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Understanding and Using Models in Energy Policy

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Introduction

Energy carries the ability to do work, create wealth, warm cities, and improve the lives of people. The debate over whether the market or central planning better serves these ends has been settled in China on the side of the market. Transition economies like China have decided that they prefer to harness the power of the market place, but while correcting problems that the market does not address well.

But China now faces a new challenge. In the past, China could use the levers of command and control to allocate capital and set regulations governing energy use. China in this way was able to achieve unprecedented success in reducing the rate of growth of energy use and the intensity of its economy. How can China achieve its development, security, and environmental goals in a market economy, which is to say in a situation where the government has less direct control over consumer behavior? Development continually increases demand for energy by industry, commerce, and transportation, though, to China's great credit, energy demand has for two decades grown slower than the economy. Now, however, with China's entry in the World Trade Organization, the Chinese government will have less direct control over energy use. China must therefore substitute the best practices of market-based economies, if it is to both protect the environment and sustain energy and economic development. One answer is to understand better where the country might be headed, and which policy tools might have the greatest impact in steering the country in the desired direction.

This paper provides an international perspective on how Chinese policy makers can apply best practice for modeling and planning energy development during China's transition to a market-based economy. The paper suggests how energy models should be used and interpreted, and how policy planning can be served by the use of models. Policy planning and energy futures modeling is a blend of art and economics, unfortunately, and must be used and interpreted with that knowledge. Effective policy makers will appreciate the strengths and limitations of demand forecasting and know how to interpret results, and ask the right questions.

Chinese specialists are already advanced in the use of energy supply and demand models. Several institutes regularly produce scenarios of possible energy futures, and use these to interpret energy policies. Chinese leaders have long used projections of future energy requirements as a key element of policy making. In fact, it was China's look ahead to the future taken shortly after restructuring of the economy began in 1979 that resulted in significant energy intensity reduction in the Chinese economy over the past two decades. The results have helped the nation achieve its development objectives while reducing the drain on capital and reducing growth in emissions of environmental pollutants. China's problem today is finding a way to continue that success.

Economists in market economies generally agree that the role of the government is to shape or set boundaries for and facilitating operation of the energy market. This role includes setting goals for development, environmental protection, and national security and establishing laws that provide the foundation for the market and ensure fair competition. This role also involves setting standards to reduce energy demand growth, imposing taxes to reduce energy imports, and providing funds to research and develop new energy technologies.

The Role of Models in a Market Economy

Key tools for assessing and planning sustainable energy policies include long-run marginal cost analysis, scenario analysis, economic modeling including econometric modeling and the so-called Delphi method, and technology assessment. Forecasting tools enable policy makers of all types to anticipate the future in order to minimize risk. But three challenges confront those who grapple with the benefits and costs of sustainable energy policy measures. First, estimating the benefits of pollution control is made uncertain by the imprecise methods of measuring the extent of damage–or benefits–that mitigating local and global environmental pollution brings. These costs are often, in market democracies at least, determined through a political process. Second, economic modeling suffers from well-known uncertainties about the future of technology, human behavior, and the effectiveness of policy. Third, transition economies are usually distorted economically so that the difficulty of modeling "normal" economies is greatly compounded. Methodological differences in modeling approaches can also yield significant differences in economic evaluations of sustainable energy policy.

To be valid, economic models must be based on sound economic principles, valid assumptions, and they must be transparent. A key question is "What drives the model?" What are the functions that create change, and what are their variables? Extrapolation of past trends and use of parameters unrelated to behavior are often not credible.

Types of Models

So-called "top-down" energy-economic models are typically based on econometric parameters, such as price and income elasticity of demand, while bottom-up models are based on engineering and optimization techniques. The strength of top-down or macroeconomic models is that they can incorporate so-called feedback effects. They can model economic growth, fuel price changes, and changing energy demand in an internally consistent manner, and in a way consistent with economic and behavioral theory. Growth and prices are generated by the models are endogenous results, while bottom-up models usually assume the values of these variables. Bottom-up models, like the name suggests, handle much more detail about energy supply and demand systems, particularly with regard to technology. Bottom-up models can estimate energy demand on the basis of economic growth, structural change, price response, and technical energy-efficiency improvements not attributed to price response. These models typically are driven by rates of economic growth that are assumed by the modeler, and, like macroeconomic models, can also include assumptions about the rate of technical, non-price-related efficiency improvement.

Because economic development remains a priority for China, Chinese energy models will need to be driven by the engine of economic growth. Obtaining sufficient supplies of energy to facilitate an increase in living standards in China to middle-income levels over the next few decades will require enormous investment and technological innovation. At the same time, the government can no longer intervene in energy development as powerfully as in the past, but must instead influence the behavior of investors, firms, workers, and consumers. That means using tools limited to the provision of information, providing incentives and disincentives, setting environmental and energy-efficiency standards, and investing in research and development. An important part of that task is to attend to so-called market failures, which can stem from a market's imperfect provision of information, inability to internalize the costs of environmental protection, social security, and national security, and its failure to invest in research and development for which the investor cannot capture returns.

Most macroeconomic energy models GDP growth as a driver, with GDP itself driven by variables such as growth in the labor force and growth in productivity. For example, GDP can be defined as the number of workers times labor productivity per worker. Energy demand or changes in energy demand can next be modeled as a function of key variables including GDP per capita, the income elasticity of energy demand, energy price, energy price elasticity of demand , and population.

Price elasticity is defined as the percentage change in energy demand for every 1 percent change in energy price, and income elasticity of demand is defined as the percentage change in energy demand for every 1 percent change in GDP per capita. The price elasticity, for example, is usually calculated over a set of times series data as the correlation coefficient of energy demand on energy price. U.S. energy economists have often found that correlations of demand and price changes show that demand for oil changes by 0.7 percent for every 1 percent change in energy price. That means, for example, that if the oil price doubled, all other things equal, demand for

oil would drop to 62 percent of the previous level.

A simple model for energy demand can be put together from changes in GDP, energy price, and the estimated GDP elasticity of demand, the estimated price elasticity of demand, and population (for example: $E = X^y * P^p * Pop$, where E is energy, X is GDP, P is price, Pop is population, and y and p are elasticities).

Many global energy studies have simply treated transition and developing economies as economies in "competitive equilibrium." (Manne and Richels 1992). This practice is misleading fashion because many developing countries remain essentially planned economies, and to some extent that is true of China's economy (Chandler 1988; Logan 2001). Because this practice is not consistent with reality or even economic theory and is impossible to accept empirically, the result too would be unacceptable. The modeler, of course, could modify baseline energy demand arbitrarily to anticipate economic reform, but this, too, would be inelegant. Indeed, the model would no longer be a proper general equilibrium model, but a bottom-up model, most likely lacking transparency in handling reform.

An equilibrium model would produce its own prices endogenously–internal to the model–rather than assume them exogenously–that is, take them from the literature. A model can still be valid if key variables and parameters are assumed, as long as they are credible and, more importantly, as long as they are transparent. A bottom-up model would assume these variables and combine them with assumptions for technical efficiency. Energy demand for the steel sector, for example, could be modeled by assuming a quantity of steel produced per dollar, change in steel production as a function of economic growth (to reflect structural change through reform), the future price of energy used for steelmaking, the price elasticity (responsiveness) of energy demand, and the annual rate of reduction in the energy intensity of steel production as a result of technical change.

Both top-down and bottom-up models must address the problem of consumer behavior. How much will consumers cut energy demand as prices increase? How much will they increase demand as their incomes rise? Energy price elasticities in most models must be assumed exogenously using empirical studies. Elasticities are estimated by performing a regression analysis of energy prices and price response over time. One can either estimate elasticities specific to an economy or, more tenuously, assume that consumers locally react to prices the way consumers do everywhere–when prices go up, demand goes down. In Western Europe, Japan, and the United States the ratio, or price elasticity of demand, seems to hover around -0.7 (Edmonds and Reilly 1985). Chinese consumer may–or may not–behave similarly.

A key concept for policymakers is that of the discount rate. There are two distinct but confusing aspects to discount rates for energy alternatives, and this distinction often lies at the heart of controversy between top-down and bottom-up modelers. Bottom-up and top-down modelers would probably agree that the apparent consumer discount rate for energy efficiency is quite high–over 50 percent in many sectors, meaning that there is a high preference for consuming now rather than in the future. The controversy arises in the interpretation of the meaning of this

discount rate. Some economists argue that the apparent rate reflects real preferences among consumers, and that historic energy use patterns in market economies are optimized for public welfare. Other economists would argue, however, that the apparent rates reflect only distortions in the economy, and can be greatly reduced. This latter group would point to subsidies for energy use, regulation of electric utility prices, and lack of consumer financing as examples. The discount rate in their work is used only to incorporate the time value of money, and may be as low as 3 percent to reflect the long-term cost of capital.

Energy and climate policy modeling involves the problem of fuel choice. Coal, oil, and natural gas and their products release different amounts of carbon per unit of energy produced. Natural gas produces only 55 percent as much carbon dioxide for a given unit of energy as coal. However, natural gas can often be used more efficiently than coal for the same applications. Incorporating efficiency of combustion means that gas generally produces less than half as much carbon per unit of energy used.

The Use of Scenario Analysis

Exploring the future with energy-economic models is best done in scenarios. This practice establishes a baseline projection, or scenario, against which little experiments can be run by testing the change in energy use, say, or carbon emissions, resulting from the changes in assumptions. The term scenario, borrowed from the theater, describes an effort to tell a consistent, transparent story about the future. For a baseline scenario, one would normally generate a "business as usual" case, which more-or-less continues past trends. The key to policy in this type of exercise, however, is to articulate a theory of change. One cannot just assume that technology will be used because it is available, and one must articulate why prices, technology, purchases, preferences would change. The only tools available for such analysis–and the only tools available for governments to change the world–are research and development, information, standards, taxes, and incentives.

Once Chinese leaders have considered the analytical complexities of options for sustainable energy development, they will be prepared to address complex issues of public administration. Among the more difficult problems they will address are how to conduct planning and management in a down-sized government, promote interagency cooperation, encourage stakeholder participation, conduct a productive research and development program, anticipate future barriers and problems, design appropriate incentives and disincentives for clean energy development, and design environmental protection measures all the while protecting the national security. These questions could be a rewarding if difficult challenge for China's leaders.

Macroeconomic Considerations

Market mechanisms can have both positive and negative impacts on the environmental sustainability of economic development. Often, market reforms can even promote sustainability. The experience of energy sector reform in transition economies provides a case study of this issue. The formerly planned economies of Central Europe and the Former Soviet Union were

very energy intensive before the revolutions of 1989-1991. That energy intensity was caused by four main economic factors of central planning. First, industry dominated Stalinist economies, and heavy industry such as steel making requires more energy per unit of value-added than light manufacturing or services, which have a higher ratio of labor cost (Chandler 1986; Chandler 1990). Second, central planning grossly distorted price signals. Energy pricing under communism was just a way of keeping score. Prices had nothing to do with cost and were rarely adjusted. To their credit, most transition economies have endured great pain to impose more realistic energy prices. Third, soft budget constraints, as described by Hungarian economist Janos Kornai, help explain the inefficient economic behavior induced by central planning (Kornai, 1986). In plain language, soft budget constraints meant that production cost did not matter, or, perversely, the-higher-the-better. Enterprise budgets for labor, capital, and energy were allocated based on planned quotas, and bankruptcy for inefficiency and waste was nearly impossible. The "opportunity cost" of capital, labor, and resources was not a concern for enterprise managers, whose opportunity cost was in not consuming planned allocations because that meant less allocation next year and less "profit" overall. Josef Bognar, also a Hungarian economist, called this system "cost-plus pricing." If enterprise managers could negotiate a budget with the central planners in which they used twice as much steel and twice as much energy as was physically required, they would get more "profit" for bonuses, internal projects, or expanding their little empires. And fourth, technological development was stifled. While the Soviet system trained and educated more scientists and engineers than the west, and while these experts developed advanced technologies, the market did not demand and develop them. Price incentives and hard budget constraints in the west drive technological development as a way of cutting costs. Competition among suppliers drives technology for improving quality and adding new services. Incentives and competition, of course, have only recently been introduced. Each of these four factors were prominent elements of the Chinese economy until recently, and they account in large part for the high energy intensity of Chinese society despite low per capita consumption levels.

Fortunately, reform in Central European nations–as in China–has resulted in dramatically improved energy efficiency–at least as measured in terms of energy intensity. Energy intensity has dropped by one-fifth in the countries Eastern Europe, which are the most advanced in reform. Conversely, in nations in which reform has lagged, energy intensity has increased. Energy per unit of GDP went up significantly in Ukraine and Central Asia over the last decade.

China has, through energy reform, made unprecedented progress in energy intensity reduction. For two decades the world's second largest energy consumer has reduced its energy intensity faster than any developing nation in history. While Chinese economic growth has averaged 9.5 percent each year since 1980, the country held energy consumption growth to 4.8 percent. (World Bank, 1996; Levine, 1999; Chandler *et al* 1998; IEA, 1999). This remarkable example demonstrates that economic and energy demand growth can be decoupled to a large degree.

Economic restructuring and price reform can be implemented through education, training, technical assistance, demonstrations, and finance. But these measures have varying impacts depending on the economic sector and conditions in which they are applied. Thus, a key

requirement for policy makers is to state their theory of change. When leaders propose policy measures, it is vital they consider how policy actions work or do not work in a market economy. That is the subject of a later section in this paper.

Barriers to Sustainable Development in the Marketplace

The positive impact of economic efficiency and resource conservation prompted by market reforms has been demonstrated and discussed above. On the other hand, economists generally agree that a set of market failures can lead to a less-than-optimal economic and environmental solution. Market failures have been defined as in terms of an inability to accomplish certain societal goals for equity, security, and environmental protection. This inability is said to stem from a few key aspects of markets. For example, the market's short-term perspective means that long-run costs associated with the environmental pollution such as global climate change are not reflected in the price of energy. Similarly, equity concerns are affected by the fact that unfair labor practices can provide an advantage to unscrupulous employer. Also, security of oil supplies is generally outside the concern of the market and, indeed, security of oil resources has figure prominently in western military intervention in the Middle East, as the Iraqi War of 1993 illustrates. Other examples of market imperfections stem from so-called "split incentives." The classic illustration of this problem in the energy sector is that of the landlord-tenant relationship. The landlord who buys the appliances in an apartment and the tenant who pays the electric bills have very different motivations. The former seeks to minimize the first or purchase price of appliances while the latter seeks to minimize power consumption in order to hold down the utility bill. The tenant may want the landlord to save him money by spending more for an energy-efficient model, but the landlord has limited motivation to do so.

Even when consumers want to purchase cost-effective products, their ability to do so may be limited by imperfect information. A consumer who is not an energy engineer may have trouble understanding the full cost consequences of a purchase, and manufacturers may make mis-leading claims. Government can play a role to ensure fairness in the marketplace in such circumstances.

Best Practice Policy Modeling

A variety of policy interventions can help overcome barriers to sustainable energy development, but there is no single solution to them. Market economies have not fully exploited the potential for clean energy technology. Current practice uses energy perhaps only one-tenth as efficiently as is technically possible over the long-term (Ayres, 1989; Gibbons and Chandler, 1981). But technical development and market deployment of energy end-use efficiency and clean energy supply technologies are limited by market barriers, market distortions, and technology. A question for Chinese energy policy makers is how to assess the value of such opportunities and to promote them in a market economy.

At least three questions should be asked regarding policy proposals made to address these problems:

- Is the proposed approach commensurate with the challenges of economic growth and development, national security, and environmental change? In other words, are the policy measures of large enough scale to make a difference?
- Does the program leverage the power of the market place? That is, does the policy use the strengths of the market or simply distort it?
- Does the policy lead to sustainable development? In other words, does it create negative results for jobs, oil security, or environmental pollution?

Examples of policies that are used extensively internationally include:

1. Appliance efficiency standards
2. Appliance labeling programs
3. Government procurement policy
4. Loans and tax incentives
5. Demand-side management utility programs
6. Emissions taxes and standards

Energy efficiency policies such as standards, incentives, and information programs are applied by every major developed market economy (IEA 1999a, 1999b, 2000, 2001a, 2001b, 2001c). Energy efficiency standards, for example, are used to establish minimum energy performance levels for manufactured equipment and new buildings. Similarly, tax and financial incentives are used to make clean energy investments more attractive to investors. Information, labeling, training and certification programs can educate consumers and encourage efficiency levels exceeding minimum codes. Some developing countries realize that codes and standards can be effective and have taken steps to implement them. South Korea launched a standards and labeling program for appliances and lamps in 1992; standards have been ratcheted up over time and equipment efficiency has significantly improved (Egan and du Pont 1998). Mexico enacted mandatory efficiency standards on refrigerators, air conditioners and motors, initially at modest levels of efficiency but later equivalent to U.S. standards (Friedman 1998). The Philippines adopted minimum efficiency standards for room air conditioners and refrigerators, is considering standards for motors, and has begun to develop building thermal standards.(Wiel et al. 1998).

Energy security may become a high priority issue as China's oil imports grow. The International Energy Agency projects that China will increase its oil imports by 2020 to a level approaching Saudi Arabia's total oil production today (IEA 1997). That outcome would raise significant geopolitical issues for China's government.

Long-term global change has become a challenge recognized by many governments around the world. China is a signatory to the United Nations Framework Convention on Climate Change, which has as a goal the stabilization of greenhouse gas emissions in the atmosphere. Economic reform and efficiency can provide environmental benefits by reducing energy waste and facilitating beneficial structural change (Gray 1995). Central Europe has proven this latter point as that region's economic reforms have led to reduced energy intensity and lower rates of carbon dioxide and other undesirable emissions. A similar if not more impressive result has in fact been

achieved by China over the past two decades as the country restructured the economy, liberalized energy prices, and imposed hard budget constraints on enterprises. Still, it is well known that markets have a relatively short-term perspective focused not surprisingly on profits and return on investment. A longer-term perspective is required to adequately address global and even local environmental costs, and it is a role of government to provide that vision.

China has the potential for cross-cutting solutions to its energy problems. Greater efficiency could over the next two decades cut the rate of energy used per unit of output by one-quarter to one-half, but lack of political and financial infrastructure impedes cost-effective solutions. Fuel switching to abundant natural gas would cut carbon dioxide emissions by half compared to coal. Indeed, gas can be transported long distances and delivered at competitive costs, and it is exceedingly abundant, with decades of supply available at current prices. Moreover, linking China and South Asia to Siberian and Central Asian gas supplies could also improve efficiency and reduce global as well as local pollution.

The Chinese government is wisely considering its energy future and the barriers impeding economic development, national security, and environmental protection. Over the next two decades, existing but underutilized technology could penetrate emerging markets and help China achieve its goals. To achieve the benefits of advanced technology and best management practice, a new, market-based perspective will be introduced. This new approach can help unleash the power of the marketplace. But leaders will also have to grapple with market distortions created in any market, as well as the correction of policies that no longer are appropriate in a market system.

Conclusion

Governments everywhere have–and have missed–opportunities to improve their energy systems and, in so doing, facilitate reform, promote economic growth, and reduce environmental pollution.
Successful sustainable energy programs share five key elements:

- Functioning market mechanisms.
- Presence of local expertise.
- Appropriate incentives.
- Emphasis on high internal rates of return
- Viable financing.

Government assistance has been most useful when it has leveraged private business interests or at least leveraged financial investments. The cost of unsustainable energy use remains an overwhelming problem for leaders everywhere. Some nations help their citizens adjust to the realities and burdens of energy reform. China has been one of those nations, but has much more work to do.

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