology adoption by utilities when evaluating energy savings. When measuring DSM savings in practice, electricity utilities make simplistic assumptions about household behaviour absent a DSM program and, without a reasonable benchmark, this likely leads to biased estimates of energy savings. To verify this, we apply the common practice of measuring refrigerator DSM savings by electricity utilities to our model, and find that the "measured" energy savings are several times larger than those implied by our model. We conclude that ignoring the process of technology adoption by households could be one reason why electricity utilities overestimate energy savings from DSM programs.