

**Cooking with *Interdyme*: International Cuisine**

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# Cooking with *Interdyme*: International Cuisine

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*Operational proof ... it's all theory until you see for yourself whether or not something works.*

Julia Child<sup>2</sup>

The international group of researchers, consultants and model builders that make up the Inforum community are unified by similar interests and philosophy. We share the need to understand the dynamics driving the differential rates of economic growth, competitiveness and trade between countries. While we recognize that the macroeconomic modeling approach is useful, many of the key questions confronting the different world economies, such as productivity, growth, investment and trade, can be best understood through interindustry modeling. This approach not only illustrates linkages from the demand side, but also the interrelation of sectoral prices.

In addition, the Inforum approach is dynamic, in that what has happened in the past conditions the future, both through lags in equations as well as through the importance of capital stock and expectations. Inforum models are structural, and the structure is imposed by accounting relationships as well as close attention to achieving reasonable responses to exogenous changes. Like a long-distance runner, an Inforum model should be able to run for long periods without falling down or wearing out. Equations such as those for investment or consumption should be sensible in the long- as well as short-run.

Finally, just as the links between industries are important, links between countries are equally important. The modeling of a set of economies linked via bilateral international trade flows is a central feature of the Inforum modeling strategy.

For several years, the Inforum group has focused on the development of common software that enables the combination of the best features of the macroeconomic and interindustry modeling. This software is called *Interdyme*, which stands for 'Interindustry Dynamic Macroeconomic' modeling.<sup>3</sup>

Building economic models has been characterized as a 'craft'. It is also a lot like learning a good recipe and developing it further on your own. In this paper I will lead an excursion into the world of cooking with *Interdyme*, finding parallels and analogies with being a powerful chef. The paper also aims to contribute to the understanding of building and use of interindustry models.

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<sup>2</sup> All subsequent quotes in this paper are taken from Julia Child.

<sup>3</sup> Almon (2016) is dedicated to the topic of building interindustry macro models, and Chapter 16 illustrates most features of *Interdyme* using a small model called *Tiny*. Meade (2016) provides an overview, and Almon (2005) a short presentation.

## 1 What Do We Want to Cook?

*You don't spring into good cooking naked. You have to have some training. You have to learn how to eat.*

Good model building presupposes understanding what you want from a model. What problems should it solve? What questions should it answer? What good advice can be learned from it? To some extent, the answers to these questions are a matter of taste, as in the enjoyment of food. However, there is a case to be made that 'learning how to eat' the results of a model suggests developing a taste for certain good qualities:

- *Industry detail* – Modeling behavior at the industry level is crucial for many questions, and using interindustry relationships to determine the interaction of production and prices of different industries sheds light on many economic questions.
- *Dynamics* – A dynamic model solves over time, and relates future behavior to economic events of an earlier period. The model should be stable and behave sensibly over long periods.
- *Macroeconomic* – It is important to relate the main aggregates of economic accounts to the detail underlying them, and incorporate macroeconomic relationships where appropriate.
- *Internationally linked* – Economies are intertwined, through bilateral trade, and linking mechanisms include the influences stemming from changes in exchange rates and relative prices. Financial flows between countries are also very important.

For many years, the Inforum group has been creating and developing models with these properties for several countries. Since the 1990s, a common software framework called *Interdyme* has been under continuous development, which greatly facilitates the development of models that:

1. Use vectors, matrices and macroeconomic variables;
2. Solve over time, either in historical simulation or forecasting;
3. Can use "fixes", which are very flexible applications of assumptions on exogenous or endogenous variables. Fixes can be applied to any type of variable in the model.

*Interdyme* consists of the *G7* program, a standard set of C++ classes and other code for building a variety of types of models, as well as the helper programs *IdBuild*, *Fixer*, *Macfixer* and *Compare*. We will explore each component of the software in more detail below. However, the role of each component in developing a model is summarized in the following list:

- *G7* – This program is used for organizing data, reading and writing to Excel, estimating regression equations, setting up equation results for *Interdyme* and *IdBuild*, and viewing the model results in graphs or grids.
- *Interdyme C++* - Includes a template for a model, called "Tiny", which can be adopted for your own model. The *Interdyme* cupboard includes Matrices, Vectors, Tseries (macro variables), Equations and Fixes, ready for the eager chef.
- *IdBuild* – A smart program, which can cook up C++ code for the model.
- *Fixer and Macfixer* – Powerful programs for adding assumptions which distinguish one scenario from another.
- *Compare* – Used to make an attractive presentation of tables in text or Excel.

The development of a new model starts with a plan, or recipe, determined jointly with the choice of available data or ingredients. The initial recipe may be rather simple if the cook is new or in a

hurry. But the beauty of cooking (and model building) is that we can try again, revisiting and improving until our guests want to cry out “*c’est délicieux!*”

## 2 Choosing Ingredients

*You don't have to cook fancy or complicated masterpieces - just good food from fresh ingredients.*

The choice of ingredients for a good dish results from considerations of taste, nutrition and the appearance of the food on the plate, as well as the preparation time available for the cook. The choice of ingredients for a good model is quite similar. In the case of a model, some of the choices are:

- *Level of sectoral detail* – Similar to choosing the amount of salt: too little and the model is not interesting, too much and you have a risk of high blood pressure!
- *What to model?* – Meat, vegetables or both? The simplest model considers only the expenditures side of GDP, in constant prices. The addition of a price-income side greatly extends the range of questions that can be answered. Some minimal macroeconomic accounting is necessary, or should we include most of the national accounts?
- *Extensions to the basic model* – These are like side dishes, while not strictly necessary, they can enhance the flavor of the model. Examples include: energy use and emissions, multifactor productivity (MFP), demographics, occupations and skill levels, detailed tax accounting, health care accounts, R&D accounts and regional indicators or regional detail.
- *Linkages* – Some variables may be determined in another model. Examples include the Bilateral Trade Model (BTM), which can determine merchandise exports and import prices, based on demands and prices in the other linked models. Another example is the Demographic Projection Model (DPM), which forecasts population by sex and age<sup>4</sup>. Linkages may be one-way or two-way. In the latter case, some iteration will be necessary.

The choice of the level of sectoral detail is often constrained by the data available. For example, if you are building a model using *PortableDyme*<sup>5</sup>, based on World Input-Output Database (WIOD) data, you may decide to stick with the 35 industry sectors offered. If you have obtained Global Trade Analysis Project (GTAP) data for your country, you may choose the 57 sectors provided in their SAM<sup>6</sup>. Eurostat IO tables are available at a level of about 65 sectors. Some statistical agencies provide input-output data accessible from their web site, sometimes at a very detailed level. However, the detailed data are usually available only for one year. If you need to construct time series of industry and commodity data, you may need to aggregate the data to a higher level<sup>7</sup>.

Models with only 8 to 15 sectors such as the *Tiny* model are useful for explaining modeling techniques and the features of *Interdyme*<sup>8</sup>. However, such small databases can also be useful for

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<sup>4</sup> Developed initially by Dowd (1999).

<sup>5</sup> Großman, Hohmann & Wiebe (2013) provides an excellent introduction to *PortableDyme*. Also see Großman & Hohmann (2015).

<sup>6</sup> GTAP SAMs can be converted back to a standard input-output framework using the tools available in *G7*, including the “xl”, “vmake”, “getsum” and “vc” commands. This procedure was followed in Meade (2015).

<sup>7</sup> *G7* provides the “resector” command, which is useful for aggregating or splitting from one sectoring scheme to another. See the Inforum Help (2015), p. 177.

<sup>8</sup> See Almon (2016), *The Craft of Economic Modeling, Part III*, Chapter 16.

developing a prototype model of a country. Such prototypes can be used to explore the desirable macroeconomic simulation properties, which can be valuable learning for developing the more detailed model. In the other direction, a model may be quite detailed. The US group has developed a model named *Iliad*, which currently has 352 commodities. This is not a standalone model, but is linked to the 121 commodity *LIFT* model<sup>9</sup>. The models comprising the Inforum international system range between 43 and 121 commodities.

Related to the choice of sectoral detail is the decision whether to use a commodity-by-commodity, industry-by-industry table, or to model both the use and make (or supply) matrices. We have found that the choice of the commodity-by-commodity matrix, derived using commodity technology tastes better, and leads to less indigestion. The “PtP” technique is a logical, iterative technique that can be used to derive such a table<sup>10</sup>. This technique has been used to derive every version of the US model tables since the mid-1960s, and is used for many of the country models developed by Inforum partners.

The question of “What to model?” can be approached in stages. The early development of a model may include only an exogenous projection of final demands in constant prices, combined with a Seidel input-output solution. Next, equations can be developed for final demands such as personal consumption, investment, imports, etc. To the extent that these equations are based on prices, the prices can be left exogenous at this stage. The next logical step is the development of labor productivity or labor demand equations, which can forecast hours worked and employment.

When making a Pad Thai, there is a special sauce you can buy already mixed, that makes it easier to get it on the plate for a starving family. However, if the sauce is lacking, it can be made by hand, with fish sauce (*nam pla*), brown sugar, tamarind, vinegar and (yes!) ketchup. In building an economic model, you are often faced with a similar situation.

For example, with regard to personal consumption and investment, and sometimes construction, there is the question of using (or developing) a bridge matrix. Like many questions, this is often constrained by data availability. However, if personal consumption data by category and by commodity are available, but no bridge matrix can be found, an initial matrix can be filled in by hand, or borrowed from another country, and then balanced to the control totals. The balancing will most likely not be perfect, but the matrix is still extremely useful. Investment is more logically modeled by the industry performing the investment (which can be related to output and other variables), not by the investment commodity purchased. A bridge or capital flow table that links investment by buyer to investment by commodity is a good feature of any model, but may need to be made from scratch, using available ingredients.

With a fully developed expenditure (or real) side, the price-income side can be developed. As a simple placeholder, value added categories can be forecast using ratios to real output. One by one, these ratios can be replaced with equations for wage rates and labor compensation, profits or net operating surplus and depreciation (consumption of fixed capital). The latter equations can make use of capital stocks developed while building the investment equations.

Macroeconomic accounting is handled using the *IdBuild* program, which can be used to write out C++ code in functions that are called by the model builder in the main model sequence. Such functions may include:

1. Aggregations of sectoral variables (vectors and matrices) into scalar “macro” variables.

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<sup>9</sup> McCarthy (1991) and Meade (2001, 2013b) provide descriptions of LIFT, which includes many standard features of Inforum models.

<sup>10</sup> Almon (2000) and Almon (2016), Chapter 19.

2. Identities that define relationships in the national accounts.
3. “Behavioral ratios” that can be used as exogenous levers relating one variable to another, such as a tax rate (ratio of personal taxes to personal income).
4. Regression equations used to explain macro variables, such as interest rates, transfer payments, savings rate, or the aggregate wage rate.
5. In addition one can define additional variables not explicitly included above, which can be used as iteration counters, flags, indicator variables, etc.

Extensions to the basic or standard model often grow organically from request by clients, colleagues or from research interests. These extensions usually involve a combination of additional vectors, matrices and macrovariables, along with additional modules either written by *IdBuild* or by hand. The extension may involve the modeling of a satellite account produced by a national statistical agency, such as a transportation, health care, or R&D satellite. Variables in these satellite accounts can often be naturally related to commodity, industry or macroeconomic data already in the model. In other cases, such as in energy modeling, there is a need to reconcile data available from the energy statistics which are in physical or other units, to prices and constant price indicators available from the input-output framework. These relationships are usually robust, but they introduce a host of issues not always considered in the basic IO framework.<sup>11</sup>

Linkages between models can be handled in several alternative ways.

1. If the models being linked are all *Interdyme* models, then the model program can be set up to use more than one simulation bank (called a “Vam file”). In this way, data forecast by one model can be directly read and used by another model.
2. Exogenous assumptions, called “fixes” can be written out by *G7*, based on the forecast of one model, and applied to the other model. Such fixes may be expressed as actual values, indexes or growth rates.
3. Batch input files to *G7* called “add files” can be developed that process data from one model, and directly write data into the simulation file of another model before it is run. Such data are treated as exogenous to the target model.

In either case, the linking sequence can be automated, so that joint model solutions can be iterated until convergence is reached. This is the method used by the *BTM*.<sup>12</sup>

### 3 The Cookbook

*Nothing is too much trouble if it turns out the way it should.*

For a good chef, the cookbook is a useful guide, but she may improvise for the sake of her guests, the availability of necessary ingredients, or experience with other, similar menus. Likewise, we may present a recipe for a standard model, but it needn’t be followed slavishly. This section presents what might be viewed as the ‘standard’ model developed by Inforum, and the model builder can of course change and elaborate from this pattern.

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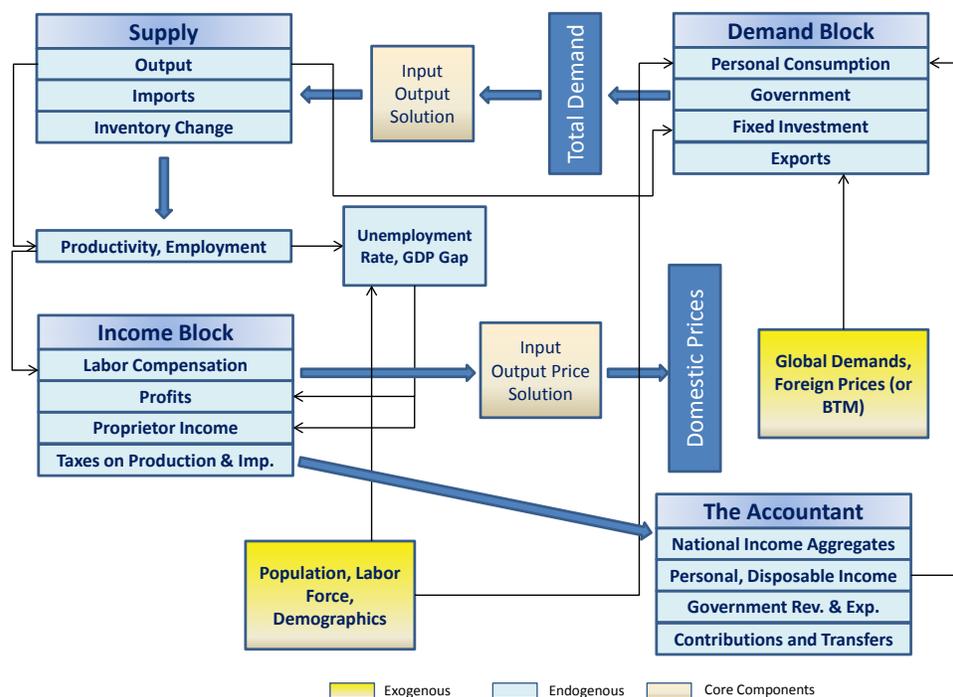
<sup>11</sup> For example, electricity may be priced differently according to whether it is sold to a residential, commercial or industrial user.

<sup>12</sup> See Nyhus (1991), Ma (1996), and Bardazzi and Ghezzi (2014, 2015)

Inforum models are generally characterized as IO Econometric models<sup>13</sup>. The core of the standard model consists of the multisectoral quantity and price relationships. Detailed variables are aggregated to obtain the aggregate macroeconomic product and income versions of GDP. Figure 1 below shows a simple schematic diagram of a typical model.

Macroeconomic properties of the models are very important, but it is useful and realistic to model behavior at the industry level. For example, investments are made in individual firms in response to market conditions in the industries in which those firms produce and compete. Aggregate investment is simply the sum of these industry investment purchases. Decisions to hire and fire workers are made jointly using investment decisions and an outlook for product demand in each industry. The net result of these hiring and firing decisions across all industries determines total employment and the unemployment rate. In the real world economy, pricing decisions are made at the detailed product level. Modeling price changes at the commodity level certainly captures the price structure of the economy better than an aggregate price equation. Prices and incomes are forced into consistency through the fundamental input-output identity and the aggregate price level is determined as current price GDP divided by constant price GDP.

**Figure 1. Summary Diagram of Representative Model**



Econometric equations are estimated for imports, and inventory change by commodity; personal consumption by category; and equipment and structures investment by industry. Consumption and investment bridge matrices are used to translate the consumption by category and investment by industry to the commodity level. Exports, government, consumption, and investment are calculated in the Demand Block before doing the IO solution. The Gauss-Seidel solution used to

<sup>13</sup> Almon (1991) is a good introduction to the general idea behind the IM model. See West (1995) for a comparison of IO Econometric and CGE models. Grassini (2001) provides a more lengthy description of the typical Inforum model.

solve the quantity IO system jointly determines domestic output, imports, and inventory change. Input-output coefficients are projected to change over time using a logistic curve.

Employment and hours worked are typically estimated as productivity functions, linking hours to industry output; and average hours worked equations, linking employment to hours. In the Income Block, wage equations by industry are used to obtain labor compensation. Other components of value added, such as profits, depreciation, and proprietors' income, may also be estimated depending on the data availability in any given country. Some countries have only compensation, gross operating surplus, and indirect taxes comprising total value added.

Value added is used in the IO price solution to obtain prices by commodity or by industry, depending on the type of IO table available.<sup>14</sup> Some prices may be set exogenously, in which case several value added components need to be revised to maintain consistency. Alternatively, the modeling approach can focus on estimating price regressions directly, then adjusting value added to be consistent with price<sup>15</sup>. There is no need anywhere in the model to deflate value added, and there is no logical need to have a constant price IO table that adds up down the column.<sup>16</sup> The income side of the model is calculated in nominal terms only, though several variables may be deflated by the GDP deflator or average consumption deflator to obtain the "real" versions of those variables.

The macro accounts include most of the tables used in a typical SNA presentation, or in the case of the U.S., the National Income and Product Accounts (NIPA). A typical model will also include population by demographic category; labor force and participation rates; financial variables including monetary aggregates and interest rates; and full detail on transfers, contributions, and taxes in the government accounts. Government expenditures by detailed category are usually specified exogenously in real terms and converted to nominal values using a price.

Prices calculated in the price-income side of the model are used as variables in the personal consumption, equipment and structures investment, and export/import equations. The result of the expenditure side calculation implies a certain level of GDP and of total employment (and unemployment rate) as well as sectoral outputs. All these variables may play a role in the wages and profits (or surplus) equations, so that tightness or slack in the economy affects the growth of value added and prices.

The typical model solves annually and a typical forecast interval is from 10 to 50 years, although some of the models have been developed for very long-term applications. The models are dynamic, in that many of the equations include lagged effects or relations using first differences. Although the models are "bottom-up" in that detailed data is used to form the macro-aggregates, they may be controlled from the top down if necessary, to force consistency with another macro model forecast.<sup>17</sup>

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<sup>14</sup> The U.S. *LIFT* model and several other models use a "purified" commodity-by-commodity table using commodity technology, using the "PtP" technique outlined in Almon (2000). Some models use industry-by-industry tables.

<sup>15</sup> This is the approach followed by the German Inforum team, GWS, in their *Inforge* model. See Lutz, et. al. (2003).

<sup>16</sup> See Meade (2007) and Almon (2009) for suggestions about possible problems that arise from using double-deflated value added.

<sup>17</sup> Such an exercise often reveals potential inconsistencies in the macro model, which is not required to maintain the detailed accounting consistency of an interindustry macro model.

## 4 Herbs, Spices and Special Sauces

*In France, cooking is a serious art form and a national sport.*

National cuisines can often be recognized by their unique flavors. The taste of fresh basil, virgin olive oil and fresh pasta with a local wine; feta cheese with grilled lamb, eggplant and fava beans; oyster mushrooms stir-fried with pak choi and pork; boiled wheat berries and lentils with cardamon, chilis, asafetida and chicken; we are lucky to live in an age where we can easily experience food from all over the world! As the food is different, so are the people. Political aspects, natural resources and geography all combine to make the national economies special as well. When developing a large set of models, there is a temptation to make them all from one template, or “cookie-cutter”. This certainly eases the task of developing a model for a new country, and in linking the models through bilateral trade flows.

However, there is also a strong case for allowing the models to be different; whether it be in sectoral classification, model structure, or behavioral characteristics. Some countries have large state-owned enterprises, so the government is an important player in the economy. Fiscal systems differ widely between countries, although EU member countries have adopted certain common standards. For example, the value added tax is widely used in Europe, Canada and Japan, but has not been tested in the U.S. Certain countries have instituted regimes to price carbon emissions, and others haven't. Social insurance schemes vary widely between countries. Wage and employment rigidity are known to differ widely as well, with obvious implications for unemployment. Age structures and the provision of health care also differ widely across countries. Although the standard input-output and System of National Accounts (SNA) are statistical standards used to portray every economy, the data in the IO tables and national accounts in each country differ partly due to the reasons mentioned above.

If one were to do a survey of the family of Inforum models, he would find that questions such as the modeling of personal consumption, employment, prices and investment have been approached in different ways. The models have also evolved with different classification schemes. Prices, imports and exports data are converted to a common scheme when linking through BTM, and then country-specific assumptions are converted back to the native classification from BTM. Although more complicated than using the same classification, such as WIOD or GTAP, this approach has proven to be workable and yielded sensible results.

On a cautionary note, the number of models in the current BTM and in the next version (3) under development is rather small compared to the number of countries in WIOD, GTAP and some of the multi-regional databases. If the number of countries were to be increased significantly, a hybrid approach may be called for, where models with national partners continued to build unique models, but where additional country models were built according to a standard template.

## 5 Kitchen Techniques

*Once you have mastered a technique, you barely have to look at a recipe again.*

As a child, I watched with amazement as my mother separated egg yolks from whites, and whipped up the egg whites to cook a soufflé. Years later, when I tried this, the egg yolk ended up on the floor, so I bought a special egg-separator to catch the egg yolk and separate the white. When my mother visited one day, she asked me why I was using that tool, and showed me her method again, which consisted in breaking the egg in half, and tossing the yolk back and forth from one half to the other, letting the whites drop into a bowl. Now I know the technique!

Perusing the equations in a well-constructed model, the novice wonders how the modeler chose the variables and the equation forms. They may seem to have sprung happily and fully formed,

like Athena from the head of Zeus. More likely, the choices made were the result of many trials and errors. As beginners, we easily fall into traps or develop bad habits. However, by keeping certain principles in mind, good practices can begin to take shape.

Some good advice given in *The Craft*<sup>18</sup> include:

1. *Account for important influences* – An equation for sectoral investment should certainly include some measure of capacity requirements, such as a distributed lag of past sectoral outputs. An equation for imports by commodity should include a measure of domestic demand.
2. *Economize on variables* – A wise choice of a short list of variables usually results in an equation which is more sensible and robust. Too many variables run the risk of problems with multicollinearity.
3. *Use appropriate dimensions* – Relate per capita variables to other per capita variables, where possible. Relate growth rates to growth rates. Use relative prices when estimating demand equations. Real per-capita consumption of food should depend on real per capita income and the relative price of food.
4. *Mix trend and stationary variables with caution* – A stationary variable is one which should not be expected to have a trend over long periods. Examples are the personal income tax rate, the unemployment rate or personal savings rate. Trend variables are usually trended due to economic growth, population growth or inflation. Mixing the variables may cause problems of interpretation and in model behavior.
5. *Avoid “umbrella” variables* – Ask which direction most of the causality should run. Put causal variables on the right hand side. For example, output and employment for a given industry are highly correlated. But the main direction of causality is from output to employment.
6. *Allow for lags as necessary* – Many variables act with a lag. Lag weights should be gently prodded to lie along a sensible curve, using the G7 “sma” command.
7. *Have plausible parameter values* – Ask of every parameter what it means in an intuitive way, and think about the responses it will contribute to the model.
8. *Fit adequately* – While not the first in the list, fit is still important, particularly at the end of the regression interval, when the model takes off from history.
9. *Aim for coefficient robustness and stability* – Test the equation out of sample. Change the regression limits to see how much the coefficients and fit change.

As you estimate equations for your model, you should evaluate them with these principles in mind. For overall guidance, we must again ask ourselves the question: “What do we want to cook?”, “What kind of model do we want to build?” Perhaps your answer is: “A model of a real world economy, that works like that economy, and shows similar characteristics.” Perhaps it is: “A model which is elegant and beautiful, and attractive to theoretical economists.” Or: “A model where all equations fit very well.” All of these answers are heard, but they are often in conflict with each other. A model where each equation fits very well may still have nonsensical forecasts and strange simulation properties when the equations are combined. An elegant and theoretically beautiful model may fail to fit the data, except perhaps in a calibration year. A model that tracks the performance and properties of the actual economy may entail sacrificing equation fit and theoretical elegance in certain cases.

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<sup>18</sup> See Almon (2014), Chapter 8, pp.103-105.

While not forgetting the value of theoretical elegance and good fit, let us consider for a moment some criteria for deciding if a model shows similar characteristics to the actual economy. While you may not agree with all of them, let them be food for thought:

- Real GDP growth should roughly track potential GDP growth. Potential GDP growth is determined by labor force growth, average hours worked and growth in labor productivity.
- Unemployment is possible, yet there should be tendencies to return to a natural or non-inflationary rate of unemployment. In the US this is about 5 percent, but it may be higher or lower in other countries. Negative unemployment makes no sense.
- The rate of inflation should be responsive to money supply growth and to tightness in the economy.
- The ratio of real personal consumption to real disposable personal income should stay within a certain range. In other words, there is a 'normal' rate of saving, which may be different in different countries.
- The combined savings of all sectors (household, government, business, rest of world) should be identically zero, in current prices. This is guaranteed by a well-formed set of national accounts identities.
- The growth of the average nominal wage rate should respond to money supply growth, growth in labor productivity, and tightness in the labor market.
- Labor productivity growth should be pro-cyclical, increasing faster during periods of strong economic growth. Capital investment should increase labor productivity.
- Investment should respond to new capacity requirements and replacement requirements. There may be an effect of the cost of capital on investment.
- Higher 'expected' inflation should lead to higher nominal interest rates.
- Fiscal stimulus should matter more in the short-run than in the long-run.
- Imports by commodity should respond to domestic demand (intermediate and final) for that commodity, but should not generate negative output, which is nonsensical.

Perhaps this list is too long, but perhaps you are ready to suggest others. Certain of these properties, such as pro-cyclical labor productivity, can be enforced through careful estimation of a single set of equations. Other properties, such as the effects of money on inflation, or the tendency to return to normal rates of unemployment, may be more difficult to achieve, and require the combined effects of several parts of the model.

The good cook will periodically taste the dish as it develops, even if not fully cooked. The model builder must also 'taste' what is developing in her model. As a model is continuously extended and improved, tests can be devised to see how closely the forecasts and simulation behavior of the model agree with what we think we observe in the actual economy. Perhaps the most common type of experiment is to change one variable and examine the responses of other related variables. It's useful to calculate short- and long-run multipliers that summarize this response, and discuss if their sign and magnitude are reasonable. Even if you don't agree with the properties of your model, it is advisable to be aware of them!

## **6 Appearance is Everything**

*It's so beautifully arranged on the plate - you know someone's fingers have been all over it.*

Part of the pleasure of eating at a good restaurant, or enjoying a meal with friends in your home is the beautiful tablecloth, silverware, dishes and the tasteful presentation of the food itself. The enjoyment of a model likewise requires good presentation. The kitchen tools *G7* and *Compare* can be used skillfully to prepare attractive tables, graphs, and several types of listings of information. The art of tasteful and informative presentation is a valuable skill, and particularly

useful for interindustry macro models, because of the great quantity of detail available. It is important to communicate the ‘big picture’ using several graphs and display tables, and then provide opportunities to drill down to the industry and category detail.

Japanese restaurants traditionally display plastic models of food that is served in the restaurant within. This helps the foreign tourist make selections, but the Japanese seem to enjoy it as well. The closest we can come to that idea is to make graphs of our data. For a single forecast scenario, we often develop a ‘show’ file, with the file extension .sh. For the US *LIFT* model, there is a file called fore.sh that displays a summary of the forecast in about 25 attractive graphs. These cover GDP growth, cyclical decomposition, demographics, labor force, unemployment, federal budget, trade balance, investment and depreciation; capital and labor income, interest rates, inflation and money growth, savings rate, personal income tax rates, and a few other topics. The show file also makes extensive use of commentary that the user can read while perusing the forecast. It is a pleasant, leisurely way to take in the forecast results, but also a useful tool for locating problems in the assumptions or equations that should be fixed. For the latter purpose, we also develop ‘review’ add files, with the extension .rev, in a subfolder called Review. There are many of these files, which serve as workhorses for reviewing output, prices, employment, imports, exports, investment, and many other sectoral variables. Some of them are also designed to view different components of the accountant, such as transfer payments, government budget, or labor force and employment variables.

Two or more scenarios can be compared in *G7*, with each scenario assigned to a different bank letter. We have followed the precedent of naming these compare add files with the .cmp extension. In many cases, a baseline scenario is developed bi-annually or quarterly, that incorporates recent economic data, and embodies a best guess of ‘business as usual’ in the economy. Alternative scenarios are constructed that show the effects of modifying one or more assumptions in the baseline scenario. The .cmp files can quickly show the same variable in two or more scenarios, or show the differences from the baseline.

The *Compare* program is not just for comparing, but for making tables of any simulation or sets of simulations made with the model. Commonly used tables are setup in files called ‘stub files’ with the extension .stb. Data can be displayed as levels for given years, as growth rates year to year, or over a range of years. One stub file contains the definitions for a macroeconomic summary table, another prepares a presentation on construction by category, another for demographic detail. After running a scenario, it is handy to make a table using *Compare* to look over the main macroeconomic aggregates to understand the overall shape of the forecast. Two or more forecasts can be put in the same table (hence the program’s name). In this case, each variable will have several lines. The first line shows the first scenario in levels. The other lines show the alternate lines, either as levels, differences from base, or percentage differences.

*Compare* can write table output to text files or to Excel. A little-known feature of this program is that it can also be used to create Excel graphs.<sup>19</sup> From *Compare*, the user has the full spate of Excel graph options available, including graph types, fonts, colors, fill patterns, and the ability to specify titles and other text for the graph. Of course, this can also be done using Excel VB macros, but the use of *Compare* means you have the full range of your databank or Vam file immediately available.

In cooking, it is good to have command of the ingredient list, the recipe, and any special techniques required for the dish. But there is a certain *savoir faire* in knowing the right appearance, and the smells and sounds the food makes as it cooks. The English say that a picture

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<sup>19</sup> See the description of the “xlgraph” command starting on p. 232 of the *Inforum Help Documentation*.

is worth a thousand words, but a skillful analysis of a model requires both graph and table output. Tables enable easy reading of values, differences of values, growth rates, sums and checking of identities and control totals. However, graphs often show up patterns or behavior of the model not easily gathered from looking at the table. After developing a new feature of a model, estimating new equations, or introducing a new set of data or fixes, it is a good practice to run through a standard set of tables and graphs. Keep an open mind, and be ready for the unexpected!

## 7 Kitchen Tools

*Always start out with a larger pot than what you think you need.*

The main tool in our well-stocked kitchen is *G7*, which in the words of Julia Child above, is a “large pot”. *G7* is a program designed for building models; estimating regressions; developing databanks of scalar, vector and matrix variables; and comparing scenarios and/or counterfactual historical simulations using plots and tables. *G7* is available for free from the Inforum website, and is under continuous development.<sup>20</sup> Its current features are thanks to many ideas, wishes and work of current and past Inforum staff, international partners, students and other users.

The use of *G7* for developing macro models is described in *The Craft of Economic Modeling, Part I*, which is used in a course for teaching macro modeling at the University of Maryland. *Part II* describes a fully operational model known as *QUEST*. *Part III* describes the use of *G7* and *Interdyme* to develop Interindustry macro and other multisectoral models.<sup>21</sup>

The historical databanks that are developed in preparation for building a model (and improved and extended as the model development progresses) consist of macrovariables (scalar variables), vectors, and matrices. As the model forecasts, the same databanks are extended into the future with the forecast results. This makes it quite convenient to view historical data and forecast in context. Many databanks or scenarios can be loaded into *G7* at any given time, making it possible to compare or plot different outcomes for a given variable. Vector and matrix variables can also be viewed in a spreadsheet format.

The companion program *IdBuild* writes C++ code implementing identities or regression equations, for an interindustry macro model. Regressions and identities for scalar variables can be written by *G7* to files that are processed and translated by *IdBuild* to provide part of the model structure. The other main component starts with a template that includes some code for a very simple model. This code is replaced and expanded by the model builder as the model is developed.

Exogenous variables can either be loaded directly in the databank before the model is run or they can be set through “fixes”. Fixes can also be used to modify endogenous variables. They may be specified as overrides, either in level, growth rate, or index form. Additionally, they may be specified as modifiers (add factors or multiples) of endogenous equations or previous fixes. Finally, the model user has the capability to specify various relationships using a family of fix types called equation fixes. *G7/Interdyme* is the system that has been used to develop most of the Inforum models as well as the Bilateral Trade Model. All results from the model can also be viewed in *G7*, which also eases the comparison of several simulations or scenarios. *G7* is also commonly used to prepare assumptions for exogenous and endogenous variables for the models.

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<sup>20</sup> <http://www.inforum.umd.edu/software/g7.html> . Extensive documentation is also available there, which is viewable as either html, pdf or windows help files.

<sup>21</sup> All three parts are available at <http://www.inforum.umd.edu/papers/TheCraft.html>.

IO coefficients need not be constant, but can be made to change over time either through fixes or endogenous equations. In some models, estimation of price responsiveness of some of the coefficients has been successful. Fixes could be used to model, for example, different paths of energy efficiency improvement by sector.

## 8 Forcing the Issue

*You are the boss of that dough.*

In modeling, as in cooking, things don't always turn out the way we like on the first try. Sometimes relationships that economic theory strongly suggests should hold are not discernible in the data. The estimation of econometric equations is plagued by the well-known problems of multicollinearity, simultaneity (bi-directional causality), identification issues, as well as problems of statistical definition, either of the variable itself, or how it is deflated to constant prices.

In a structural economic model, it is good to incorporate regression equations that have correct signs and magnitudes for the regression parameters. Stable behavior of the model in a long-run forecast can be improved by choosing sensible equation forms, judiciously selecting of right-hand side variables, and gentle "nudging"<sup>22</sup> of coefficients to a more appropriate sign or value, if this can be obtained without too much loss of fit.

This type of adjustment can be achieved very elegantly with the *G7* "con" command, which imposes a soft constraint. A soft constraint imposes a subjective judgment about the tradeoff between the appropriate values or relationships to achieve adherence to the constraint versus the goodness of fit of the equation.

A related idea is the desirability of sensible distributed lag weights. In many situations, one variable responds to another over a period of time, so the solution is to include several lags of that variable in the equation. A common example is the estimation of equipment investment based on a distributed lag on changes in output. Due to multicollinearity, these lag coefficients will often be quite jumpy, or switch from positive to negative. The Almon lag technique comes to the rescue. This technique embodies a soft constraint which specifies that distributed lag weights lie along a line or a polynomial of a specified degree. This is achieved using the *G7* "sma" command.

Mechanically, the soft constraint is programmed by adding a specified number of "artificial observations" to the regression. For example, one might estimate a consumer demand equation for food using the following regression equation:

$$\ln cfood = \beta_0 + \beta_1 \ln pfood + \beta_2 \ln Y$$

where:

*cfood* is real per-capita consumption of food

*pfood* is the relative price of food to the aggregate consumption deflator

*Y* is real income per capita

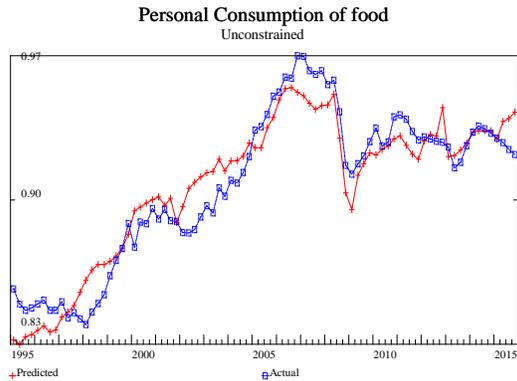
Estimation of this equation on U.S. quarterly data from 1995 to 2015 yields the following equation and plot:

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<sup>22</sup> This is not "fudging".

$$\ln cfood = -.98 - .81 \ln pfood + .53 \ln Y, R^2 = .898$$

Figure 4. Personal Consumption of Food, Unconstrained



One may impose a constraint on this equation to specify the price elasticity  $\beta_1$  to be equal (or closer) to -0.5. This value may have been taken from another study or from a cross-sectional regression. The format of this constraint command is:

```
con <numobs> -0.5 = a2
```

The regression parameters are identified in G7 as a1, a2, a3, etc. (a1 is usually the constant term). The -0.5 is the value of the desired constraint. The parameter <numobs> requires some explanation. It specifies how many artificial observations to add to the equation, each of the form:

Y	const	X1	X2
-0.5	0	0	1

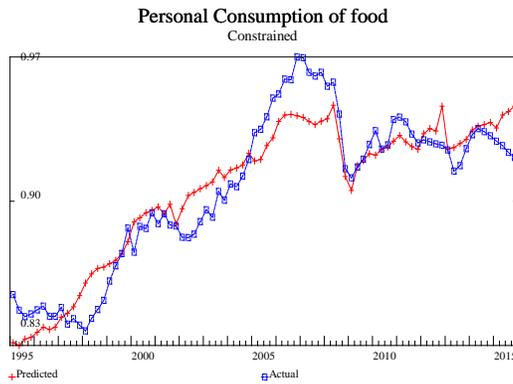
The “error” in this equation is squared and added to the overall sum of squares to be minimized. It represents the distance from the constraint being satisfied. The value of <numobs> one chooses will depend on his or her subjective preference for the closeness of fit and behavior of other parts of the regression in comparison to the preference for the satisfaction of the constraint. It will also depend on the units of the variables. If the mean of Y and the standard error are large numbers, the value for <numobs> may need to be very large. If they are small, you may need to use a small fractional value for <numobs>. In this case, it is easier to think of it as a weighting factor for the constraint. After some experimentation, I chose the following:

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con .05 -0.5 = a2
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with the following equation and plot:

$$\ln cfood = -.74 - .50 \ln pfood + .46 \ln Y, R^2 = .882$$

Figure 5. Personal Consumption of Food, Constrained



The constraint enabled us to get quite close to the desired value for the price elasticity, with a relatively small loss of fit. However, the income elasticity also decreased slightly. Getting the price elasticity any lower may lead to an unacceptable income elasticity. Constraining both parameters to desired values may lead to a poorly fitting equation.

In summary, the soft constraint can be a valuable tool in situations where we have information not contained in the time series data. This may either be results from other related studies and literature, or knowledge implied by economic theory. Such knowledge may also stem from experience in working with models, such as what type of equation will contribute to a reasonable model response to changes in policy parameters or exogenous shocks. Applied economists and econometricians alike may feel hesitant to use the soft constraint, arguing that it is too subjective.

However, the modeler must make many subjective decisions on the choice of model type, the structure of the model, and the variables and functional forms to use in particular equations. There is much subjectivity involved in this process as well. We think it is best to accept the fact that many choices are subjective, but to make the choices known, so they can be discussed and critiqued. In many types of models, such as CGE and DSGE, model parameters are chosen with regard to calibration on perhaps only one year of data. The soft constraint allows for a combination of fitting historical data and adherence to preconceived parameters. For that reason, it lies between the CGE approach and strict regression without constraints.

The topic of optimization of a model is related to that of soft constraints<sup>23</sup>. The goal is to improve or optimize the model over an objective function, while sacrificing some loss in the closeness of fit of certain regression equations. However, unlike soft constraints, the objective function in this case can involve not only one, but several regression equations, and so in a general sense can be thought of as the optimization of the whole model.

The first step in optimizing must be to create the objective function. This objective function must be built into the model. The optimization technique in *Interdyme* uses the convention that it minimizes the value in the last period of the simulation of some specified variable, which is the value of the objective function. For example, the objective function may be specified to improve the overall fit of the model in historical simulation. In this case, it would be formed as cumulated sums of squared relative fractional differences between the simulated values and the actual historical values of each variable. Weights can be chosen that correspond to degree of importance of each variable. The objective function need not be related to historical fit, but may

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<sup>23</sup> This topic is covered in *The Craft of Economic Modeling, Part II*, Chapter 9.

be chosen to reflect a certain policy goal, like minimizing the “misery index”<sup>24</sup>, or obtaining a ratio of the federal deficit to GDP of some desired value.

The second step is to choose key regression parameters in certain estimated equations that will be varied in order to improve the value of the objective. It is probably good to focus on a small set of parameters, less than a dozen. At present, optimization of an interindustry model can vary only parameters in equations estimated by *IdBuild*, which are usually macro equations such as the personal savings rate, or the aggregate wage rate.<sup>25</sup> Though not currently available for sectoral equations estimated using the “detached coefficient” approach, the model-builder may choose to implement certain of those equations in *IdBuild*, and then their parameters can be selected for optimization.

In order to optimize the model, it is run many times, perhaps a hundred to a thousand, depending on the difficulty of finding an optimum. The model builder specifies starting values for the set of parameters, as well as a “step length”, which determines by how much they will vary initially. For each model run, the objective function is evaluated, and the parameters are modified using the Simplex optimization algorithm. When it has converged, the final model run will embody the values of the selected parameters at the final values, which will be different from those estimated from the regression.

A word should perhaps be said in this section on the topic of “fixes” in an *Interdyme* model. Fixes are ways to make a model work the way we want it to, not necessarily the way that emerges from its equations. Although the power that fixes provide can be abused, they distinguish *Interdyme* from several alternative model building software packages, in which this type of control is clumsy at best<sup>26</sup>. Given a certain model version, and set of historical data, the set of fixes used defines a scenario, in a repeatable way. Fixes may be used to specify alternative policies, different rates of technology or productivity growth, alternative demographic projections, or different paths of adoption of renewable energy. Output from another model may be used to generate fixes for an *Interdyme* model. This is one way of linking models.

Just as an experienced and careful baker must take responsibility for the quality of his bread, the model builder must own the quality of results coming out of her model. To do this involves many subjective decisions along the way, including the use of constraints, possible employment of optimization, and reliance on fixes. She is the boss of that dough!

## 9 Icing on the Cake

*A party without cake is just a meeting.*

We have been told late in the meal to save room for desert. After building a more or less standard model, you may have appetite for more. Or, if you are full, you may safely skip this section!

The interindustry macroeconomic structure provides many ‘hooks’ for building extensions to the basic model. Some of these extensions are satellite models, just as many statistical agencies construct satellite accounts to the standard national accounts and input-output framework. For example, in the last several years, the Bureau of Economic Analysis has constructed Arts and cultural, Health care, Research and development, Travel and tourism, and Transportation satellite

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<sup>24</sup> The “misery index” is the sum of the unemployment rate and the inflation rate.

<sup>25</sup> Manprasert (2004) develops an optimized version of the *TIDY* model of Thailand focusing on the savings rate equation. See pp. 156-170.

<sup>26</sup> I have in mind *E-views*, *Matlab*, *Stata* and *GAMS*, which I have tried for building Inforum-type models.

accounts<sup>27</sup>. These accounts have analogs in a model framework. The satellite account is backward-looking, relating historical indicators of health care to historical IO data. A health care satellite model can be used for forecast this framework forward in time. Satellite models can be used to focus on parts of the economy in more detail, or to show the implications of the model from a different perspective.

A worthwhile extension is into the area of energy and emissions analysis. Interindustry macro models can be used to track energy consumption by all industries, as well as the energy in final demand, especially household consumption, imports and exports. In many countries, energy accounts are published which show detailed production and consumption of energy for many energy products (electricity, natural gas, liquid fuels, etc.) and different end-uses. Many of the tables in these accounts may be in current and constant dollars, but much of the information is also given in quantities (barrels, gallons, Kilowatt-hours, petajoules, etc.). These accounts can be more or less successfully linked to the IO framework, either by linking ratios or by regressions. Difficulties arise where one energy product sells for different prices according to market, as is the case in the U.S. with electricity and coal, or where definitions differ (the energy accounts may include electricity transmission losses as part of production, where the IO accounts do not). If emissions data have been compiled by industry on CO<sub>2</sub> and various other greenhouse gases and pollutants, coefficients can be constructed that link the emissions to the factors driving them in each industry, which is often fossil fuel consumption, but may also involve the production process, as is the case in cement and steel products. Another extension is the use of the model to analyze water use requirements by industry. This topic has become extremely important as the world grapples with extremely difficult water issues.

We can use data on intermediate inputs, labor and capital to form estimates of multi-factor productivity (MFP) by industry<sup>28</sup>. These estimates are based on indexes of the growth of output less weighted sums of growth of inputs. A common division of inputs is the KLEMS (capital(K), labor(L), energy(E), materials(M), services(S) ), but in some recent U.S. work, capital and labor of been further disaggregated<sup>29</sup>. Such a module is useful for relating estimates of MFP to the current and constant price historical IO tables and related data, but also in forecasting MFP into the future, and investigating the effects of changing economic structure on MFP growth.

Although we are economists, we sometimes venture into other fields, just like Americans like to try their hand at Indian cooking. Demographics are important to many areas of the model, especially the age effects on consumption of different categories of goods and services, and the effects of age distribution on the costs of retirees and medical care, as well as determining the resource base of current workers who can pay for them. A demographic projections model can be built as a separate model and linked with the interindustry macro model, or it can be brought in as an integral part of that model. Arguably, key parameters in the demographic model, such as

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<sup>27</sup> Arts and cultural: Kern et al. (2014); Health care: Dunn et al. (2015); R&D: Okubo (2007); Travel and tourism: Osborne and Williams (2016); Transportation: Fang et al. (1998), also see US Bureau of Transportation Statistics.

<sup>28</sup> Meade (2013a) presented a start in this direction with the previous version of the U.S. Inforum LIFT model. We are extending this approach with the current version of the model.

<sup>29</sup> See Dumas et al. (2015) for the most recent update of this set of accounts that represent a joint effort on the part of BEA and BLS.

fertility, mortality and immigration should be related to economic conditions, so the relationships between the demographic model and the economic model work both ways<sup>30</sup>.

## 10 International Cuisine

*If you're in a good profession, it's hard to get bored, because you're never finished -- there will always be work you haven't yet done.*

We are obviously in a good profession! In the area of building new models and linking them, there is still much to be done. The Inforum system of macroeconomic, dynamic, input-output models has been producing annual forecasts and analyses of policy and economic events since 1979. Version 2 of the system contains models for the United States, Canada, Mexico, Japan, Korea, China, Germany, France, United Kingdom, Italy, Spain, Austria, and Belgium. Models of Poland, Hungary, Russia, South Africa, and Thailand have also been developed, but are not yet a part of the linked system. Although this work is never done, but we have recently passed a big milestone, with the development of a new Bilateral Trade Model (version 3.0). In this version, bilateral trade equations have been newly estimated with current data, and we have added Russia, rest of Eurozone, the oil-producing countries, and rest-of-world regions. The new system is based on a combination of UN Comtrade data and EU COMEXT data.<sup>31</sup>

Each of the country models is linked to the others bilaterally by commodity, through trade flows and prices. The links are at both the macroeconomic and sectoral level. The macroeconomic side provides the exchange rate assumptions. All other links are at the sectoral level. Thus, steel imports in the USA influence steel exports of Japan; German auto prices affect the price of auto imports to the USA; and, USA grain prices affect Canadian exports of Grain. Exchange rates are exogenous. The system emphasizes the flows of goods and services at the industry level between countries together with the price impacts of such flows.

BTM uses country and sector specific data on prices and investment to estimate the import shares and then the importing country's imports to obtain the level of imports from each exporting country. Summing across the importers then yields the exports by country and commodity. These estimates are then used in the country models as indicators of exports. In addition, BTM gives the importing country model the forecasts for its import prices by commodity.

The forecast horizon of the system is currently 2035. The system can be used to study the industrial and aggregate impacts of macroeconomic developments such as changes in exchange rates, trade policy, and government policy. A recent study, for example, examined the impact on U.S. industries of a U.S. carbon tax with varying degrees of policy response in China.<sup>32</sup> In the current conference, Bardazzi and Ghezzi present the use of BTM 3.0 to investigate the effects of increased investment in Europe.

Our next work will be to improve the system to facilitate the addition of new countries to the system. BTM itself is written in Interdyme, and is an excellent example of the potential for linking Interdyme models with each other.

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<sup>30</sup> The thesis by Dowd (1999) explores these topics in great depth. However, a simple demographic calculator can be built that makes it possible to control the demographic projections by fixing fertility, mortality and immigration by age.

<sup>31</sup> See Bardazzi and Ghezzi (2014).

<sup>32</sup> Meade and Nyhus (2011).

## 11 After Dinner Drinks

*Everything in moderation...including moderation.*

After cooking and eating a large meal, and eating desert, it's sometimes nice to enjoy a German schnapps, and discuss ideas. Where are we going with our work? What could we do together in the future? How can we make a bigger impact?

The growing popularity of multisectoral models is due partly to the recognition that for many policy and other economic questions, industries matter. Whether it be the determination of winners and losers from a free trade scenario, comprehensive tax reform, carbon mitigation, impacts of foreign direct investment, health care reform, or rebalancing of the world economy, industry impacts are important for determining changes in employment and income. The integration and consistency achieved by using the IO framework for the computation of outputs and prices provides a further boon. It helps, for example, to determine to what extent different industries' prices are affected by a carbon tax, or cheaper natural gas.

Despite the pressing importance of using models to address domestic policy questions, no important problem is without international implications. To understand how changes in one country affect other economies, linking of models is extremely valuable. We have found the bilateral linking helpful in understanding the transmission of economic shocks as well as providing a valuable database for understanding the means of that transmission.

The models we have developed and projects we have pursued highlight some enduring research interests, that may prove fruitful for future collaborative or comparative work:

*Labor productivity and multi-factor productivity* – The input-output database is a good framework for constructing KLEMS data. This tool has been used to project KLEMS components and productivity measures into the future. We can continue to investigate alternative cost function and production function approaches to estimating productivity.

*Model properties and dynamics* – This includes a wide variety of topics, including the topic of multipliers discussed briefly in section 5. A continuous task in model development is testing and evaluating the responses of models to shocks, both in the short- and long-term. Of special interest is the determination of the long-run growth path of the economy in an inter-sectoral model, and incorporating equations that allow for disequilibrium but encourage returning to the growth path.

*Energy-environment modeling* – Several of the models have been extended to incorporate more detailed information on energy systems and emissions. Separate models have also been developed that link to the main national model. The modeling framework is also quite suited to the study of water resource issues.

*Health care and demographics* – The projected rise in health care costs in some countries, particularly the U.S., will cause large structural shifts and have implications for productivity and GDP growth. Personal consumption equations that include demographics are a good tool for understanding the growth in this health care cost, and the integrated model can be used to investigate the implications for the consumption and production of other non-health goods and services.

*Infrastructure investment* - Roads, bridges, electric and water facilities, airports and other infrastructure are known to be important to the overall productivity and competitiveness of a country. Analyzing these productivity effects econometrically poses many problems, but information from transportation and engineering studies can help. The model can be used to estimate the cost of substandard infrastructure to the economy.

*International trade and investment* – Bilateral and multilateral country studies have analyzed several free trade agreements and expansion of the EU. Several partners have also explored the offshoring of jobs, or “hollowing out” due to foreign direct investment and transfer of operations overseas.

*Labor force and education* – Incorporation of an employment matrix (occupation by industry) enables the projection of demand for workers of various skill and education levels. These projections can be combined with projections of labor force by education and skill level to detect shortages or bottlenecks (as well as oversupply) of certain labor categories.

The Inforum team will continue to build new versions of the national models, and develop models for new countries. Furthermore, there are ongoing efforts in several countries to apply Inforum modeling software and techniques to the development of regional models and special purpose energy-environment models. The U.S. group and the partners continue to learn from each other, especially at these annual conferences. We are striving to adopt new techniques from both the macro and the IO literature into the design of our models and software. We are especially eager to work with researchers in countries which do not currently have an Inforum model.

But perhaps the most important aspect of our collaboration is to share ideas, possibilities of joint projects and new techniques we have learned. It is valuable to have this time together, and relax after the end of a long meal.

As the Russians have taught us to say: “*За здоровье!*”<sup>33</sup>.

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<sup>33</sup> za zda-ró-vye, “to your health!”

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