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Econometric general equilibrium modeling

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Abstract

The point of departure for the study of the impact of energy and environmental policies is the neo-classical theory of economic growth formulated by Cass (1965) and Koopmans (1967). The long-run properties of economic growth models are independent of energy and environmental policies. However, these policies affect capital accumulation and rates of productivity growth that determine the intermediate-run trends that are important for policy evaluation.

Heterogeneity of different energy producers and consumers is critical for the implementation of energy and environmental policies. To capture this heterogeneity it is necessary to distinguish among commodities, industries, and households. Econometric methods are essential for summarizing information on different industries and consumer groups in a form suitable for general equilibrium modeling.

In this paper we consider the application of econometric general equilibrium modeling to the U.S., the economy that has been studied most intensively. The framework for our analysis is provided by the Intertemporal General Equilibrium Model (IGEM) introduced by Jorgenson and Wilcoxen (1990). The new version of the IGEM presented in this paper is employed for the evaluation of proposed legislation on climate policy by the U.S. Environmental Protection Agency (2011).

JEL classification: C51; C68; D58; E13; O41; O51; Q43; Q50

1. Introduction

Economic growth is a critical determinant of U.S. demand for energy. Emissions from the combustion of fossil fuels are an important source of U.S. requirements for pollution abatement. An essential first step in modeling the impact of energy and environmental policies is to analyze

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the growth of the U.S. economy. The appropriate point of departure for modeling U.S. economic growth is the neoclassical theory of economic growth, originated by Solow (1956, 2005). This theory has been developed in the form appropriate for modeling the interrelationships among energy, the environment, and U.S. economic growth by Cass (1965) and Koopmans (1967)[1].

Maler (1974) and Uzawa (1975) have presented neo-classical theories of economic growth with pollution abatement. A recent survey by Brock and Taylor (2005) summarizes the extensive literature on this topic. Solow (1974a,b) has provided a theory of economic growth that includes an exhaustible resource. The classic textbook treatment of this topic remains that of Dasgupta and Heal (1979), who also give a detailed survey of the literature. In this paper we focus on pollution abatement, since the U.S. economy is relatively open to trade in natural resources, exporting coal and importing oil and natural gas.

In the neoclassical theory of economic growth wage rates grow at the same rate as productivity in the long run, while rates of return depend on productivity growth and the parameters that describe saving behavior. These long-run properties of economic growth are independent of energy and environmental policies. The neoclassical theory of economic growth also provides a framework for analyzing intermediate-run growth trends. These trends reflect the same determinants as long-run trends, but also depend on energy and environmental policies through their effects of capital accumulation and rates of productivity growth. In this context the “intermediate-run” refers to the time needed for the capital-output ratio to converge to a long-run stationary value. This often requires decades, so that the impact of energy and environmental policies on intermediate-run trends is critical for policy evaluation.

The slowdown of the U.S. economy during the 1970s and 1980s and the acceleration of growth during the 1990s and 2000s are striking examples of changes in intermediate-run trends. Two events associated with the slowdown – the advent of more restrictive environmental policies and the increase in world petroleum prices – have led to a focus on the interactions of energy supplies and prices, environmental quality and its cost, and the sources of economic growth. Similarly, Jorgenson (2009a) has demonstrated that the rapid development of information technology is the key to more rapid growth in the 1990s and 2000s.

Nordhaus (2008, 2010) has applied the Cass–Koopmans theory of economic growth to the analysis of energy and environmental policies in his important studies of climate policy for the world economy. The necessarily schematic modeling of technology limits consideration of issues that are very important in implementation of energy and environmental policies at the national level, such as the heterogeneity of different energy producers and different consumers. To capture this heterogeneity we distinguish among commodities, industries, and households. We employ an econometric approach to summarize information on different industries and different consumer groups in a form suitable for general equilibrium modeling. We next consider the application of the econometric approach to the U.S. economy.

The framework for our econometric analysis of the impact of energy and environmental policies is provided by the Intertemporal General Equilibrium Model (IGEM) introduced by Jorgenson and Wilcoxen (1990) and summarized below[2]. The organizing mechanism of this model is an intertemporal price system balancing demand and supply for products and factors of production. The intertemporal price system links the prices of assets in every time period to the discounted

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[1] Barro and Sala-i-Martin (2004) provide a standard textbook treatment.

[2] The G-cubed model of the world economy introduced by McKibbin and Wilcoxen (1999) and analyzed by McKibbin, Morris, and Wilcoxen (2010) is another important application of the econometric approach.

value of future capital services. This forward-looking feature is essential in dealing with the critique of macro-econometric models by Lucas (1976).

Forward-looking behavior of producers and consumers is combined with backward linkages among investment, capital stock, and capital services in modeling the dynamics of economic growth. These mechanisms are also featured in the Cass–Koopmans neoclassical model of economic growth. The alternative time paths for economic growth depend on energy and environmental policies through the impact of these policies on intermediate-run trends.

In disaggregating the economic impacts of U.S. energy and environmental policies, we preserve the key features of more highly aggregated intertemporal general equilibrium models like those of Nordhaus. One important dimension for disaggregation is to distinguish among industries and commodities in order to measure policy impacts for narrower segments of the U.S. economy. This makes it possible to model differences among industries in responses to changes in energy prices and the imposition of pollution controls and the policy impacts on markets for different fuels.

A second avenue for disaggregation is to distinguish among households by level of wealth and demographic characteristics. This makes it possible to model differences in responses to price changes and environmental controls. It is also essential for analyzing the distributional effects of energy and environmental policies, as in Jorgenson, Slesnick, and Wilcoxen (1992) and Jorgenson, Goettle, Ho, Slesnick, and Wilcoxen (2011). We begin our discussion of econometric intertemporal general equilibrium modeling by outlining the methodology.

At the outset of our discussion it is necessary to recognize that the predominant tradition in general equilibrium modeling does not employ econometric methods. This tradition originated with the seminal work of Leontief (1951), beginning with the implementation of the static input-output model. Leontief (1953) gave a further impetus to the development of general equilibrium modeling by introducing a dynamic input-output model. This model can be regarded as an important progenitor of the intertemporal general equilibrium model described below. Empirical work associated with input-output analysis is based on determining the parameters that describe technology and preferences from a single inter-industry transactions table.

The usefulness of the "fixed coefficients" assumption that underlies input-output analysis is hardly subject to dispute. By linearizing technology and preferences Leontief solved at one stroke the two fundamental problems that arise in practical implementation of general equilibrium models. First, the resulting general equilibrium model can be solved as a system of linear equations with constant coefficients. Second, the "input-output coefficients' can be estimated from a single data point. The data required are now available for all countries that have implemented the United Nations, Commission of the European Communities, International Monetary Fund, Organisation for Economic Co-operation and Development, and World Bank (2009) *2008 System of National Accounts* (2008 SNA).

An input-output approach to modeling environmental policy was introduced by Kneese, Ayres, and d'Arge (1970). Their work was particularly notable for introducing a "materials balance" implied by conservation of mass for all economic activities. Materials balances bring out the fact that material not embodied in final products must result in emissions of pollutants. These emissions accumulate as solid waste or enter the atmosphere or hydrosphere and reduce air or water quality. The assumption that pollutants are generated in fixed proportions to output is a natural complement to the fixed-coefficients assumptions of Leontief's input-output models in implementing the materials balance approach.

The obvious objection to the fixed-coefficients approach to modeling energy and environmental policies is that the purpose of these policies is to change the input-output coefficients. For example, the purpose of many environmental regulations is to induce producers and consumers to substitute less polluting inputs for more polluting ones. A prime example is the substitution of low-sulfur coal for high-sulfur coal by electric utilities to comply with regulations on sulfur-dioxide emissions. Another example is the dramatic shift from leaded to unleaded motor fuels in order to clean up motor vehicle emissions.

Johansen (1960) and Johansen (1974) provided the first successful implementation of an empirical general equilibrium model without the fixed-coefficients assumption of input-output analysis. Johansen retained Leontief's fixed coefficients assumption in determining demands for intermediate goods, including energy. However, he employed linear-logarithmic or Cobb–Douglas production functions in modeling the substitution between capital and labor services and technical change.

Johansen also replaced Leontief's fixed coefficients assumption for household behavior by a system of demand functions originated by Frisch (1959). Finally, he developed a method for solving the resulting nonlinear general equilibrium model for growth rates of sectoral output levels and prices and implemented this model for Norway, using data from the Norwegian national accounts. Johansen's multi-sectoral growth (MSG) model of Norway is another important progenitor for the Intertemporal General Equilibrium Model described below[3].

Linear logarithmic production functions have the obvious advantage that the capital and labor input coefficients respond to price changes. Furthermore, the relative shares of these inputs in the value of output are fixed, so that the unknown parameters can be estimated from a single data point. In describing producer behavior Johansen employed econometric modeling only in estimating constant rates of productivity growth. Similarly, the unknown parameters of the demand system proposed by Frisch can be determined from a single point, except for a single parameter estimated econometrically.

All the essential features of Johansen's approach have been preserved in the computable general equilibrium models now employed in every area of applied economics. Dixon and Parmenter (1996) and Dixon (2016) have surveyed the extensive literature on Johansen-type models. The unknown parameters describing technology and preferences in these models are determined by "calibration" to a single data point. Data from a single inter-industry transactions table are supplemented by a small number of parameters estimated econometrically.

An important advantage of the Johansen approach, like input-output analysis, is the capacity to absorb the enormous amounts of detail available for a single data point. Dixon and Parmenter describe a model of Australia with 120 industries, 56 regions, 280 occupations, and several hundred family types. The current data base for the GTAP model of global trade constructed by Hertel (1999) and collaborators includes data on trade and production for 113 regions of the world and 57 commodity groups for the year 2004[4].

2. Econometric general equilibrium modeling

The obvious disadvantage of the calibration approach is the highly restrictive assumptions on technology and preferences required to make calibration feasible. Almost all general equilibrium models retain the fixed-coefficients assumption of Leontief and Johansen for modeling the demand for intermediate goods. However, this assumption is directly contradicted by massive empirical evidence of price-induced energy conservation in response to higher world energy prices beginning in 1973.

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[3] Holmøy (2016) describes the current version of Johansen's Multisectoral Growth Model of Norway.

[4] See: https://www.gtap.agecon.purdue.edu/databases/v7/v7_contributors.asp.

British Petroleum's (2011) *Energy Outlook 2030* shows that world energy use per unit of GDP peaked in the early 1970s and has fallen by more than 50% through 2010. The reductions in energy utilization induced by successive energy crises in the 1970s and the higher level of energy prices prevailing in the 1980s has been documented in great detail by Schipper, Meyers, Howarth, and Steiner (1992). This extensive survey covers nine OECD countries, including the U.S., for the period 1970–1989 and describes energy conservation in residential, manufacturing, other industry, services, passenger transport, and freight transport sectors. Reductions in energy-output ratios for these activities average 15–20%.

Fixed coefficients for intermediate goods also rule out a very important response to environmental regulations by assumption. This is the introduction of pollution control equipment to treat wastes after they have been generated, substituting capital for other inputs, such as energy and materials. This is commonly known as end-of-pipe abatement and is frequently the method of choice for retrofitting existing facilities to meet environmental standards.

A typical example of end-of-pipe abatement is the use of electrostatic precipitators to reduce emissions of particulates from combustion. Regulations promulgated by regulators like the U.S. Environmental Protection Agency, encourage the use of this approach by setting standards for emission on the basis of the "best available technology". Bergman (2005) provides a detailed survey of computable general equilibrium models of energy and the environment.

Another important limitation of the Johansen approach is that changes in technology are taken to be exogenous. This approach rules out changes in the rate of productivity growth that result from substitution among inputs in response to price changes. Jin and Jorgenson (2010) have separated technical change into those that are *autonomous* or exogenous and those that are endogenous or *induced* by price changes. They show that almost half of the productivity growth at the industry-level in the U.S. over the period 1960–2005 is induced by price changes. Jaffe, Newell, and Stavins (2003) survey the literature on induced technical change in energy and environmental economics.

A representation of technology and preferences that overcomes the limitations of the Johansen approach requires econometric methods. A common extension of Johansen's methodology employs constant elasticities of substitution between two inputs into production. This follows the model of substitution between capital and labor inputs proposed and implemented by Arrow, Chenery, Minhas, and Solow (1961). An especially popular extension of Johansen's methodology is the Armington assumption used to model substitution between domestic and imported varieties of a particular commodity group. This assumption is employed in IGEM.

Unfortunately, the assumption of a constant elasticity of substitution is impossible to maintain for more than two inputs. As Uzawa (1962) and McFadden (1963) have shown, constant elasticities of substitution among more than two inputs imply, essentially, that elasticities of substitution among all inputs must be the same. A less restrictive approach is to generate complete systems of equations for the inputs of capital, labor, energy, materials, and services (KLEMS). Each system gives quantities of inputs as functions of prices of the inputs and the level of output. This approach was originated by Christensen, Jorgenson, and Lau (1973). An important application by Berndt and Jorgenson (1973) was used in econometric modeling the impact of U.S. energy policies by Hudson and Jorgenson (1974)[5].

The KLEMS approach to modeling producer behavior was extended to include autonomous and induced technical change by Jorgenson and Fraumeni (2000). This was employed by Jorgenson

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[5] Jorgenson (1998a) surveys applications of the model of U.S. energy policy developed by Hudson and Jorgenson.

and Wilcoxen (1990) in their original implementation of IGEM. The latest version of IGEM discussed in this paper employs the state-space model of technical change recently introduced by Jin and Jorgenson (2010). The system of equations for inputs is augmented by latent variables generated by a model implemented by means of the Kalman filter.

Despite the severe limitations of the calibration of models of producer behavior to a single data point, this approach has its defenders. For example, Dawkins, Srinivasan, and Whalley (2001) have advocated calibration to a single point rather than the econometric methodology outlined above. Their argument is buttressed by the lack of suitable data for implementation of econometric methods like those of Jin and Jorgenson (2010). These methods require extensive time series data on outputs, inputs, and productivity growth.

Data appropriate for econometric modeling of producer behavior were generated for the U.S. by Jorgenson, Gollop, and Fraumeni (1987). These data provided the empirical basis for the econometric models employed by Jorgenson and Wilcoxen (1990). For the new version of IGEM the U.S. data cover the time period 1960–2005 and are based on those of Jorgenson, Ho, and Stiroh (2005). These data augment the framework of Jorgenson, Gollop, and Fraumeni by distinguishing between capital inputs that employ information technology equipment and software and other capital inputs. This is critically important in capturing the impact of investment in information technology in the 1990s and 2000s.

The completion of the EU (European Union) KLEMS project on June 30, 2008, represents a major breakthrough for econometric modeling of producer behavior. This project has involved collaboration among 18 European research institutes, using a common methodology for generating the data described by Schreyer's (2001, 2009) OECD manuals for the measurement of productivity and capital. These manuals are consistent with the new United Nations et al.' (2009) *2008 System of National Accounts* and the new architecture for the U.S. national accounts proposed by Jorgenson, Landefeld, and Nordhaus (2006).

The results of the EU KLEMS project are summarized by Timmer, Inklaar, O'Mahony, and van Ark (2010). This project has generated time series data on prices and quantities of capital, labor, energy, materials, and services (KLEMS) inputs for 25 of the 27 EU members. For the major European economies the data cover the time period 1970–2005. The project also includes similar data for Australia, Canada, Japan, Korea, and the U.S., following the methodology of Jorgenson et al. (2005).

Industry-level KLEMS data are now incorporated into the official national accounts for Australia, Belgium, Canada, Denmark, Finland, Italy, and The Netherlands and will soon be available for the United States. These data will be updated annually and will provide the basis for implementation of econometric models of producer behavior like those of Jin and Jorgenson (2010). This sweeps away the empirical underpinning of the argument for calibration methods by Dawkins, Srinivasan, and Whalley. Lack of available data is no longer an obstacle to replacing the calibration methods used in Johansen-type models by econometric methods.

The World KLEMS Initiative formed at Harvard University on August 19–20, 2011, will maintain the EU KLEMS data base and extend this to include major emerging and transition economies—Argentina, Brazil, Chile, China, India, Indonesia, Mexico, Russia, Taiwan, and Turkey. Jorgenson and Schreyer (2013) have developed a methodology for constructing aggregate and industry-level production accounts within the framework of the United Nations et al. (2009) *2008 System of National Accounts*, employed by national accountants around the world. This presents data for outputs, inputs, and productivity appropriate for econometric modeling of producer behavior.

3. Econometric modeling of technology and preferences

As in the descriptions of technology by Leontief and Johansen, production in the econometric approach of Jin and Jorgenson is characterized by constant returns to scale in each sector. As a consequence, commodity prices can be expressed as functions of factor prices, using the non-substitution theorem of Samuelson (1951). The non-substitution theorem permits a substantial reduction in the dimensionality of the space of prices determined by the model. This greatly facilitates the solution of the new version of IGEM.

Constant returns to scale and the non-substitution theorem of Samuelson have been exploited in solving Johansen models by applications of "fixed point" methods for pioneered by Scarf (1973). A more common approach is the "Euler-Johansen" method originated by Johansen (1960) and Johansen (1974). Dixon and Parmenter (1996) survey the extensive applications of this method for model solution. Wilcoxen (1992) surveys methods for solving intertemporal general equilibrium models like the IGEM model of Jorgenson and Wilcoxen (1990).

Similarly, econometric models of consumer behavior can overcome the limitations of the Frisch (1959) model of consumer demand. A common approach is to use systems of equations that incorporate the theory of consumer behavior by utilizing the notion of a representative consumer employed by Frisch. Aggregate demand functions are treated as if they could be generated by a single utility-maximizing individual. The difficulty with this approach is that aggregate demand functions must be expressed as sums of individual demand functions.

Gorman (1953) has provided a set of restrictions on individual demand functions that generates a model of aggregate demand that satisfies the restrictions implied by the model of a representative consumer. These restrictions are satisfied by the linear expenditure system proposed by Klein and Rubin (1947–1948) and estimated by Stone (1954). This is the most common model of consumer behavior for computable general equilibrium models. Muellbauer (1975) provides a less restrictive set of conditions for the model of a representative consumer. These conditions are satisfied by the demand system proposed by Deaton and Muellbauer (1980).

Browning, Hansen, and Heckman (1999) have emphasized the importance of heterogeneity of consumers in studies based on household-level data on consumer behavior. This is a particularly crucial issue in the calibration of macro-economic models to empirical results from micro-economic data, following the program of research proposed by Lucas (1980). Dawkins et al. (2001) support this program enthusiastically and include it in their list of calibration methods for macro-economic models, as well as computable general equilibrium models.

Browning, Hansen, and Heckman provide a detailed survey of the very extensive literature on micro-economic models of the type proposed by Lucas. They conclude that the "gulf" between macro-economic and micro-economic models is so great that the "large shelf" of micro-econometric estimates available for application to macro-econometric modeling is "virtually empty". This is due primarily to the heterogeneity of economic behavior at the micro-economic level. Fortunately, the gulf between the calibration approach proposed by Lucas and supported by Dawkins et al. (2001) and the micro-econometric modeling approaches summarized by Browning et al. (1999) has been bridged.

Jorgenson et al. (1982) have estimated an aggregate model of consumer behavior, using Lau's (1977) theory of exact aggregation. The aggregate demand functions are represented explicitly as sums of individual demand functions. From the point of view of general equilibrium modeling the novel feature of this approach is that the model completely dispenses with the notion of a representative consumer. However, the individual demand functions can be recovered from the aggregate demand functions and incorporate all the implications of the theory of individual consumer behavior. This model was employed in the original version of IGEM by Jorgenson and Wilcoxen (1990).

The exact aggregation model proposed by Jorgenson, Lau, and Stoker includes the demographic characteristics of individual households, as well as prices and household expenditures, as determinants of consumer behavior. Most important from the perspective of Browning, Hansen, and Heckman, individual preferences are heterogeneous. The model was implemented from aggregate time series and individual household data. The demographic characteristics of the households successfully capture the enormous heterogeneity of the U.S. population reflected in the census and survey data proposed for econometric modeling by Lucas.

Jorgenson and Slesnick (2008) have recently extended the exact aggregation approach to include labor supply, as well as the intertemporal allocation of full wealth. Full wealth includes the value of the household' human wealth, as well as the household's tangible and financial wealth. Jorgenson and Slesnick (2008) implement this model of aggregate demand for goods and leisure for the U.S. using 150,000 individual household observations from the Consumer Expenditure Survey and price data from the Consumer Price Index covering the period 1980–2006.

Following Slesnick (2002) and Kokoski, Cardiff, and Moulton (1994), Jorgenson and Slesnick generate price data for U.S. regions at different points of time. They also construct quality-adjusted wages for individual workers that incorporate the determinants of human capital. The wages are obtained from the Consumer Expenditure Survey and vary across regions and over time[6]. The advantage of these data sources is that the wage data match expenditure data for individual households. In this paper we summarize the Jorgenson–Slesnick exact aggregation model of consumer behavior employed in the new version of IGEM.

The exact aggregation approach to econometric modeling of data for individual households generates a model of aggregate behavior. This model was incorporated directly into the intertemporal general equilibrium model of Jorgenson and Wilcoxen (1990) and the others summarized by Jorgenson (1998b). The fact that individual demand functions can be recovered from the aggregate demand functions makes it possible to evaluate energy and environmental policies in terms of measures of individual welfare, as demonstrated by Jorgenson, Slesnick, and Wilcoxen (1992). We extend these measures of household welfare to incorporate labor supply, using the model of Jorgenson and Slesnick (2008). Jorgenson et al. (2011) have applied the results to the analysis of energy and environmental policies.

Jorgenson (1998b) provides a survey of the extensive applications of the econometric approach to general equilibrium modeling. This approach was incorporated into the official guidelines for preparing economic analyses of environmental policies by the U.S. Environmental Protection Agency (2000, 2010). The new version of the IGEM model outlined in this paper is employed for the evaluation of proposed legislation on climate policy by U.S. Environmental Protection Agency (2011)[7]. A detailed list of legislative initiatives analyzed by means of IGEM is given on EPA's *Climate Economics* website[8].

U.S. Environmental Protection Agency (2010) emphasizes the fact that development of an econometric, intertemporal general equilibrium model is a very costly undertaking. The

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[6] A further extension would incorporate investment in human capital along the lines discussed by Browning et al. (1999), Tables 2.3 and 2.4, pp. 585–586. This would be appropriate for modeling changes in long-run trends in demographic behavior induced by changes in economic policies, such as social insurance. Our focus throughout this paper is on intermediate-run trends.

[7] Further details are provided by Jorgenson, Goettle, Ho, Slesnick, and Wilcoxen (2009).

[8] See: http://www.epa.gov/climatechange/economics/modeling.html.

implementation of the econometric approach to general equilibrium modeling requires a new system of national accounts like that discussed by Jorgenson (2009b) and Jorgenson and Schreyer (2013). These data must be combined with micro-economic data to generate econometric estimates of the models of producer and consumer behavior.

4. Conclusion

We conclude that econometric general equilibrium modeling is a very important addition to economic methodologies for evaluating energy and environmental policies. The traditional approach originated by Johansen is based on calibration of the models of household and producer behavior to data for a single data point. This is a very useful simplification, but imposes highly restrictive assumptions on technology and preferences, such as the fixed coefficients assumption for intermediate goods employed by Leontief. This is a severe limitation in the application of these models to the analysis of energy and environmental policies.

The intertemporal price system embodied in IGEM since its introduction by Jorgenson and Wilcoxen (1990) is essential to overcome the Lucas (1976) critique of macro-econometric models, which applies equally to computable general equilibrium models. Econometric general equilibrium models retain long-established principles of micro-economic theory in modeling producer and consumer behavior. Exact aggregation over models for individual households makes it possible to incorporate demographic characteristics that reflect the enormous heterogeneity of individual behavior.

The new version of IGEM employs the model of producer behavior developed by Jin and Jorgenson (2010). Jin and Jorgenson (2010) model substitution among inputs in response to price changes, using a system of equations like that introduced by Christensen et al. (1973). They have represented technical change by means of latent variables that are estimated by means of the Kalman filter.

For decades the progress of econometric general equilibrium modeling has been hampered by the lack of appropriate national accounting data, except for the United States. With the completion of the EU KLEMS project in 2008 and the establishment of the World KLEMS Initiative in 2010, this obstacle has been cleared away. These data are already available for the U.S., Japan, and major European countries and are being incorporated into official systems of national accounts.

The industry-level production accounts employed by Jorgenson et al. (2005) and employed in IGEM are consistent with the United Nations et al.' (2009) *2008 System of National Accounts* and the new architecture for the U.S. national accounts proposed by Jorgenson et al. (2006). Using the econometric methodology presented in this paper, it is possible to develop econometric general equilibrium models for the major advanced countries of the world. Data will soon be available to extend this approach to forty or more economies, including the leading emerging economies like China and India.

The new version of IGEM for evaluation of alternative climate policies employed by the U.S. Environmental Protection Agency (2009) incorporates a new model of household behavior developed by Jorgenson and Slesnick (2008). This model successfully incorporates labor–leisure choices, as well as choices among goods and services, into the evaluation of climate policy. The model also incorporates demographic characteristics of individual households that reflect the heterogeneity of the U.S. population.

Like the models of household behavior used in previous versions of IGEM, the Jorgenson–Slesnick model encompasses all the restrictions implied by the theory of consumer behavior. The new model also satisfies the conditions required for exact aggregation, so that we construct a model of aggregate consumer behavior for IGEM by aggregating over individual households. Jorgenson et al. (2011) then recover money measures of the impact on household welfare of changes in climate policy.

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