NATIONAL ENERGY TECHNOLOGY LABORATORY

Assessment of Macroeconomic Modeling in NEMS

Sensitivity Studies with the NEMS Macroeconomic Model

October 29, 2010

DOE/NETL-2010/1426

U.S. DEPARTMENT OF ENERGY

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Acknowledgements

Phil DiPietro, Director of Situational Analysis and Benefits Division, Office of Systems Analyses and Planning, and Charles Zelek, Team Leader, Benefits Team, provided valuable guidance and encouragement in this task.

Summary

This paper summarizes results of an exploratory study of how the macroeconomic impacts of energy prices and consumptions are modeled in the National Energy Modeling System (NEMS), the key modeling system used by the Energy Information Administration (EIA) to prepare the Annual Energy Outlook and Service Report Side Cases covering such issues as proposed climate change legislation and differing outlooks for world crude oil supplies. Sensitivity studies were used to quantify the impacts of energy prices and consumptions on metrics of national prosperity, such as real GDP. A secondary purpose of this report is to document methodology, so that additional studies can be undertaken by others in a practical and efficient fashion.

A primary motivation for this study is a perceived insensitivity of the macroeconomic model in NEMS to energy prices when high-world-oil-price or climate-change-policy scenarios are compared to business-as-usual scenarios such as the Annual Energy Outlooks. A key finding was that observed sensitivities are partly a reflection of demand elasticities in the demand models of NEMS, since these demands are used to overwrite endogenous consumptions in the macroeconomic model. The macroeconomic model in NEMS is the IHS/Global Insight mid-term forecast model of the U.S. economy (hereafter called the GI macro model), generally regarded as a best-in-class model. Another key finding was that the GI macro model, as implemented in NEMS, "fails-to-solve" when prices increase beyond a certain point without sufficient reductions in consumption. The GI macro model's internal reaction functions, or elasticities of consumptions with respect to prices, are effectively replaced by those from the NEMS demand models through the use of NEMS derived consumption overwrites. Although NEMS based reaction functions are generally believed to be consistent with the GI model's reactions functions, and both are believed to be more or less valid in business as usual scenarios, the existence of a "failure-to-solve" limit, as with any algorithm, implies a *potential* bias to only model scenarios within the model's feasibility domain. In the case at hand, the potential bias would be for efficiency and conservation in climate change and energy security scenarios with high energy prices. A final key finding was that certain exogenous drivers in the GI macro model, which exert a profound impact on macroeconomic growth and are typically varied between macroeconomic growth scenarios, are assumed to be independent of energy prices. One such driver examined in this study is total factor productivity (TFP). Based upon available data and the literature, TFP may not be entirely independent of energy prices.

With respect to the sensitivity of real GDP to energy prices, three types of elasticities were estimated to reflect the integration of the GI macro model in NEMS: (1) a direct elasticity with respect to prices in the GI macro model at constant consumptions; (2) an indirect elasticity reflecting the combined effect of an elasticity with respect to consumptions in the GI macro model and an elasticity of demands with respect to prices in the NEMS demand models; (3) a hypothetical indirect elasticity not currently modeled in NEMS, reflecting the combined effect of an elasticity with respect to total factor productivity in the GI macro model and an assumed elasticity of total factor productivity with respect to prices. Some scenarios examined resulted in annual real GDP losses in 2030 as great as 15 %, or more than 3 trillion dollars (constant 2000 dollars) when hypothetical impacts to total factor productivity were combined with the impacts of energy prices and consumptions.

The methodology developed in this study greatly facilitated experimentation with the macro model and its implementation in NEMS, enabling sensitivity studies to be completed in minutes on a laptop rather than the tens of hours that would be needed on a workstation for a single, fully integrated NEMS run.

Background

A primary goal of energy R&D is a reduction in prices of energy throughout the economy consistent with environmental and energy security constraints. Models such as NEMS are routinely used to project the pickup and penetration of advanced technologies into the market place with a consequent reduction in the costs of energy (Geisbrecht 2009; Klara 2006; NRC 2007). NEMS tends to project muted impacts of changing energy prices at a macroeconomic level as shown in Figures 1 and 2, which compare real GDP trends from recent EIA projections for divergent scenarios of world oil price and climate change policy. The AEO2009 scenario (American Recovery and Reinvestment Act of 2009 version) includes an outlook for much higher world oil prices. The S.2191 scenario (Lieberman-Warner Climate Security Act of 2007) includes significant CO_2 emission controls without the higher oil price projections of the AEO2009. The AEO2008 scenario includes neither. The similarity in GDP for these divergent scenarios is probably not coincidental since they are internally consistent and is likely a reflection of a general insensitivity on the part of the macroeconomic model and its implementation in NEMS. The implications of this insensitivity are important to developers like the National Energy Technology Laboratory (NETL), which use NEMS to project the benefits of R&D. If a modeling artifact is involved, the real world benefits of R&D are likely understated in climate change or energy security scenarios in which energy prices and the impact of technology R&D are most significant.

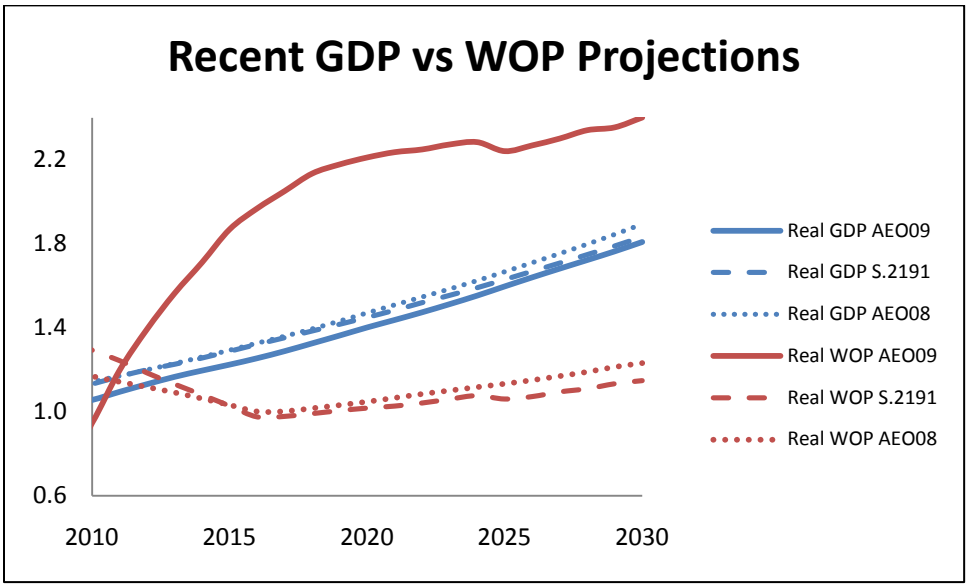

Figure 1. Recent EIA Projections for Real GDP and World Oil Price (Normalized to 2005 = 1).

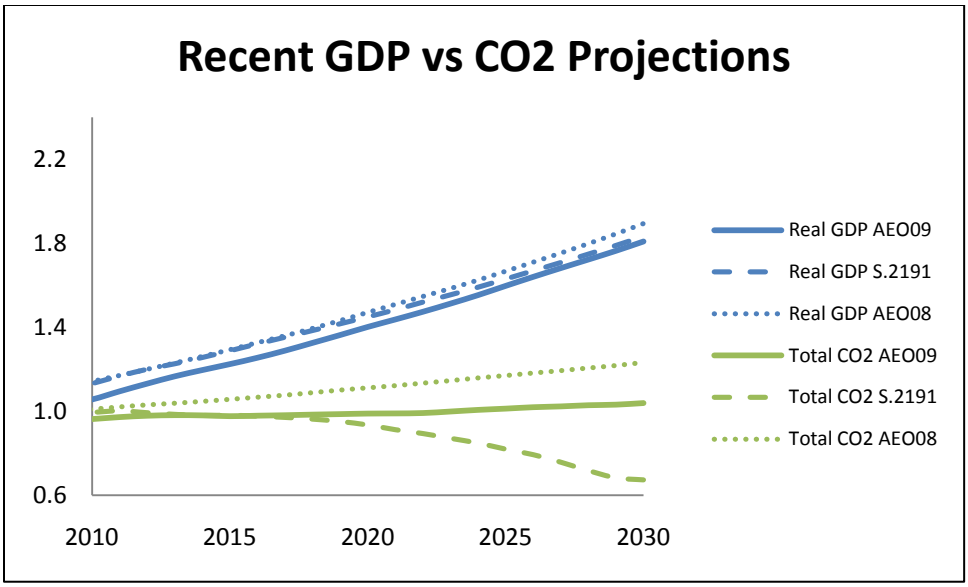

Figure 2. Recent EIA Projections for Real GDP and CO2 Emissions (Normalized to 2005 = 1). CO2 emissions are a proxy for alternative climate change policies and the resulting impacts on energy costs.

Methodology

Global Insight Macroeconomic Model and EVIEWS

The framework for integrating macroeconomic effects with the energy supply and demand models in NEMS is described in EIA's model documentation (EIA 2010), of which the following is a brief synopsis. The macro model in NEMS is the IHS/Global Insight mid-term forecast model of the U.S. economy (hereafter called the GI macro model). The GI macro model is contained in an EVIEWS work file which contains the model object and associated data objects. The GI macro model used in the AEO2009 (M_US2008A) consists of 1,727 equations and 2,022 variables (295 exogenous and 1,727 endogenous) where each variable is a serial object holding quarterly values from 1959Q1 to 2039Q4. The complex econometric nature of the model's equations ultimately dictated a methodology based on empirical sensitivity studies.

EVIEWS is a Windows based forecasting and analysis package that integrates estimation, forecasting, statistical analysis, graphics, data management, and simulation, licensed by QMS, Inc. Procedures are implemented by issuing commands interactively or batch-wise in a "drivers" file (DRIVERS.PRG). In the NEMS framework, this file is scripted by NEMS immediately prior to executing the GI macro model as an external process. Understanding the command language is required to edit the drivers file and thereby define a sensitivity case, known as scenarios in EVIEWS. A powerful functionality is provided in EVIEWS to define, execute, and archive scenarios, consisting of alternate values for select variables. Depending on the nature of the variable, the alternate values are imposed as an override of an exogenous driver variable or an exclusion of an endogenous solution variable and its corresponding equation. Exclusions essentially convert an endogenous solution variable to an exogenous driver variable using the imposed values for the variable.

NEMS Energy Prices and Consumptions File

Another file scripted by NEMS just prior to execution of the GI macro model is a "NEMS solutions" file (ALTDATA.WK1), which forms part of the interface between the GI macro model and the rest of NEMS. This file contains energy prices and consumptions as determined in the supply and demand models of NEMS that are then imposed on the GI macro model as exclusions of endogenous solution variables. EVIEWS reads this file, translates annual changes in NEMS variables into scaled changes in corresponding macro model variables, and finally executes the GI macro model. Projected time trends from NEMS are spliced onto historical trends from GI for the auto-regressed, or lagged, variables of the GI macro model.

EVIEWS Sensitivity Calculations

For sensitivity studies, it is neither necessary nor productive to use fully integrated NEMS simulations. Because of how it is implemented (external, standalone process) the GI macro model can be used in a standalone fashion for sensitivity studies, condensing run times from tens of hours on a workstation to minutes on a laptop with EVIEWS installed. The run folder only needs to include MCEVWORK.WF1 (GI macro model), and three files from a baseline run of NEMS: DRIVERS.PRG (NEMS output requiring edits with a text editor); ALTDATA.WK1 (NEMS output requiring no edits); and MCHIGHLO.XLS (NEMS input requiring no edits)[1]. Sensitivity studies are defined by editing DRIVERS.PRG. EVIEWS program language commands are inserted that declare sensitivity scenarios and overrides and exclusions of variables (see the EVIEWS program documentation and user help manuals). Sensitivity studies vary the time trends for how a driver variable is projected to change, splicing these trends onto the historical trends. Excerpts of a typical DRIVERS.PRG edited for sensitivity studies are shown in the Appendix, where five scenarios are defined, starting with the Baseline Scenario (S-1) that applies NEMS derived overwrites for energy prices and consumptions from AEO2009. Each subsequent scenario incorporates the previous scenarios, such that S-2 consumption reductions are added to the S-1 specifications, and S-3 price increases are added to the S-2 specifications. S-4 is a null (placeholder) scenario related to proprietary exogenous variables used in the GI and EIA macro side cases; in the studies reported herein, no variables were changed. S-5 is a scenario that includes variations in exogeneous drivers of special interest because of their possible dependency on energy prices.

Results and Discussion

Simulations were undertaken to examine the sensitivity of the GI macro model and its implementation in the NEMS framework to energy prices and consumptions, parsed as inputs to the macro model from the NEMS supply and demand models. Trends were determined for those metrics generally believed to be indicative of prosperity, such as real GDP growth. Changes in energy prices and consumptions were specified via exclusions of endogenous solution variables in the GI macro model. The baseline for these simulations is the AEO2009 including the American Recovery and Reinvestment Act of 2009, hereafter referred to as Scenario 1 (S-1).

[1] MCHIGHLO.XLS, a "macro side cases" file read by EVIEWS, contains ratios of key GI macro model outputs from GI's proprietary low or high macro forecast to the baseline forecast. These factors are used only if a macro side case is indicated in DRIVERS.PRG, as discussed later.

The impacts of additional variables were determined in subsequent sensitivity studies to gain insight into those observed for the primary NEMS energy price and consumption drivers. These variables included those likely used for the IHS/GI macro side cases. Changes in these variables were specified as overrides of exogenous driver variables. As discussed later, a major assumption in the NEMS implementation of the GI macro model is that these variables are independent of energy prices and consumptions, but some may not be entirely independent.

GDP Sensitivity to Selected Drivers

The sensitivity of real GDP to NEMS energy price and consumption trends is shown in Figure 3, which compares the GDP trend of the Baseline (Scenario 1) to two sensitivity scenarios. Scenario 2 assumes that annual growths in energy consumptions are reduced by 75 % from the Baseline. Scenario 3 further assumes that annual growths in energy prices are increased by 200 % from the Baseline. Scenario 3 assumptions include those of Scenario 2. While the impacts on GDP are substantial in the case of consumption reductions (S-2), they are generally smaller than in the IHS/GI macro side cases discussed later.

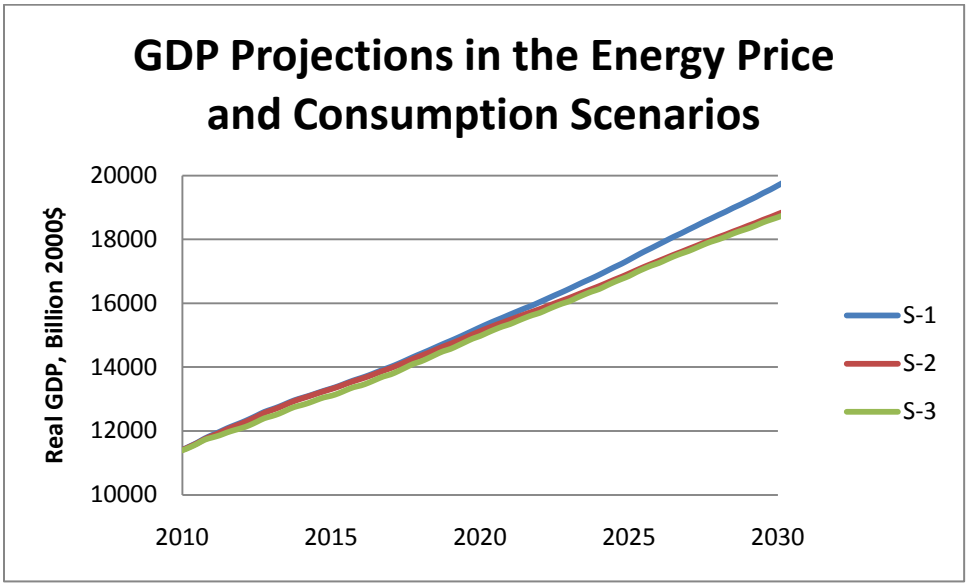

Figure 3. Real GDP Sensitivity to NEMS Energy Price and Consumption Trends. Baseline (S-1) growth rates in consumptions were reduced 75 % in S-2 and S-3. Baseline (S-1) growth rates in prices were increased 200 % in S-3.

Relationship of GDP to Energy Prices - Short versus Long Term Concepts

There is a diverse literature relating to the sensitivity of real GDP to energy prices. There are papers concerned with gradual, sustained price increases in long term equilibrium models, suggesting that energy consumptions act as small components of overall economic activity (Peace and Weyant 2008) because of (assumed) options for substitution over the long term. There are also papers concerned with crude oil price shocks in short term dynamic models, suggesting relationships with coincident recessions (Blanchard and Gali 2007; Roubini and Setzer 2004). As a mid-term econometric model, the GI macro

model doesn't necessarily conform to either viewpoint (software brochures mention the modeling of business cycles and recessions, but only as scenarios with crafted exogenous drivers featuring shocks and other volatilities).

A comparison of GI macro model projections to historical data for real GDP growth is shown in Figure 4, which shows that the model's focus as used in NEMS is on long term trends rather than short term business cycles. The stagnant trend for projections as compared to history may reflect stagnancies in exogenous drivers (no shocks or volatilities), model insensitivity, or both. Model insensitivity cannot be ruled out without a careful back-casting study to see how the model fits the historical trends for known volatilities in both exogenous and endogenous variables.

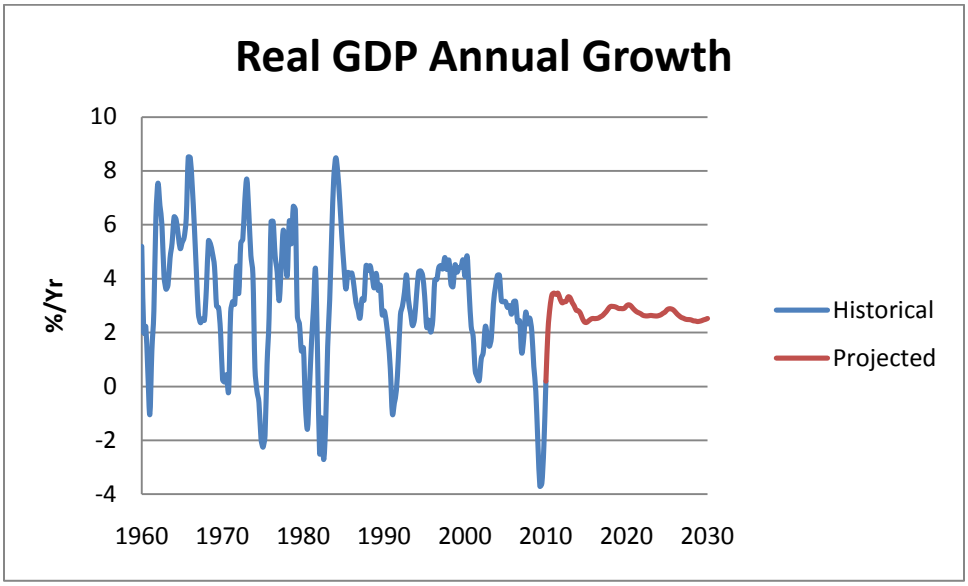

Figure 4. Year-to-Year Annual GDP Growth History Compared to Model Projections (historical and projected values are year-to-year quarterly values in the GI model). Projections clearly are focused on long term trends as opposed to the volatility generally associated with short term business cycles, bubbles, and recessions.

Elasticity of Real GDP to Energy Prices - Direct and Indirect Factors

The trend lines for the projections in Figures 3 and 4 do not show the volatility observed in the historical data. In recognition of the evident focus of model projections on long term trends, the sensitivities of real GDP to various drivers are quantified in terms of elasticities. In Scenario 2, real GDP fell about 5 % in response to energy consumptions that were reduced about 10 - 20 % (average = 15 %). In Scenario 3, real GDP fell further, about 0.5 %, in response to energy prices that were increased about 40 - 160 % (average = 100 %). Key energy consumption and price changes in the scenarios are shown in Figures 5 and 6, respectively.

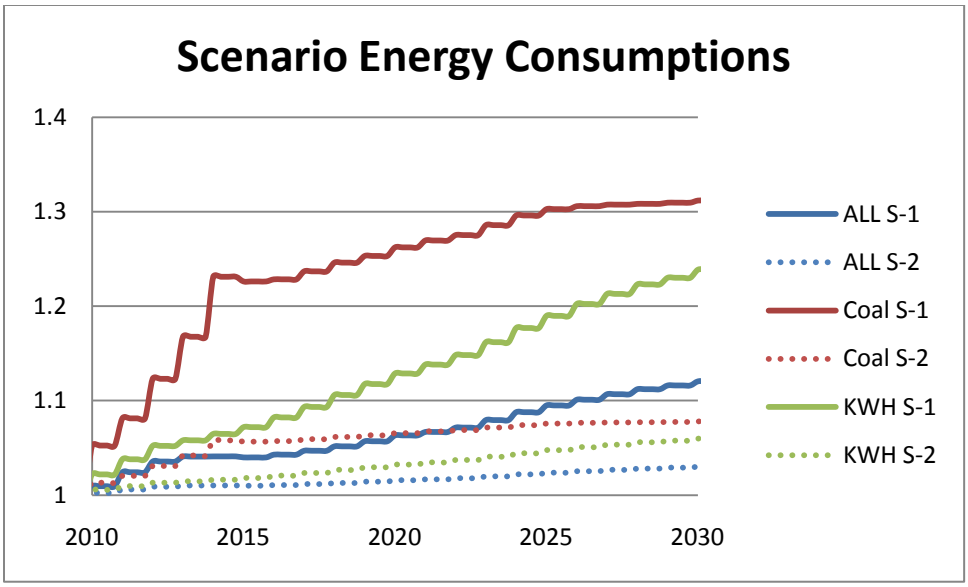

Figure 5. Energy Consumptions (S-3 = S-2; Normalized to 2009 =1). All = Total Energy (all forms); Coal = Coal (all end users), KWH = Electricity (all users).

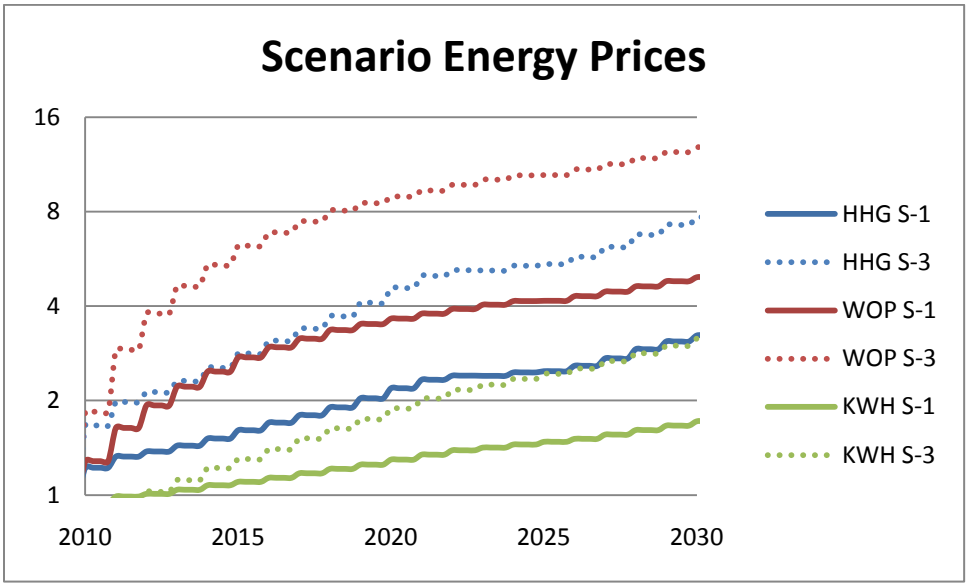

Figure 6. Energy Prices (S-2 = S-1; Normalized to 2009 = 1). HHG = Henry Hub Gas Price; WOP = World Oil Price (average import price); KWH = Electric Power Price (average delivered price to all users).

To reflect the implementation of the GI macro model in NEMS, elasticity of real GDP to energy prices when NEMS derived consumption overwrites are held constant is defined herein as direct elasticity in the GI macro model. It is estimated to be on the order of -0.005 (0.5 % reduction in real GDP divided by 100 % average increase in energy prices). Elasticity of real GDP to energy consumptions when NEMS derived price overwrites are held constant is a component of an indirect elasticity to energy prices in the

GI macro model since consumptions as a function of energy prices are determined outside the GI macro model, in the supply and demand models of NEMS. Elasticity of real GDP to energy consumptions when NEMS derived price overwrites are held constant is on the order of 0.33 (5 % reduction in real GDP divided by 15 % average reduction in consumptions). The elasticity of energy consumptions to energy prices in the supply and demand models of NEMS, assumed herein to be on the order of -0.10, implies an indirect elasticity of real GDP to energy prices on the order of -0.033. Clearly, the indirect form of elasticity (sensitivity) dominates, and this could be expected to be the case with fully integrated NEMS simulations.

Model Feasibility Domains

An interesting observation in the sensitivity studies was that the feasibility of arbitrary price increases depended upon simultaneous reductions in consumptions when NEMS derived consumption overwrites were included and held constant. Consumption overwrites effectively disable the GI model's internal reaction functions, or elasticities of consumptions with respect to prices. In the NEMS implementation of the GI macro model, these reaction functions are replaced by elasticities of demands with respect to prices in the various NEMS demand models. In the sensitivity studies reported herein, these reaction functions were also disabled in that consumption overwrites were specified exogenously so that they could be varied independently from energy prices. Without consumption reductions, energy price increases beyond a certain point resulted in model crashing due to mathematical infeasibilities. This could be a reflection of limitations on energy expenditures, as a fraction of total expenditures, since energy consumptions beyond a certain point also were not solvable without offsetting reductions in energy prices, as shown in Figure 7[2]. "Failures-to-solve" for an econometric model could be indicative of a scenario which is outside the bounds of the data upon which the model's correlations and coefficients are based. Although not entirely satisfactory from a modeling viewpoint, a "failure-to-solve" could be an outcome with significant implications, especially for scenarios that are beyond business as usual, such as climate and energy security scenarios with energy prices that are high by historical standards.

[2] This is analogous to how a consumer could rebound from higher gasoline prices without changes in driving habits as long as expenditures could be kept constant by higher mileage efficiency.

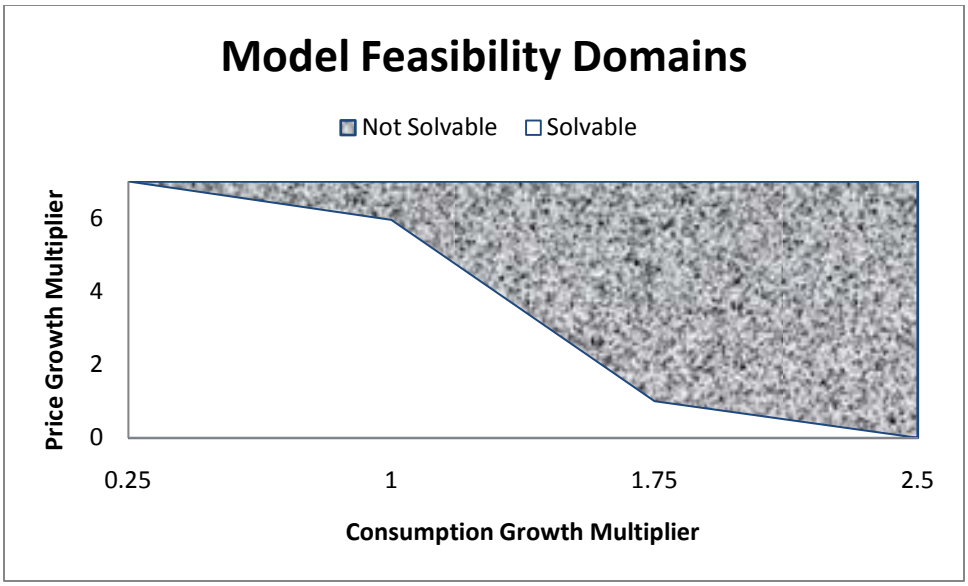

Figure 7. Domains of Model Failure by Energy Price and Consumption Trends. Growth multipliers are applied to the Baseline rates.

The implication for NEMS is that the macro model may not be solvable for climate change scenarios with significant energy price increases unless sufficient reductions in consumptions are included[3]. Although efficiency and conservation have generally been paired with price increases in climate change legislative proposals, a model that requires this as a precondition would be ineffective for scenarios where such a pairing is either not called for or fails to materialize due to unforeseen risks. In other words, the model could effectively contain a bias towards the modeling of high energy price scenarios only in conjunction with consumption reductions.

Exogenous Drivers in the Low and High Macro Side Cases

Compared to the general insensitivities with respect to NEMS energy prices and consumptions, EIA's macro side cases show substantial changes in GDP and related concepts from the baseline, as shown in Figure 8. Which exogenous drivers are manipulated to produce these side cases is thus of great interest, since the implicit assumption is that each is essentially independent of energy prices and consumptions. The next effort would have been to identify these drivers and assess for their possible dependency on energy prices, but side case drivers are not explicitly declared in NEMS, since the macro side cases are not actually modeled per se. Macro model outputs for side cases are simply derived from the baseline by means of ratios derived from the proprietary GI baseline and side cases.

[3] This is reminiscent of price limits in past "energy security" scenarios where exogenous world oil prices could only be increased up to a certain limit without model failure.

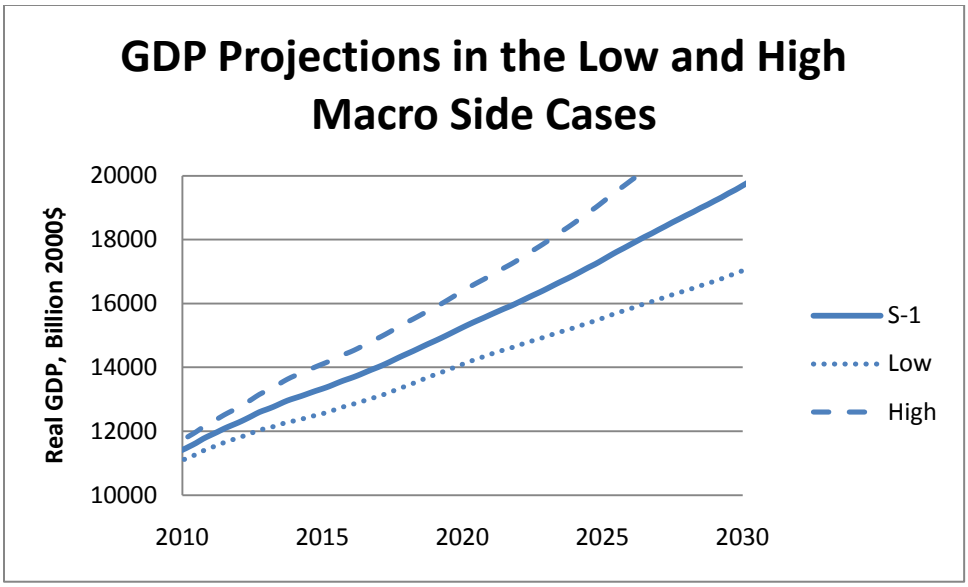

Figure 8. Real GDP in the Baseline and Macro Side Cases. Net impacts of exogenous drivers in the Macro Side Cases are substantial relative to the impacts of plausible variations in NEMS energy prices and consumptions.

A general description of the drivers that are changed from the baseline to the low and high macro side cases is available to registered users on the IHS/GI web site. In this paper, Figure 9 is a place-holder that otherwise would show the transition from the baseline to low macro side case as select driver variables are added, but since such data are proprietary to IHS/GI and its licensees, the intermediate steps and variables are censored.

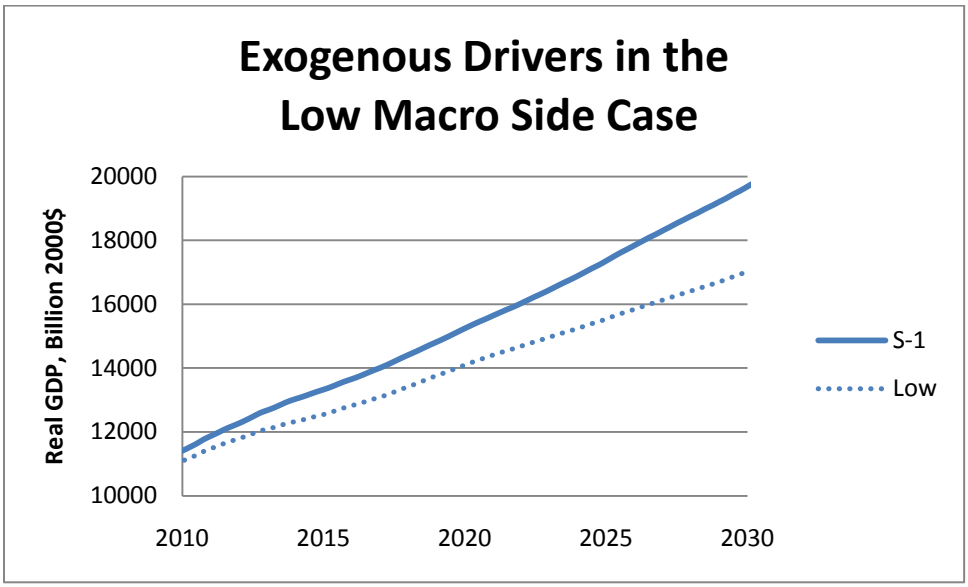

Figure 9. Impact of Low Macro Side Case Exogenous Drivers. The intermediate impact of specific exogenous driver variables is censored since they are proprietary to IHS/GI and its licensees.

Total Factor Productivity - Exogenous Driver of Special Interest

One prominent driver variable almost certainly manipulated to produce the macro side cases is total factor productivity (TFP), introduced by Solow (Solow 1956), who was awarded a Nobel Prize in 1987. TFP has become a standard concept in macro modeling with an extensive literature, including discussions for or against incorporating a dependency on energy prices and consumptions. A basic problem with TFP lies in its derivation, essentially as a residual in econometric modeling. A generally accepted framework for modeling TFP as an endogenous variable does not exist. As an exogenous variable, it is essentially a projection of past trends extending back to Solow, which at best can only be modified in a scenario framework (as in the macro side cases).

As shown in Figures 10 and 11, the impact of modest shifts in TFP can be quite profound. The elasticity of real GDP to TFP in the GI macro model is on the order of 1.2 (12 % reduction in real GDP divided by 10 % reduction in TFP). A dependency of TFP on energy prices would give rise to another indirect elasticity of real GDP to energy prices. Unlike the previous ones which in effect are modeled in NEMS, this one is not since TFP is assumed to be independent of energy prices. Notably for our purposes, NEMS does not attempt to model any impacts on TFP, opting instead for the GI macro case values by default. From a modeling standpoint, NEMS is effectively insensitive to any dependencies of TFP on energy prices.

As shown in Figure 11, the growth trend in the sensitivity case is not unlike the so-called low growth phase of the 1970s, a period of sustained energy price increases that has been discussed relative to a dependency of TFP on energy prices (OECD 1988; CBO 2006). Assuming a hypothetical elasticity of TFP to energy prices on the order of -0.05, loosely implied by Figure 12, another indirect elasticity of GDP to energy prices results (-0.06 = -0.05 multiplied by 1.2). If included, this elasticity would increase the total elasticity of real GDP to energy prices from something on the order of -0.04 for those factors that are modeled to something on the order of -0.10.

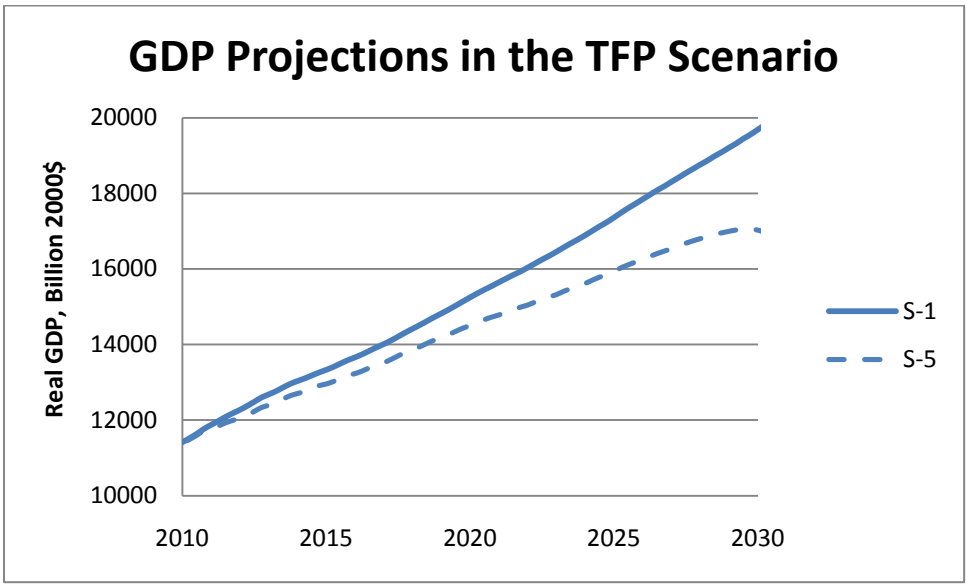

Figure 10. Real GDP in the Baseline and TFP Scenario (S-5). Impact of reduced growth in total factor productivity is comparable to the impacts in the Low Macro Side Case (S-4).

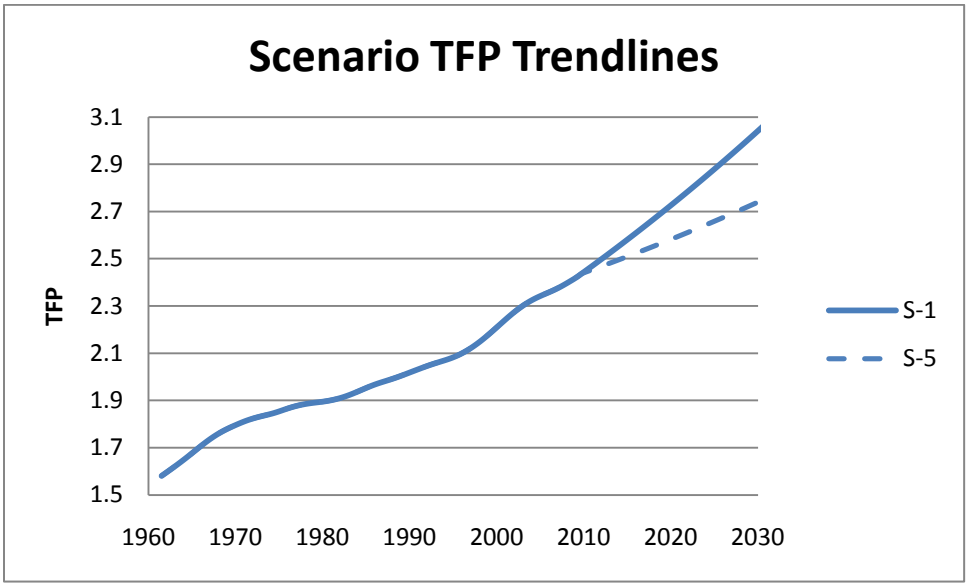

Figure 11. Total Factor Productivity in the Baseline and TFP Scenario (S-5). The reduced growth rate in S-5 is not unlike the historical rate during the 70s and 80s.

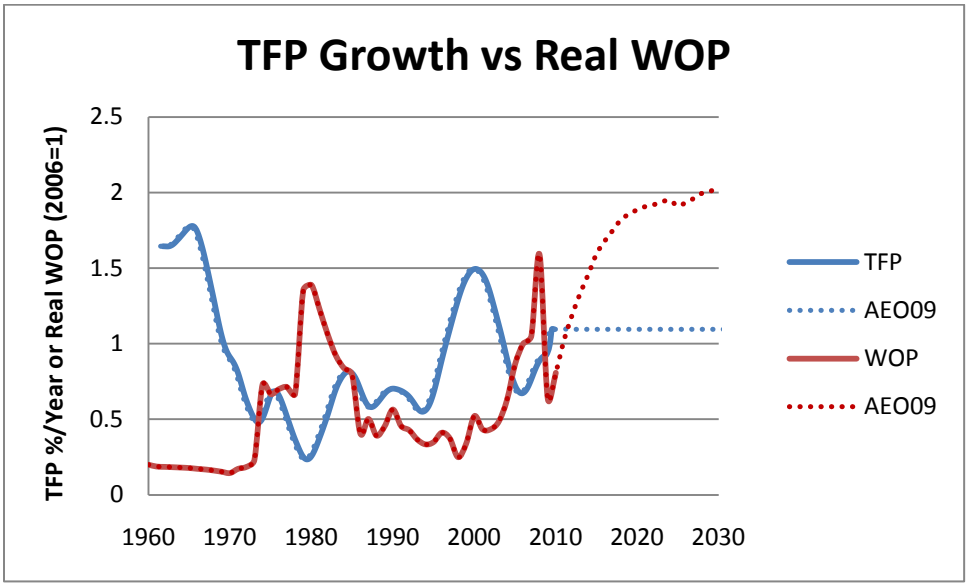

Figure 12. Historical and Projected Trends for TFP Growth and WOP (Normalized to 2006 = 1). Low productivity growth periods appear to coincide with periods of high oil prices, but EIA projections assume a constant growth rate for TFP irrespective of future trends in energy prices.

Sensitivity of Other Metrics to Selected Drivers

Shown in Figures 13 through 16 are the sensitivities of some of the many other metrics available from the GI macro model. They were chosen here to illustrate the breadth of metrics available as well as to suggest metrics supplemental to real GDP for inferring the economic feasibility of a scenario from a

policy standpoint. Metrics on sector based activity, for example, might relate to abrupt dislocations that imply difficult adjustments for a real economy. Metrics such as CPI might help to put otherwise similar real GDP trends into perspective.

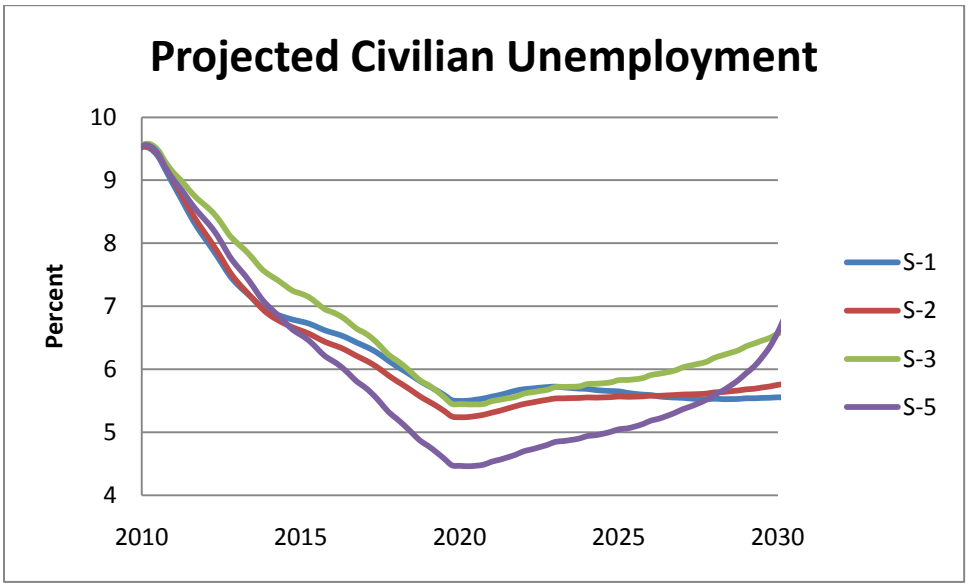

Figure 13. Civilian Unemployment Rate by Scenario.

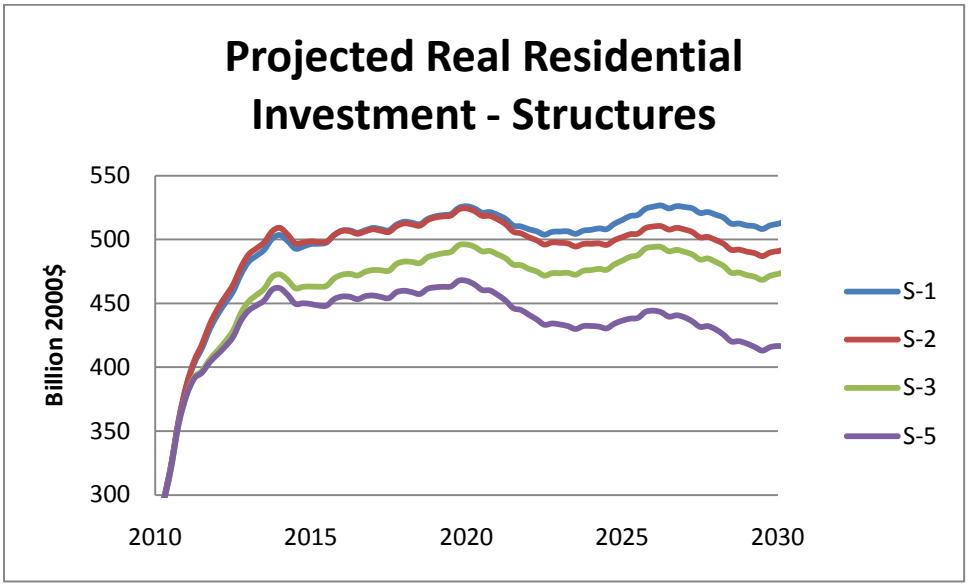

Figure 14. Real Residential Investment - Structures by Scenario.

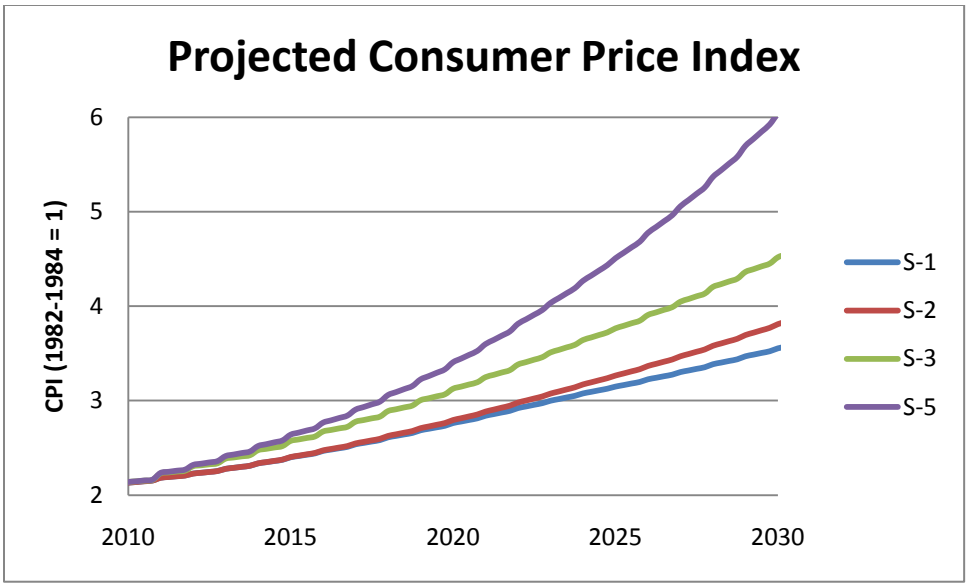

Figure 15. Consumer Price Index by Scenario.

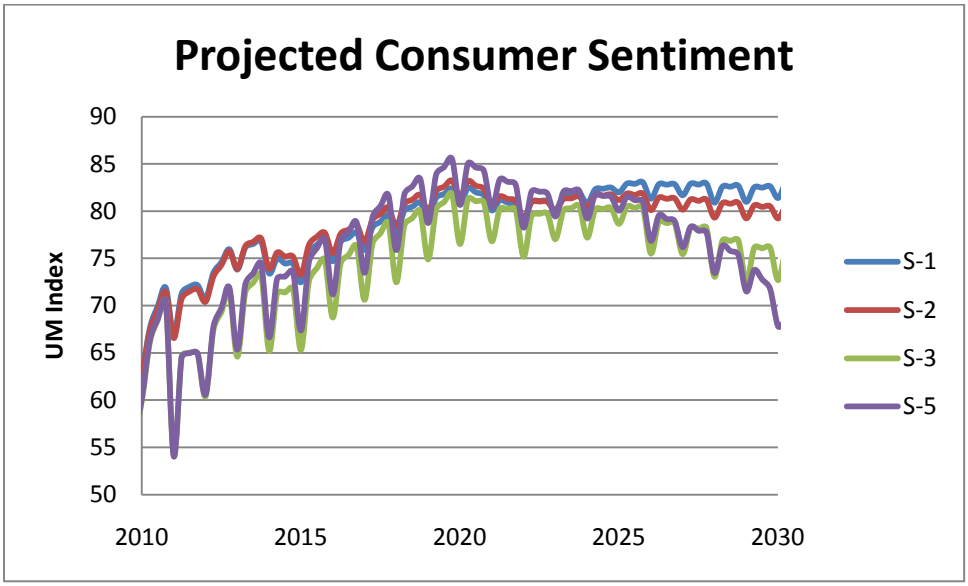

Figure 16. University of Michigan Consumer Sentiment Index by Scenario.

Conclusions and Recommendations

With respect to the sensitivity of real GDP to energy prices, three categories of elasticity were quantified on the basis of long term trends observed in the projections. Collectively, they imply an elasticity of real GDP with respect to energy prices approaching -0.1:

(1) Direct/Modeled - a direct elasticity with respect to energy prices in the GI macro model on the order of -0.005.

(2) Indirect/Modeled - an indirect elasticity on the order of -0.033, marginally consistent with energy expenditures running about 10 % as a direct component of GDP (IER 2010). This elasticity is comprised of a direct elasticity of real GDP with respect to consumptions on the order of 0.33 in the GI macro model, and an elasticity of consumptions with respect to prices, assumed to be on the order of -0.10 in the NEMS supply and demand models.

(3) Indirect/Not Modeled - an indirect elasticity not currently modeled in NEMS, on the order of -0.06. This elasticity is comprised of a direct elasticity of real GDP with respect to total factor productivity on the order of 1.2 in the GI macro model, and an elasticity of total factor productivity with respect to prices on the order of -0.05, assumed on the basis of preliminary data.

The implementation of the GI macro model in NEMS disables the GI macro model's internal reaction functions governing how energy consumptions respond to energy prices. These reaction functions are overwritten by those in the NEMS demand models. In the sensitivity studies described herein, these reaction functions were also effectively disabled so that energy price and consumption trends could be varied independently. In doing so, it was possible to map out a model feasibility domain with regard to solvability of the GI macro model. With respect to reductions in energy consumptions, the GI macro model was tolerant (no "failures-to-solve"), but with respect to energy price increases, the model was only conditionally tolerant, ultimately requiring a pairing with consumption reductions for energy price increases beyond a certain point. In all cases where the model could be solved, the direct sensitivity of real GDP to energy prices was quite small. The "failure-to-solve" for energy price increases beyond a certain point without consumption reductions presents a potential modeling bias for consumption reductions when NEMS is applied to high energy price scenarios outside the scope of the historical (business as usual) data upon which the model is based. The limits to relaxing assumptions related to consumptions in EIA's climate change scenarios is thus of immediate interest. Since consumptions are exogenous in the NEMS implementation of the GI macro model, the realism of assumptions concerning efficiency- and conservation-driven reductions cannot be inferred because the macro model solved, or solved with minor impacts to metrics like real GDP. Direct assessment of the underlying assumptions in the demand models of NEMS would be necessary.

Total factor productivity is one exogenous driver variable in the GI macro model that has a potentially significant dependency on energy prices. The NEMS implementation of the GI macro model assumes that such a dependency does not exist. TFP exerts a profound impact on real GDP and many other metrics. The dependency of TFP and other exogenous drivers on energy prices provides a systematic framework for assessing the use of NEMS as a tool to model the viability of high energy price scenarios such as those related to climate change and energy security. Other macroeconomic models should be reviewed with respect to TFP modeling. One model in the public domain is the Fair model, which may be incorporated into the hybrid econometric input-output model being developed by the Regional Research Institute at the West Virginia University (Jackson, Rey, and Kahsai 2010). Evidence for a dependency of TFP on energy prices should also be reviewed, and if warranted, a model crafted and tested in NEMS. Generally such a model would overlay deviations onto a long term trend of TFP based upon energy price movements.

The GI macro model offers a wealth of metrics beyond real GDP (1,727 endogenous outputs) that could be useful for inferring the feasibility of scenarios from an economic policy standpoint. Some relate to the abruptness of transitions in sector activities, such as employment, while others such as CPI relate to the overall well-being of consumers.

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Appendix

Excerpts of EVIEWS Drivers.PRG for Sensitivity Studies

Declaring Scenario 1…

```
 m_us2008a.scenario(n) "Scenario 1"
'Override exogenous energy price and quantities in the GI model with assumptions
' from NEMS.
 m_us2008a.exclude    CNEFACR      CNEGAOR     CSVHOPER      CSVHOPGR  _
DENDUCOAL         DENDUELC     DENDUNG     DENDUPET     DALLFUELS  _
ENGDOMPETANG       JEXCHOITP    JEXCHMTP    JGDPOITPR    JGDPMTPR   _
IPSG211A3         IPSN2121     PNGHH       PNGWL        POILIMP    _
POILWTI           JPCNEFAC     JPCNEGAO    JPCSVHOPE    JPCSVHOPG  _
QGASASF           WPI051       WPI053      WPI054       WPI055     _
WPI0561           WPI057       WPI0574     JQINDMPROXY
 m_us2008a.exclude  JGDPOITPR    JGDPMTPR   POILIMP
 show m_us2008a
 m_us2008a.solve
.
.
.
```

Applying Macro Side Case Multipliers to Scenario 1 Solution…

```
if (macmode <> 2) then
  for %highlo _
CDFHEMAVC  CDFHEMAVCCP  CDFHEMAVCR   CDFHER      CDFHEXCASR  CDMVLVR    CDMVR     CDMVTTPR    CDOOAOR    CDOOR    _
CDOR       CDR          CNCSR       CNEFACR     CNEGAOR     CNFHOMER   CNFOUTR   CNODRUGR    CNOR       CNOTOBR  _
CNR        CONS         CONSR       COSTEFXNREXE  CPI       CSVHOPDOMR  CSVHOPER   CSVHOPGR    CSVHOPMSCR  CSVHOPTR _
CSVHOPWASR  CSVHSR      CSVM        CSVMR       CSVOOR      CSVOPBR    CSVR      CSVRECR     CSVTSPICR  CSVTSPLR _
CSVTSR     CSVTSUOXLSER  CSVTSURPLLSR  DEVCDD    EEA         EG91       EGSL      GDP         GDPFER     GDPR     _
GFMLGIR    GFMLR        GFOCWSSR    GFOGIR      GFOR        GFR        GNPR      GR          GSLCWSSR   GSLGIR   _
GSLR       HPMD         HPMF        HPMN        HRNFPRI     HUSMFG     HUSPS1    HUSPS2A     I          IFMVNATLR _
IFNREEINDR  IFNREEIPCC   IFNREEIPCCR  IFNREEIPCSR  IFNREEIPCTR  IFNREEIPOR  IFNREEIPR  IFNREEMISCR  IFNREEOR   IFNREER  _
IFNREETACR  IFNREETLVR   IFNREETOR   IFNRER       IFNRESBAOR  IFNRESCML  IFNRESMIR  IFNRESPUR   IFNRESR    IFREER   _
IFRER      IFRESR       IFSR        IFXR        IIR         INVR
  if (%highlo = "DEVCDD"    or %highlo = "DEVHDD"  or %highlo = "GFMLCOR" or _
     %highlo = "GFMLCWSSR" or %highlo = "GFMLGIR" or %highlo = "GFOCOR"  or _
     %highlo = "GFOCWSSR"  or %highlo = "GFOGIR"  or %highlo = "NP"     or _
     %highlo = "NP16A"     or %highlo = "NP65A")  then
    genr {%highlo}_orig = {%highlo}
    {%highlo} = {%highlo}*eviewsdb::kf_{%highlo}
  else
    genr {%highlo}_1_orig = {%highlo}_1
    {%highlo}_1 = {%highlo}_1*eviewsdb::kf_{%highlo}
  endif
  next
  for %highlo _
INVWR      IR         JCSMICH    JECIWSP    JEXCHMTP   JEXCHOITP  JPC        JPCNEGAO   JPCSVHOPDOM  JPCSVHOPE  _
JPCSVHOPG  JPCSVHOPMSC  JPCSVHOPT   JPCSVHOPWAS  JPCSVTSPL  JPCSVTSUOXLSE  JPCSVTSURPLLS  JPGDP     JPIFNRESC  JPM      _
JQPCMHM    JQPCMHMD   JQPCMHMN   JQPCMHNF   JWSSNF     KHUMFG     KHUPS1     KHUPS2A    MGAUTOR    MGCR     _
MGFFBR     MGINAPETR  MGINR      MGKCAEPR   MGKCPPR    MGKOR      MGKR       MGOR       MGPETR     MHRSNFP  _
MR         MSVTOTR    NLFC       NP         NP16A      NP65A      POILRAP    RMCORPAAA  RMCORPBAA  RMCORPPUAA _
RMFF       RMGBLUSREAL  RMMTG30CON  RMPRIME   RMTB3M     RMTCM10Y   RTXPMARG   RUC        SP500      SUVA     _
SUVLV      SUVTHAM    SUVTL      UTLB00004  WPI        WPI01      WPI02      WPI06      WPI08      WPI09    _
WPI10      WPI11      WPI12      WPI14      WPIIND_05  WPISOP3000  WPISOP3200  XGAUTOR    XGCR       XGFFBR   _
XGINR      XGKCAEPR   XGKCPPR    XGKOR      XGKR       XGOR       XGR        XR         XSVTOTR    YP       _
YPCOMPWSD  YPCOMPWSDG  YPCOMPWSDP  YPD       YPDR       YPR        YPTRFGF    YPTRFGSL
  if (%highlo = "DEVCDD"    or %highlo = "DEVHDD"  or %highlo = "GFMLCOR" or _
     %highlo = "GFMLCWSSR" or %highlo = "GFMLGIR" or %highlo = "GFOCOR"  or _
     %highlo = "GFOCWSSR"  or %highlo = "GFOGIR"  or %highlo = "NP"     or _
     %highlo = "NP16A"     or %highlo = "NP65A")  then
    genr {%highlo}_orig = {%highlo}
    {%highlo} = {%highlo}*eviewsdb::kf_{%highlo}
```

```
  else
    genr {%highlo}_1_orig = {%highlo}_1
    {%highlo}_1 = {%highlo}_1*eviewsdb::kf_{%highlo}
  endif
  next
endif
.
.
.
```

Declaring Scenarios 2 - 5…

```
m_us2008a.scenario(n, i="Scenario 1") "Scenario 2"
scalar sfact=1.0
scalar sfact1=1.0
'Domestic production of petroleum and natural gas
 genr engdompetang = sfact*@mean(engdompetang,"2008:1 2008:4")*eviewsdb::engdompetang_r_0
'Domestic production of energy excluding petroleum and natural gas
 genr engdomo      = sfact*@mean(engdomo,"2008:1 2008:4")*eviewsdb::engdomo_r_0
'Demand for all fuels
 genr dallfuels    = sfact*@mean(dallfuels,"2008:1 2008:4")*eviewsdb::dallfuels_r_0
'End-use demand for coal (exclude electricity generation)
 genr denducoal    = sfact*@mean(denducoal,"2008:1 2008:4")*eviewsdb::dendusecoal_r_0
'Sales of electricity to ultimate consumers
 genr denduelc     = sfact*@mean(denduelc,"2008:1 2008:4")*eviewsdb::denduseelc_r_0
'End-use demand for natural gas
 genr dendung      = sfact*@mean(dendung,"2008:1 2008:4")*eviewsdb::denduseng_r_0
'End-use demand for petroleum
 genr dendupet     = sfact*@mean(dendupet,"2008:1 2008:4")*eviewsdb::dendusepet_r_0
'Industrial production index - coal mining
 genr ipsn2121     = sfact*@mean(ipsn2121,"2008:1 2008:4")*eviewsdb::ipsn2121_r_0
'Industrial production index - oil and gas extraction
 genr ipsg211a3    = sfact*@mean(ipsg211a3,"2008:1 2008:4")*eviewsdb::ipsg211a3_r_0
'Highway consumption of gasoline and special fuels
 genr qgasasf      = sfact*@mean(qgasasf,"2008:1 2008:4")*eviewsdb::qgasasf_r_0
'Proxy for industrial production index
 genr jqindmproxy  = sfact*jqindmproxy_0
'Real consumer spending on fuel oil and coal
 genr cnefacr      = sfact1*@mean(cnefacr,"2008:1 2008:4")*eviewsdb::cnefacr_r_0
'Real consumer spending on natural gas
 genr csvhopgr     = sfact1*@mean(csvhopgr,"2008:1 2008:4")*eviewsdb::csvhopgr_r_0
'Real consumer spending on electricity
 genr csvhoper     = sfact1*@mean(csvhoper,"2008:1 2008:4")*eviewsdb::csvhoper_r_0
'Consumer spending on gasoline and motor oil
 genr cnegaor      = sfact1*@mean(cnegaor,"2008:1 2008:4")*eviewsdb::cnegaor_r_0

'****demand, quads
scalar scount_eia=0.0
rowvector(36) factors_eia = 0.25
!count_eia = 0
' ******************************************append names of eia (endogenous) variables to the list below to add a sensitivity variable
with corresponding multiplier in "factors_eia.fill"
'factors_eia.fill        1.0            ,1.0       ,1.0       ,1.0        ,1.0       ,1.0       ,1.0       ,1.0       ,1.0        ,1.0        ,1.0
for %sens_eia  engdompetang engdomo dallfuels denducoal denduelc dendung dendupet ipsn2121 ipsg211a3 qgasasf  jqindmproxy
smpl @all
scalar sfact_eia_{%sens_eia}
!count_eia = !count_eia + 1
sfact_eia_{%sens_eia} = factors_eia(!count_eia)
genr {%sens_eia}_delta = d({%sens_eia})
smpl 2010:1 @last
{%sens_eia} = {%sens_eia}(-1) + sfact_eia_{%sens_eia}*{%sens_eia}_delta
next
smpl s_fcst
scount_eia = !count_eia

'****real expenditures, ~ "quads"
```

```
scalar scount_exp=0.0
rowvector(36) factors_exp = 0.25
!count_exp = 0
' ******************************************append names of eia (endogenous) variables to the list below to add a sensitivity variable
with corresponding multiplier in "factors_eia.fill"
'factors_exp.fill        1.0    ,1.0      ,1.0        ,1.0
for %sens_exp  cnefacr  csvhopgr  csvhoper  cnegaor
smpl @all
scalar sfact_exp_{%sens_exp}
!count_exp = !count_exp + 1
sfact_exp_{%sens_exp} = factors_exp(!count_exp)
genr {%sens_exp}_delta = d({%sens_exp})
smpl 2010:1 @last
{%sens_exp} = {%sens_exp}(-1) + sfact_exp_{%sens_exp}*{%sens_exp}_delta
next
smpl s_fcst
scount_exp = !count_exp
m_us2008a.solve

 m_us2008a.scenario(n, i="Scenario 2") "Scenario 3"
'*****nominal prices, $/mmbtu
scalar scount_prc=0.0
rowvector(36) factors_prc = 3.0
!count_prc = 0
' ******************************************append names of eia (endogenous) variables to the list below to add a sensitivity variable
with corresponding multiplier in "factors_eia.fill"
'factors_prc.fill    1.0    ,1.0      ,1.0     ,1.0     ,1.0       ,1.0        ,1.0        ,1.0        ,1.0      ,1.0      ,1.0      ,1.0      ,1.0      ,1.0      ,1.0
for %sens_prc  pnghh  pngwl  poilimp  poilwti  jpcnefac  jpcnegao jpcsvhope  jpcsvhopg   wpi051   wpi053   wpi054   wpi055   wpi0561  wpi057
wpi0574
smpl @all
scalar sfact_prc_{%sens_prc}
!count_prc = !count_prc + 1
sfact_prc_{%sens_prc} = factors_prc(!count_prc)
genr {%sens_prc}_delta = d({%sens_prc})
smpl 2010:1 @last
{%sens_prc} = {%sens_prc}(-1) + sfact_prc_{%sens_prc}*{%sens_prc}_delta
next
smpl s_fcst
scount_prc = !count_prc
m_us2008a.solve

 m_us2008a.scenario(n, i="Scenario 3") "Scenario 4"
'*****gi (not eia) exogenous drivers
scalar scount=0.0
rowvector(36) factors = 1.0
!count = 0
' ******************************************append names of exogenous variables to the list below to add a sensitivity variable with
corresponding multiplier in "factors.fill"
for %sens  np   np16a  np65a   devcdd   devhdd    GFMLCOR   GFMLCWSSR   GFMLGIR   GFOCOR  GFOCWSSR   GFOGIR
smpl @all
scalar sfact_{%sens}
!count = !count + 1
sfact_{%sens}=factors(!count)
genr {%sens}_4 = {%sens}
genr {%sens}_1 = {%sens}
genr {%sens}_delta = d({%sens})
smpl  2010:1 @last
{%sens}_4 = {%sens}_4(-1) + sfact_{%sens}*{%sens}_delta
m_us2008a.override(m) {%sens}
next
smpl  s_fcst
scount = !count
m_us2008a.solve

m_us2008a.scenario(n, i="Scenario 4") "Scenario 5"
'*****gi (not eia) special exogenous drivers
```

```
scalar scount_spc=0.0
rowvector(36) factors_spc = 1.0
!count_spc = 0
' ******************************************append names of exogenous variables to the list below to add a sensitivity variable with
corresponding multiplier in "factors.fill"
'                        0.45
factors_spc.fill       0.50
for %sens_spc     tfptrend
smpl @all
scalar sfact_{%sens_spc}
!count_spc = !count_spc + 1
sfact_{%sens_spc}=factors_spc(!count_spc)
genr {%sens_spc}_5 = {%sens_spc}
genr {%sens_spc}_1 = {%sens_spc}
genr {%sens_spc}_delta = d({%sens_spc})
smpl  2010:1 @last
{%sens_spc}_5 = {%sens_spc}_5(-1) + sfact_{%sens_spc}*{%sens_spc}_delta
m_us2008a.override(m) {%sens_spc}
next
smpl @all
for %sens  np   np16a  np65a   devcdd   devhdd   GFMLCOR   GFMLCWSSR   GFMLGIR   GFOCOR  GFOCWSSR   GFOGIR
genr {%sens}_5 = {%sens}_4
m_us2008a.override(m) {%sens}
next
smpl  s_fcst
scount_spc = !count_spc
m_us2008a.solve
.
.
.
```

Grouping Selected Variables into Object Containers for Ready Reference…

```
group rag_favorites gdpr_1 gdpr_2 gdpr_3 gdpr_4 gdpr_5 cpi_1 cpi_2  cpi_3 cpi_4 cpi_5  jcsmich_1 jcsmich_2  jcsmich_3 jcsmich_4 jcsmich_5
ruc_1 ruc_2 ruc_3 ruc_4 ruc_5 ifresr_1 ifresr_2 ifresr_3 ifresr_4 ifresr_5
group rag_gi_exogenous np_? np16a_? np65a_? gfmlcor_? gfmlcwssr_? gfmlgir_? gfocor_? gfocwssr_? gfogir_?
group rag_special_exogenous tfptrend_?
group rag_nems_quants engdompetang_? dallfuels_? denducoal_? _
      denduelc_? dendung_? dendupet_? ipsn2121_? ipsg211a3_? qgasasf_? jqindmproxy_?
group rag_nems_quants_realexpenditures cnefacr_? csvhopgr_?  csvhoper_?  cnegaor_?
group rag_nems_prices pnghh_?  pngwl_?  poilimp_? poilwti_?  jpcnefac_?  jpcnegao_? jpcsvhope_?  jpcsvhopg_? _
       wpi051_?   wpi053_?   wpi054_?  wpi055_?   wpi0561_?  wpi057_?  wpi0574_?
.
.
.
```

Saving Entire Workfile with All Objects for Post Processing…

```
'INSERT_6 writes to the output directory the resulting mcevwork workfile.
save D:\eia\aeo2009_stimulus\mac_files\ev_test\mcevwork_out.wf1
```