Systemic Analysis in Legislating: Modeling the "Cash for Clunkers" Stimulus

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Abstract

Legislating often may lead to unintended consequences and fail to achieve intended consequences due to the complexity of political and social environments. In this article, the authors build a system dynamics model focused on the American 2009 "cash for clunkers" legislation. The authors identified dynamic hypotheses of both intended and unintended consequences in legislative history and political commentary. Unintended consequences were suggested: distortions in new vehicle sales and production, used vehicle supply and consumer driving behaviors. Causal loop and stocks and flows models were developed. Using a Vensim simulation, the authors tested for significant statistical differences in automobile related variables with and without the legislation's eight-week sales subsidy. The study found only short-lived effects on used car dealers, charitable donation programs, and sales of new cars. The reasoning and technique presented in this case study suggests a systematic and learning-intended alternative to the prevailing "art" of political decision making.

Key Words

Prospective Legislative Impact statements

Unintended statutory consequences

Legislative Learning organization

Cash for Clunkers legislation

Introduction

Few fields of human endeavor promote intended activities while triggering unintended consequences more commonly than does political governance. To legislators, regulators and executive officeholders, promotion of intended outcomes seems their raison d'être and principal focus. By comparison, their attention to discerning and avoiding prospective unintended (and undesirable) consequences of political action appears generally unsystematic and incidental.

Using decision-making processes in the governmental policy-making arena that are sensitive to systemic interconnectedness would seem vital, given the gravity of many of the issues faced. Citizens rightly may expect policy-makers to shape it in a sphere of rational analysis, allegiance to truth, and pursuit of the general welfare. Expectations are that policy makers will be wise, acting upon experience gained in enacting or implementing prior laws or through knowledge generated and accumulated, even in other jurisdictions. The overall quality of knowledge-in-use in the decision-making process in the legislative system should presumably increase over time and, with it, the quality of lawmaking.

Stone (2002) explores these expectations at length in the public policy domain and then dismisses them. She identifies a profound policy paradox between expectations and practice and then justifies it through an alternative logic of lawmaking, which seems to be the reality of policy-making in many developed, democratic nation states. However, practice of the "political art" offers rich opportunities for the development of unintended and undesirable civic consequences. And thus does the practice of politics, "the art of the possible" (von Bismarck, 1867), become the enemy of systems thinking, the integrative fifth discipline of essential organizational learning (Senge, 2006).

In previously published research (Labedz, Cavaleri and Berry, 2011), the second author and colleagues contested the inevitability of such dysfunctional behavior. We argued that such policy making ills were preventable and remediable through a mechanism called a prospective legislative impact statement ("P.L.I.S."), if developed with respect to lawmaking under consideration. We suggested that the P.L.I.S. process would incorporate the disciplines of both systems thinking and system dynamics, and offered a recent American statute (with international forebears) as a test case of our proposal. We proposed that the enactment and implementation of the 2009 U.S. Car Allowance Rebate System ("C.A.R.S."), colloquially known as "cash for clunkers", serve as the case study. The 2012 research was space-constrained to fully employ systems thinking and system dynamics techniques with respect to that law, and thus omitted testing through a system dynamics simulation of certain dynamic hypotheses proposed there. This paper addresses those gaps. In the interest of brevity, and to maximize focus here on the simulation, we move ahead to the case study, the dynamic hypotheses, and model construction and simulation. The reader is directed to the prior article for the development and justification of the P.L.I.S. response to the "political art" and the contribution of this continued research to knowledge management theory.

Case Study and Dynamic Hypotheses: Cash for Clunkers

The C.A.R.S. policy was enacted and implemented by the United States government in mid-2009 (C.A.R.S., 2009) as an eleventh-hour addition to supplemental war appropriations legislation, with initial Federal funding of $1 billion. As introduced in the Congress (H.R. 2751, 2009), it formally stated a small number of intended "results," to employ one of Stone's (2002) classifications, including the provision of incentives to replace high polluting automobiles with new, fuel efficient, less polluting automobiles. The bill's sponsor rhetorically wrapped it in pro-consumer, family-friendly, support of public services, and buy-American trappings as well. C.A.R.S. gained early support from industrial trade associations, automobile manufacturers, new car dealers and recyclers, and auto-related labor unions (111 Cong. Rec. 6348, 2009).

Only certain enumerated models of vehicles in private hands and under 25 years old could be traded in, and upon trade-in and purchase of a new qualifying vehicle the participant would receive a $3000 or $4000 taxpayer-financed payment, the amount based on the fuel efficiency improvement in estimated miles per gallon from traded vehicle to new purchase. The program started officially on July 1st. Due to unexpectedly high participation in this program, an additional $2 billion quickly was authorized under the program. The official ending date of this program was August 25, 2009, still months earlier than expected, when the additional funding was exhausted.

Because the proposed law would authorize Federal spending, its pre-enactment analysis by the nonpartisan Congressional Budget Office ("CBO") of its anticipated fiscal impact was legally mandated. The CBO analyzes spending and revenue effects of such bills, but in accordance with a mandate to provide objective and impartial analysis, its reports are devoid of policy recommendations (USCBO, 2009a) and of any analysis of broader dynamic effects of such proposals (McBride, 2013). The CBO developed specific estimates of the costs of the C.A.R.S. program based on an assumed use of 625,000 vouchers: administrative costs of about $55 million, and overall program cost of about $2.6 billion per year during 2010 through 2014. It provided no other analysis of dynamic consequences of such a law. The CBO and Congress acted urgently: the estimates and assumptions regarding C.A.R.S. were only nineteen days old when Congress approved this legislation. Other stakeholders had just a few days in which to examine and question the C.A.R.S. bill before it became law.

Arenas (2012) provides a useful definition of a dynamic hypothesis in the context of proposed action: the dynamic outcomes of a given action, expected by those who have taken the decision to initiate that action. The benefits predicted (above) by the legislation's sponsors provide the first dynamic hypotheses to be examined here through systems thinking model development methods and system dynamics simulations – as we propose they would be in the P.L.I.S. process. By examining the Congressional Record relating to C.A.R.S. and other materials (Blinder, 2008), we translate the advocates' arguments into four hypotheses of intended ("i") consequences of the stimulus:

H1i. It would accelerate motor fuel savings nationwide and provide incentives to registered owners of high polluting automobiles to replace such automobiles with new fuel efficient and less polluting automobiles or public transportation.

H2i. It would support jobs in automotive and related industries, get customers back into the automotive showrooms, help [American] dealers move cars, and improve the environment.

H3i. It would represent a direct income transfer to the owners of clunkers, who are mostly low-income people, and who would almost certainly spend the cash they receive, thereby giving the economy a much-needed boost.

H4i. It would stimulate the demand for new cars as people trade up from used vehicles and as millions of old cars would be permanently removed from service.

We turn now to some of the stated concerns about cash for clunkers, translating them into hypotheses of unintended and undesired consequences. Some analysts soon identified prospective unintended environmental consequences. Greater fuel efficiency might lead to car owners' greater willingness and financial ability to drive more miles, thereby eroding the intended environmental gain (Glaeser, 2009; McCullagh, 2009).

H1. By decreasing the fuel cost expended per mile of driving, through the program's substitution of fuel-efficient new cars for clunkers, C.A.R.S. might lead to car owners' greater willingness and financial ability to drive more miles.

Once C.A.R.S. was enacted and its implementation commenced, other stakeholders (including economists, charitable organizations, and other elements of the automotive industry) weighed in with objections. The earliest objections arose from stakeholders whose interests were excluded entirely from the legislative process. Used-car dealerships were an ignored stakeholder in the cash for clunkers deliberations. In the aftermath of the C.A.R.S. program, fewer trade-in vehicles would augment used-car inventories, because all vehicles traded in under C.A.R.S. were destroyed. Used-car dealers' demand for used vehicles might not be met for several years due to the C.A.R.S.-lessened net new car prices of 2009.

H2. By rendering a large number of used cars permanently inoperable, cash for clunkers would reduce the remaining supply of used vehicles available to prospective buyers, and by inducing such scarcity would decrease the availability of used vehicles and harm the interests of used-car dealers whose business depended on them.

Westley (2009) soon claimed that C.A.R.S. would raise the prices of remaining vehicles in the used car secondary market and increase price levels in general through monetary inflation.

H3. By rendering a large number of used cars permanently inoperable, cash for clunkers would reduce the supply of used vehicles available to prospective buyers, and by inducing such scarcity would increase prices demanded for the remaining used vehicles and thereby harm the interests of low income individuals who most needed to obtain them.

Automakers, their employees and their union representatives raised their concern that demand and consumption were merely accelerated (Pethokoukis, in Fu, 2009), so that levels of production and labor hours following the stimulus period would be trimmed.

H4. While encouraging consumers' substitution of fuel-efficient new cars for clunkers, C.A.R.S. would create little or no sustainable appetite for new car purchases, but instead would increase demand during the stimulus period but promote decreased buying thereafter.

H5. While bringing forward in time new car purchases by some individuals who instead would have purchased at later dates, without restoring the stock of prospective car buyers at those later dates, C.A.R.S. likely would diminish labor hours demanded at later times.

Charities lamented that C.A.R.S. would reduce the supply of used vehicles that taxpayers otherwise might have donated for community charitable support (Shogren, 2009).

H6. By rendering a large number of used cars permanently inoperable, cash for clunkers would reduce the supply of used vehicles that remained available for donation by their owners, thereby reducing funding of non-profit organizations and the community services they provide.

Prior experiences of several foreign governments with respect to similar stimulus programs also were available for consideration by U.S. legislators, had they wanted realism instead of rhetoric as they advanced the C.A.R.S. bill. Auto repair shops, used-car dealers and retailers in other industries already had experienced damaging effects when Germany subsidized new car sales in its so-called Abwrackprämie program (Ewing, 2009). These unintended consequences and others already were visible in at least five European nations that had implemented such programs by the time C.A.R.S. was adopted in the U.S. Miravete and Moral (2009) discuss European precedents. Lessons that could have been learned from international experience with similar programs were ignored, due in large measure to the polis approach that Stone (2002) has described and the absence of P.L.I.S. rigor.

Depiction and analysis of system structures that lead to such intended and unintended consequences are primary contributions made by systems thinking and its calculus-based analytic engine, system dynamics. Note that correspondingly-numbered hypotheses with and without the "i" designation essentially negative one another. In describing and analyzing claims, we focus below on the warnings made testable by the hypotheses of unintended consequences.

We note two points about the modeling that follows. First, while it tests specific hypotheses about specific legislation, the viability and possible contribution of the P.L.I.S. proposal itself is more broadly under scrutiny. Second, the modeling here represents the efforts of the authors relying on limited public records, rather than such modeling by a government office which would have access to considerably greater input from interested parties. If P.L.I.S. analysis were mandated by law and a federal legislative learning organization with greater resources administered it, the modeling and its inputs undoubtedly would be more robust than those presented here.

The Models

Modeling is a dynamic process, and causal loop drawings are an important tool for representing the feedback structure of systems (Sterman, 2000). The prior research used such a drawing (reproduced below as figure 1) to display the mostly-common structure that lays behind the contrasting predictions of hypotheses 1 and 1i. In it, the solid loops at center depict the long-standing twin policy aims of auto regulators and environmentalists. The miles-per-gallon ("mpg") policy has aimed since 1978 to increase the fuel efficiency of the installed automobile base through gradually-more-stringent government mandates that affect each automaker's new vehicle production (NHTSA 2011). The Drive Less policy encourages reduced use of private vehicles, and thereby reduced fuel consumption and consequent environmental pollution, through ride-sharing, high-occupancy vehicle, mass public transit, bicycling, pedestrian transit and other initiatives.

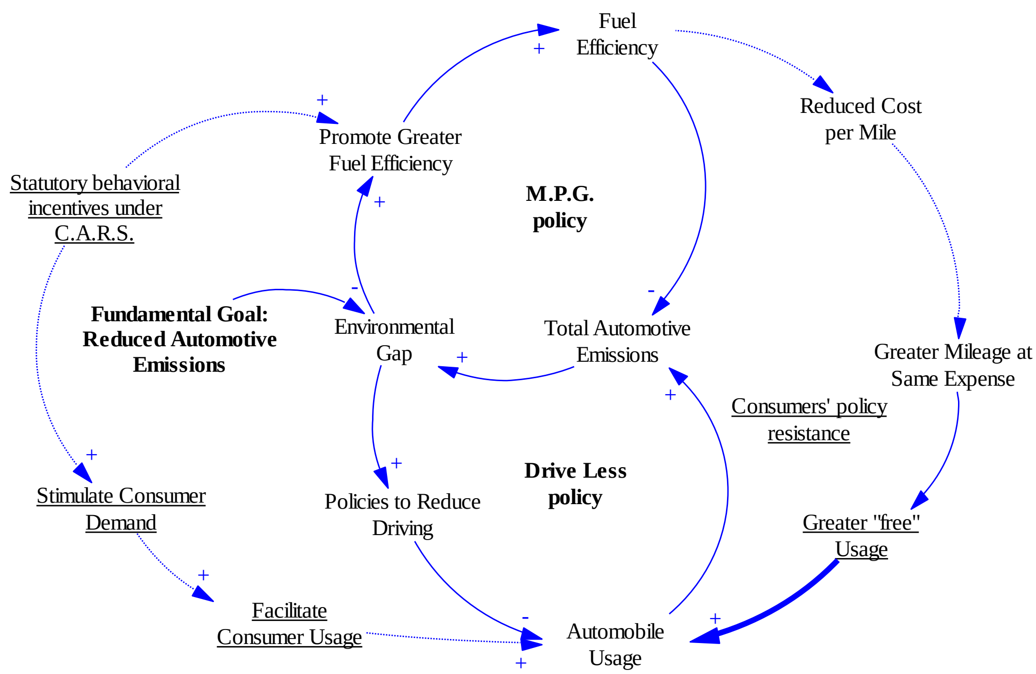

Fig. 1. CLD presenting policy aims of, and policy resistance, to C.A.R.S.

C.A.R.S. aimed clearly to support the mpg policy, because the installed base of automobiles would achieve a higher average fuel efficiency level simply as new, higher-mpg vehicles permanently replaced old and less efficient “clunkers” on a one-for-one basis. C.A.R.S aimed too to stimulate consumer purchases of new automobiles which would provide transport that, mile-for-mile, was less expensive to drivers in their private vehicles. The two intended influences of C.A.R.S. are depicted through the dashed (lighter) arrows at the left of figure 1. Its right-hand arrows however describe dynamic hypothesis 1. Here, greater fuel efficiency permits drivers to drive additional miles for no additional fuel cost, miles they otherwise would have avoided if still driving their more-expensive-to-operate clunkers.

The “textbook” process of testing these dynamic hypotheses next calls for data collection from various sources to permit the creation of stocks and flows (“S&F”) structures that incorporate and extend figure 1 and mathematical testing of the S&F model for the predicted behaviors. If the U.S. Congress already had imposed on itself the system thinking approach and discipline called for in the P.L.I.S. proposal, a governmental legislative learning organization would have been positioned in 2009 to accept such inputs of data and modeling suggestions as any and all stakeholders would submit. The authors’ sources and resources are fewer than the government’s, however. Therefore, we do not create the S&F model relating to the environmental effects stated in hypotheses 1 and 1i. Instead, we developed a causal loop drawing (figure 2) and resulting stocks and flows model (figures 3 through 5) that permits our testing of some others of the dynamic hypotheses: H2i and H2 (used car dealers), H4i and H4 (overall demand), H5 (auto workers’ labor hours), and H6 (charitable donations).

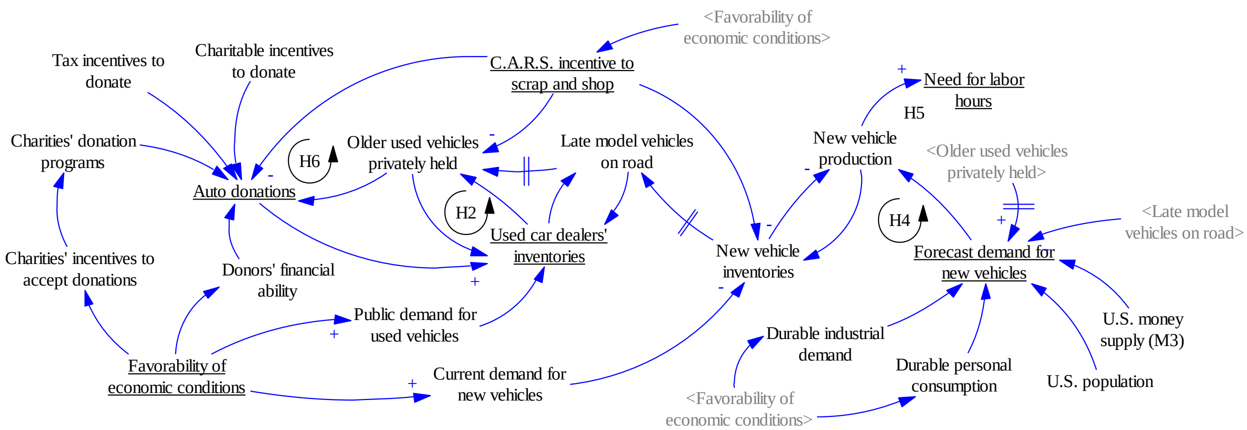

Fig. 2. CLD presenting non-policy-intended consequences of C.A.R.S.

In figure 2, the fears of used cars dealers are presented centrally and those of charities at left. For each of those stakeholders, a new, large government-sponsored incentive to scrap used vehicles augured a reduction in the inventories upon which each depends for resales and the resulting income. These concerns, and Westley's fear of a resulting increase in used car prices due to their newly-induced scarcity, have been discussed above. These are the sort of systemic issues which stakeholders would bring to a government learning office that would be charged with developing systems-sensitive P.L.I.S. for policymakers' consideration. The right side of figure 2 suggests the labor-perceived fear that P.L.I.S.-subsidized new car sales would merely effect temporary reductions in dealer inventories, without triggering any need for their replenishment or any resulting demand for increased labor hours. [For readability, we supply a larger version of figure 2 at the end of this document.]

We turn now to the S&F model that will be used to test the identified hypotheses. Because of its size, we discuss and display it incrementally in figures 3 and 4, and completely in figure 5.

The stocks and flows passage of automobiles within the United States is described in figure 3 by an aging chain structure (Sterman, 2000). It sets forth the sequencing of vehicle production, private ownership, and vehicle retirement in a structure similar to that employed in another recent impact assessment of the automotive industry (Walther et al., 2010). Automakers periodically place production orders ("MGT's Order") based on such factors as current and forecasted market ("MGT's MKT expectation") and economic conditions ("Economic Factor"), new car demand and inventories, historical sales data, and other factors that affect their industry. (Shahabuddin, 2009). As a part of the luxury and durable goods component of the economy, automobile sales have been highly cyclical: sales typically are high for certain months of each year and predictably lower in other months. "Inventory gap" is the difference between the targeted inventory level and the current one ("new vehicles inventory"), and "MGT's MKT expectation" is a lookup table based on seasonal patterns of new buyer behavior. We assigned weightings to the influences of the economic and cyclical factors, so that the production and current inventory levels would better replicate historical behavior. We assumed that targeted inventory level equals two months of current level of market demand ("prospective buyers") and have used "inventory gap" as the aggregate targeted production level.

These orders lead, after a production and shipment delay ("Targeted time") to deliveries to dealers' "New Vehicles Inventory" stock. These new cars remain there until sold, at which point they flow into "Late Model Year Vehicles on Road". Autos remain in that stock on average for just over five years. Automobiles older than that are traced in the stock of "Older Model Year Vehicles, privately held". We choose to distinguish vehicles younger and older than 66 months because that was the average finance term of new car loans in 2009 (Bird, C., 2010), reasoning that individuals were less likely to sell or replace such vehicles until those loans were repaid.

Autos leave the "on Road" stocks in three ways. Their chief (and permanent) outflow occurs through vehicle scrapping, in which reusable parts are salvaged from them before their remains are smelted, processed and recycled to some extent. This model assumes that late model vehicles are scrapped in negligible numbers and that older vehicles are scrapped at a rate which maintains the total number of vehicles on the road in equilibrium over the model period, absent the effect of C.A.R.S. Because of H6, our model provides an outflow for the temporary removal of older cars from the road when their owners donate them to tax-exempt charitable organizations. These organizations often refurbish the donations and then resell them to drivers, usually returning through the auctioning inflow (General Accounting Office, 2003). Finally, the model recognizes (for the sake of completeness, through an instantaneous return flow) the private resale of used vehicles, in which vehicles remain as Older Model Year Vehicles on Road but their legal ownership has changed. The buy-sell trading of used cars among owners and dealers does not change the total quantity of cars in the market or on the road.

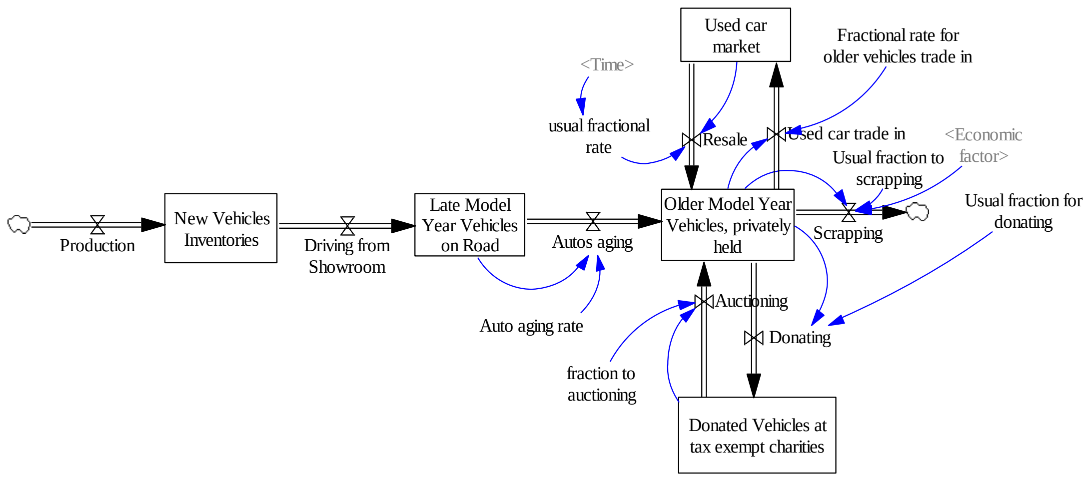

Fig. 3. S&F structure of automobiles' aging chain

Figure 4 models the corresponding demand side for new private vehicles. The simulation of new car buying behavior in the system consists of an inflow of individuals beginning to look, thereby becoming become part of the stock of "prospective buyers", and then flowing out of that stock chiefly when they buy new vehicles. (We supply a secondary, temporary outflow for consumers who become discouraged or who briefly "walk away from deals", only to return weeks later.) The inflow of prospective buyers comes principally as consumers trade in their older automobiles, and to a lesser extent from individuals who own newer "late model" cars. The earlier-discussed flow, "driving from showroom" is set identical to the "buying" flow here, because this model makes the simplifying assumption that each new car buyer acquires just one vehicle at a time. To avoid double counting, we limit the number of individuals who begin looking for new cars to the number of old vehicles scrapped, even though the individuals in question may not be the same persons.

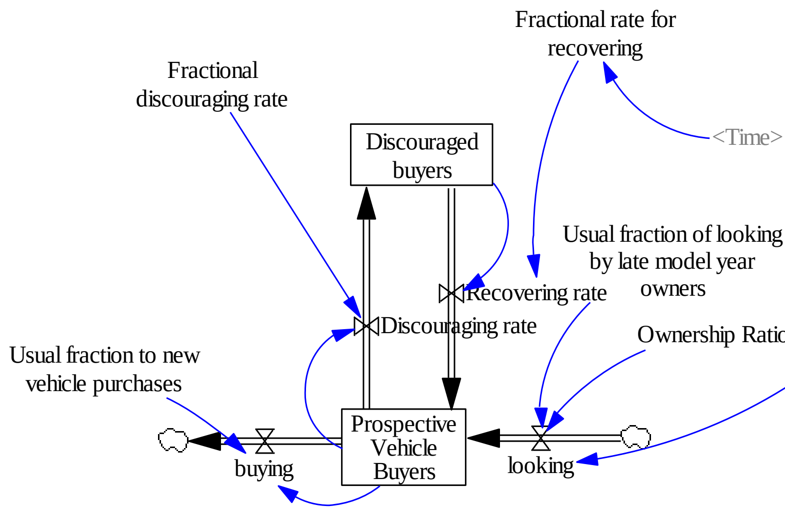

Fig. 4. S&F structure of prospective new car buyers

Figure 5 combines the partial models of figures 3 and 4 and adds one other sector. At the far right, we formulate the model element “Statutory behavioral incentives under C.A.R.S.” as a PULSE function that takes the values of zero or one. When it takes the latter, it affects the six newly shown “change in fraction” elements to which it is causally tied, as explained in the next paragraph.

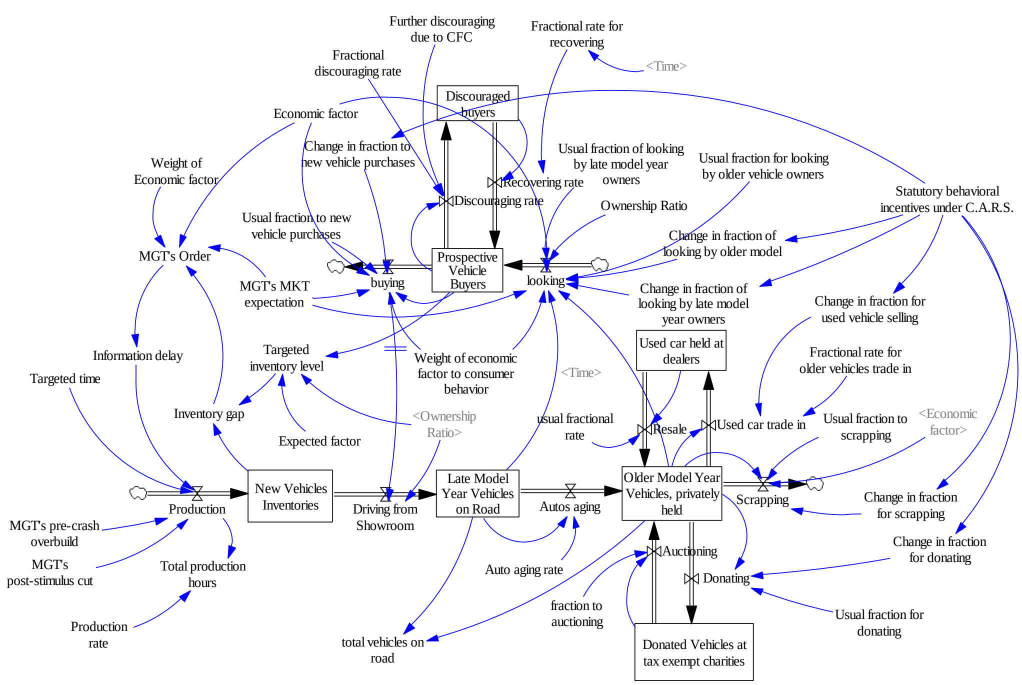

Fig 5. The complete S&F model for simulation

The dynamic hypotheses will be tested through the stocks and flows model depicted in figure 5 across a 312-week simulation period, calendar years 2006 through 2011, using the Vensim DSS (Ventana Systems, 2003) application. [For readability, we supply a larger version of the complete S&F model at the end of this document.] Although most of the figure 5 model elements depict the automotive sector generically, with or without the 2009 legislation, the six underscored "change in fraction" factors trace directly from the "Statutory behavioral incentives under C.A.R.S." element in the upper right. Weeks 183 through 190 of the simulation period correspond to the operational period of the stimulus, from July 1 through August 25, 2009. Framed as an eight-week PULSE function in Vensim, that "switch" temporarily triggers those six change fractions in simulating actual developments. If that pulse is zeroed out, however, the model produces for comparison and hypothesis testing behavior as if C.A.R.S. had never been enacted.

Government records (Council of Economic Advisors, 2009) indicate that 677,081 matching trade in and buy transactions occurred during the eight week stimulus period. Because of the subsidy offer, interest in looking for new vehicles increased and sales of new cars increased compared to the months before the subsidy. To promote its environmental aims, C.A.R.S. required that older vehicles be rendered inoperable, so older car scrapping temporarily increased to reflect each trade-in under the program. Within the used car market, because of the decrease in "privately held older year vehicles" due to this scrapping, a subsequent temporary decline in used automobile trading can be expected. These effects are captured among those six underscored change fractions.

The Data

To develop credible simulation results, modelers should observe a number of validation and model testing protocols, many of which Sterman's chapter 21 (2000) summarizes. One requires that the simulation reproduce actual behavior within the real-life system of interest. We focused on three model elements for which reference mode values could be obtained or developed. The reference elements are the stock of "New Vehicles Inventories" and the flows named "production" and "buying" of new vehicles. They serve as the check points to verify the correspondence of simulation results to historical data. It was difficult to find historical data to compare at other points in the simulation, as the elements either are abstract, proprietary and confidential, or are by nature estimated.

Several private firms offer various data sets presenting different slices of the American automotive sector, at various price points to the researcher. Official government sources offer other data. Within our research budget, we purchased access to U.S. new car sales and inventory data by model line for 2006 through 2011 from Ward's Automotive Group and Automotive News (Crain Communications, Inc.). We used U.S. government-supplied Bureau of Economic Analysis ("Bureau") and General Accounting Office data as well.

Ward's Automotive Group is a research organization that has covered the automotive industry for over 85 years. The Bureau develops economic statistics, including monthly automobile market data with related economic adjustment factors, within the U.S. Department of Commerce. The Bureau's cyclical automobile sales factors are based on Ward's monthly sales data, so Ward's data are considered the most definitive in this model. The GAO data (2003) reported to Congress the structure and scope of private automotive donations to charities, which are relevant in testing H6.

Automotive News is a weekly automotive newspaper published for industry participants. The data we purchased was sorted by manufacturer, model and make. Due to different collection methods, the commercial sources' data are not identical, but their overall trends are similar and consistent. The data from Automotive News would be more important if the model were designed to go to more detailed levels, such as to a make/model level of disaggregation.

For our purposes, the commercially-provided data contain a common defect. Due to the global nature of the automotive industry, the same model and make of a vehicle may be produced in factories the world over. Linking production and sales data becomes distorted by transnational imports and exports; it is difficult to trace in research whether automobiles sold in the U.S. are produced there or elsewhere. Thus, in establishing the reference mode for production, we use the sales and inventory reference modes as inputs to simulate production behavior. The model uses the following formula to back into the production reference mode: - Production = Ending Inventory +Sales - Beginning Inventory.

Model Validation and Testing

In developing and examining the S&F model prior to hypothesis testing, we undertook a number of commonly-stipulated tests and measures (Sterman, 2000; Rahmandad and Sterman, 2012). We extended our textual research beyond the claims made by sponsors and proponents of the legislation to other stakeholders whose perspectives extended both our CLDs and S&F drawings. This broad casting of the model boundary net is consistent with the P.L.I.S. methodology that the second author's 2011 research suggests. We conclude that an addition of further elements will not significantly change the behavior of focal model elements. We cite US population as an example. Although we believe it influences sales of vehicles over the long run, we deem it insignificant across our simulation period, as it was relatively stable from 2006 through 2010. The model's boundary might expand to include other factors like buying behavior, buyer demographics, and manufacturers' marketing efforts, but we do not believe that the model's overall conclusion and recommendation will change materially through expanding it.

The model's structure is consistent with the general description of the U.S. automotive industry. The CLD and S&F provide for key market elements, the C.A.R.S. program, and stakeholders' reaction to that government intervention. The S&F model consists chiefly of two partial models: the aging chain of vehicles from production to scrapping, and the consumer's new car buying decisions from initial interest to eventual ownership. New car production decisions are based on feedback from the most recent sales data and current levels of inventory. The model then conserves each vehicle from manufacture through ownership changes until final disposition through disassembly for scrap materials. Auto aging and scrapping rates are constrained through first-order negative feedback loops so that their associated stocks cannot take on negative values. New car buying interest is tied to the late model and older model year owner cohorts, so that new car buying is similarly, realistically constrained. (There cannot be more buyers than current owners, as we assume a simplifying one vehicle per owner policy, and in fact will be many fewer buyers at any time.) Even as simplified, the partial models thus logically replicate physical laws and conserve material (vehicles, drivers) as appropriate.

The S&F model passes Vensim's "check model" and "units check" consistency tests without use of arbitrary scaling factors. Parameter values are consistent with relevant descriptive and numerical background information, and have real world meanings. Estimated parameters were calculated to better replicate historical behavior prior to using the S&F model to test hypotheses. We also conclude that different integration methods available through the Vensim software will lead to very similar simulation results, and that integration error is not a risk.

Prior to hypothesis testing, we conducted extreme condition tests relating to scrapping rate and new car purchasing. In one pair of tests, we set the usual fractional scrapping rate successively to one and zero values. When set to one, all older year vehicles were scrapped. As a result, only vehicles under age five would be on the road. Owners who held vehicles of ages 5 to 15 years scrapped their vehicles at the beginning of the modeling period, leading to peak buying behavior at the beginning and a slowing down afterwards. When set to zero, no vehicles would be scrapped during the studied period. The number of prospective buyers will keep rising, as people owning older model year vehicles keep increasing. However, actual buying would not increase dramatically because people are using older cars for a long time without scrapping. This soon will lead to inventory overbuild, but due to the feedback loop from the sales level and the current over-built inventory level, production will stabilize afterwards. In the second pair of tests, we changed the usual fraction to new car purchases from its stipulated 80% value to 100% and zero. The change to 100% would shock manufacturers, who planned on the basis of the 80% rate, and would cause decrease in inventory. When set to zero, interested buyers would "kick the tires" but not purchase. This should lead to overbuilding vehicles and maximizing production, and the trial simulation bears it out.

The pending P.L.I.S. argument for formally applying systems thinking and system dynamics methods prior to legislating relies on the S&F model to trace unintended consequences of the government's C.A.R.S. intervention. These include "what if" scenarios, examining alternate results if the government had not implemented "cash for clunkers", "what more" scenarios, in which the intervention spawned unintended consequences including policy resistance, and "what else" scenarios in which the alternative stimulus designs might produce more satisfactory outcomes. Behavioral reproduction testing seems most important in assessing the utility of the S&F model for these purposes. In assessing the simulation's reproduction of real-world data, we tested the three key variables for which we had government-supplied or purchased historical data: automakers' new car production, and dealers' new car inventories and sales. These reference mode data extend 182 weeks before the eight-week incidence of the C.A.R.S. stimulus and continue for 122 weeks after it. Figure 6 presents the historical reference mode data for these variables and their base case values produced through simulating the S&F model.

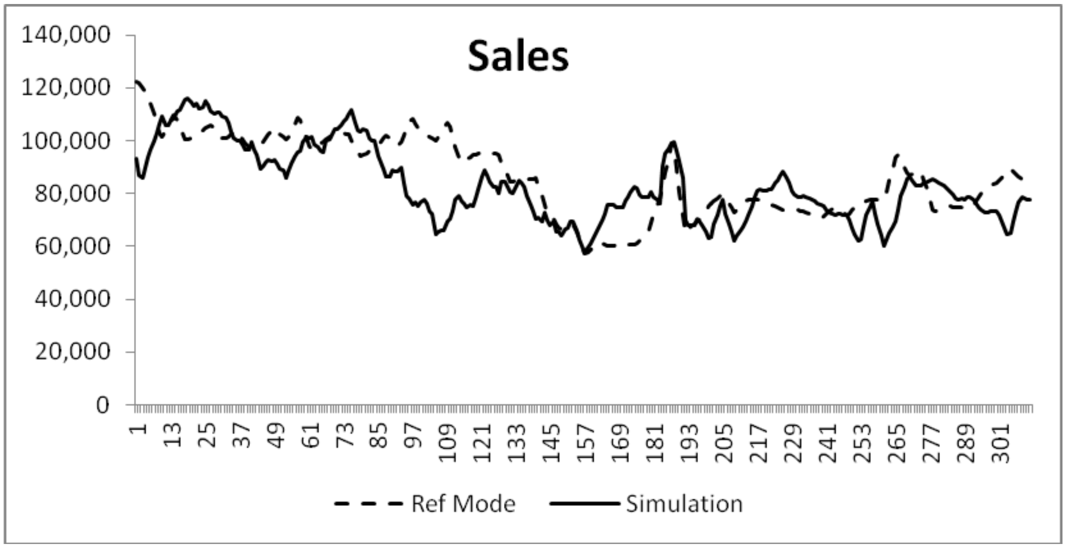

Fig. 6a. US new car sales: reference mode and simulation results

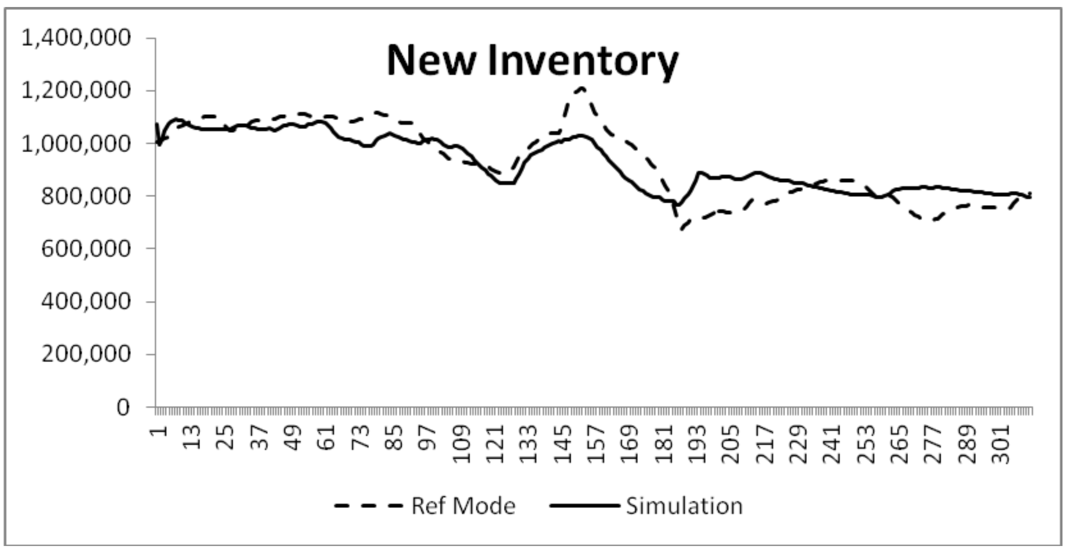

Fig. 6b. US new car inventories: reference mode and simulation results

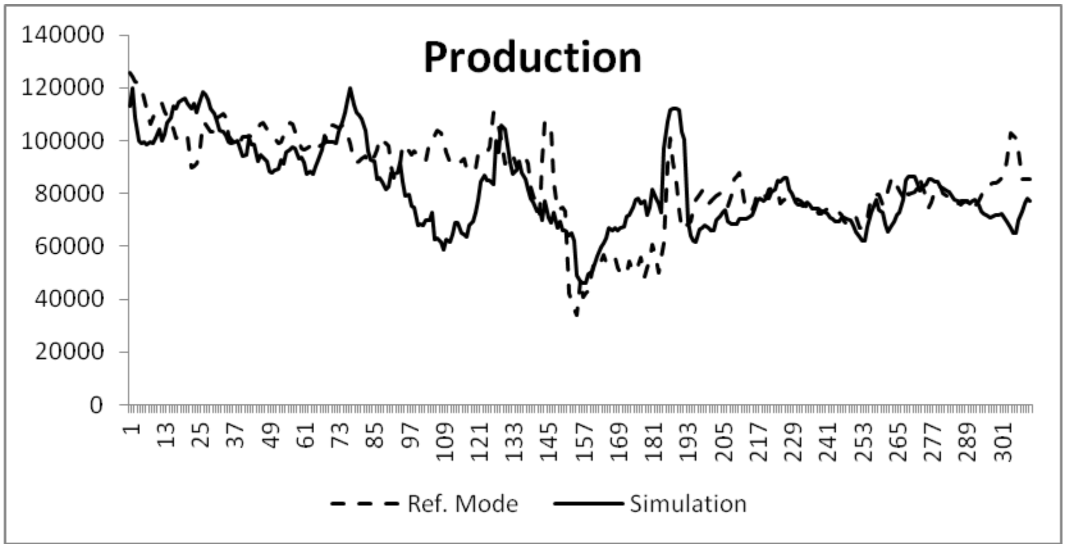

Fig. 6c. US new car production: reference mode and simulation results

Graphically, the model tracks the historical time series data, reflecting the insertion of the C.A.R.S. stimulus in weeks 183 through 190, reasonably well. It overestimates both sales and production in the months immediately preceding that mid-2009 stimulus period but then traces the actual results well during those eight weeks. Comparison of the new car inventory graphs reveals one prominent underestimation (weeks 147 through 184), matched with two later periods of overestimation of new car inventory.

We report in Table 1 summary statistics of the goodness of fit of the base model. Mean Absolute Percentage Errors (MAPE) values, as calculated between the empirical data and the base case simulation output, range from 7.13% to 13.55 %. These too suggest an adequate tracking by the simulation of the reference mode values of the three focal variables. Theil (1996) inequality statistics permit the decomposition of these MAPE values into three components: model bias, unequal variation, and unequal covariance. The table presents those values too. Per Sterman (2000), the Theil values for sales and production chiefly confirm phase shifts between simulated and historical data, which fluctuate with similar means, amplitudes and frequencies. The Theil values indicate unsystematic error in the case of inventory, as simulation output tracks actual data except for an error term with a zero mean. As seen through the U^M value in Table 1, however, the mean values of the reference mode and the simulation output for inventory are quite close.

Table 1. Behavioral reproduction test statistics for base case of simulation

	R^2	Mean Absolute Percent Error	Root Mean Square Error	U^M (model bias)	U^S (unequal variation)	U^C (unequal covariance)
Sales	0.43631	10.72%	12,403	7.98%	0.52%	91.50%
Inventory	0.75826	7.13%	76,752	0.53%	34.16%	65.31%
Production	0.41655	13.55%	14,529	5.02%	0.84%	94.14%

Test Results for Dynamic Hypotheses

Completion of these preliminary model tests now permits the testing of the dynamic hypotheses relating to unintended consequences of C.A.R.S. on used car dealers (H2), new car demand (H4), auto workers' labor hours (H5), and charitable donations (H6). The S&F model depicts the behavioral incentives of C.A.R.S. in the upper right of figure 5. In the base run, the model element Statutory Behavioral Incentives under C.A.R.S. took on the value of one only in months 183 through 190, thereby directly activating the six "change in fraction" elements to which it ties through causal arrows. To test the extent of these unintended consequences, we ran the simulation again, now with the eight-week C.A.R.S. pulse zeroed out, too. In testing the hypotheses, the two sets of simulation-produced values are compared for all weeks after the week in which the subsidy came into direct effect. For most elements, the direct effect started after week 182, but for production, due to the model's built-in information delay, the direct effect began at week 185. Specifically, we contrast the values of the model elements "used vehicle resale", "Prospective Vehicle Buyers", "total production hours" and "donating" respectively in testing the four hypotheses. We used paired-samples t tests (Norusis, 1997) to test short term direct effects during and after the subsidy period, in which our null hypotheses predicted the absence of differences between the mean values of each focal variable with and without the introduction of the C.A.R.S. subsidy, during and after the subsidy period. We used a z test to test the 2-year long term effect from the implementation of C.A.R.S. Table 2 presents the results of testing of the four dynamic hypotheses.

Table 2a. Test results for hypotheses relating to C.A.R.S. influence on used car held at dealers and on donations

	Direct effect from C.A.R.S. (8 Weeks)		Effect after C.A.R.S. (96 weeks)		2-year effect	
	t score	Confidence level	z score	Confidence level	z score	Confidence level
Used cars Trade-in	152.402474	99.95%	0.96309	83.15%	2.2168775	98.65%
Donation	318.916441	99.95%	0.9631	83.15%	2.634906	99.59%

Table 2b. Test results for hypotheses relating to C.A.R.S. influence on prospective new car buyers and on new car production hours

	Direct effect from C.A.R.S. (8 Weeks)		Direct effect after C.A.R.S.			2-year effect	
	t score	Confidence level	lengths (weeks)	t score	Confidence level	z score	Confidence level
Prospective buyers	-10.8476	99.95%	5	4.2723	99%	-2.635	99.59%
Production hours	-13.4832	99.95%	28	2.3053	99.95%	-1.055	85.31%

H2 examined the fears of used car dealers that C.A.R.S. would induce scarcity of used vehicles, thereby harming their business interests. The simulation permitted comparison of the “Used vehicle resales” flow with and without the trade-in-and-destroy stimulus during the stimulus period and after the stimulus expired. Table 2a confirms that used car sales declined markedly after introduction of the stimulus (z=2.2168, confidence level = 98.65%). On closer inspection however, the statistically significant effect occurred during the eight weeks of the subsidy (t=152, confidence level = 99.95%) and not thereafter. H2 is supported, but only as to the eight weeks of the stimulus.

H4 considered the fears of workers and their union representatives that C.A.R.S. would create little or no sustainable appetite for new car purchases, but instead would increase demand during the stimulus period but then promote decreased buying thereafter. The model’s “buying” flows, after the stimulus versus without it, are compared here to test this claim. The results suggest that cessation of the stimulus likely created a surge in Discouraged buyers unable to participate in the program, and that this surge only eroded exponentially over time. The t-scores and high confidence levels for comparisons of Prospective buyers during the eight weeks of C.A.R.S. stimulus and the five weeks immediately thereafter support that conclusion. Table 2b confirms a significant difference in hours, and H4 is supported.

As a result of the predicted change in “buying”, H5 proposed that reductions in labor hours authorized by automakers would occur in months after the stimulus, as those workers feared. Comparison of stimulus and no-stimulus values of “Total production hours” after week 185 test this hypothesis. Table 2b indicates an absence of confidence (85.31%) in suggesting any long-term effect of C.A.R.S. on production hours. H5 is rejected.

Finally, H6 tested the claims made by non-profit organizations that feared reductions in charitable donations of used cars which needed to be destroyed in order for car owners to claim their stimulus payouts. The focal model element here is the “Donating” flow. As with Used vehicle resales, discussed above, Table 2a confirms that charitable donations declined markedly after introduction of the stimulus (z=2.6349, confidence level = 99.59%). On closer inspection however, the statistically significant effect occurred during the eight weeks of the subsidy (t=318, confidence level = 99.95%) and not thereafter. H6 is supported, but only as to the eight weeks of the stimulus.

Figure 7 graphically compares the with- and without-C.A.R.S. behavior of the focal variables of table 2. In this figure appear the temporary scarcity of used cars and of donated vehicles, the surge and decay in discouraged buyers, and the merely temporary effects on production hours, all as tested for significance in table 2.

Figure 7a Comparison of used vehicle resales during and after C.A.R.S.

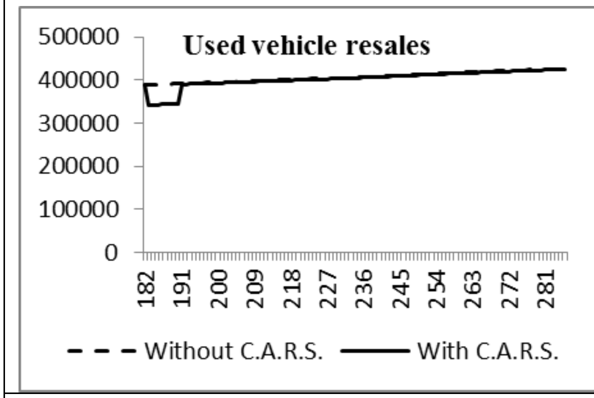

Figure 7b Comparison of prospective buyers during and after C.A.R.S.

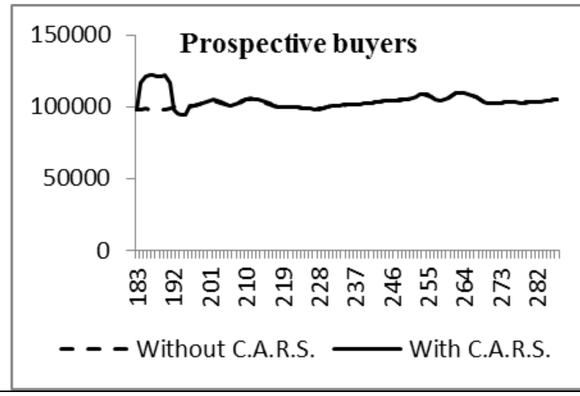

Figure 7c Comparison of production hours during and after C.A.R.S.

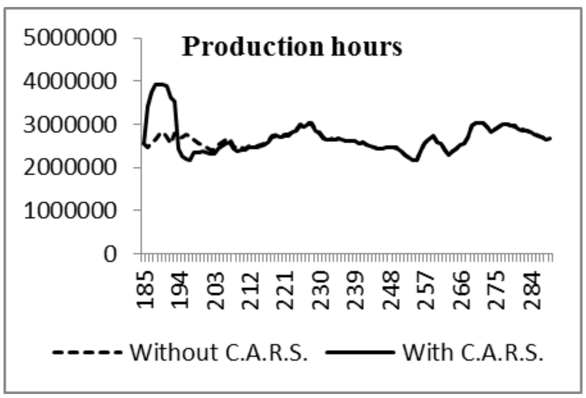

Figure 7d Comparison of donating during and after C.A.R.S.

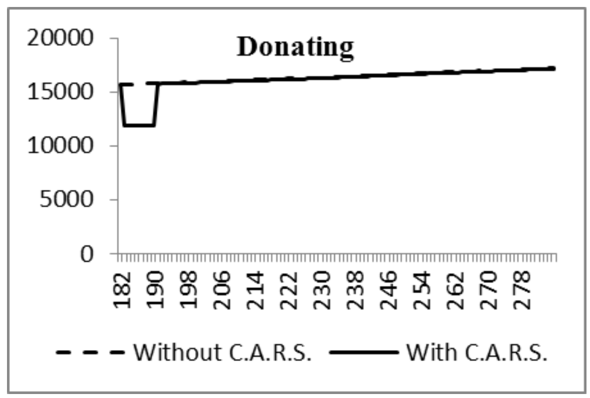

Fig. 7 Comparison of effects on table 2 variables, with and without C.A.R.S. subsidy

Discussion, Limitations, and Future Research

Through the S&F model, we tested four claims (dynamic hypotheses) relating to unintended consequences of C.A.R.S., as suggested by stakeholders in the U.S. automotive field while the subsidy legislation was under lawmakers' consideration or during the eight week period in which its stimulus was available to consumers. We found that concerns regarding vehicle shortages emerging due to C.A.R.S., raised by used car dealers (H2) and charitable organizations (H6) that received car donations, likely were unfounded once the stimulus period expired. The simulation lent its support to concerns (H4) that C.A.R.S. would not create any sustainable appetite for new car purchases, but instead would merely increase demand during the stimulus period but depress it thereafter. Finally, the modeling did not support concerns (H5) that reduced new car production hours would result from the C.A.R.S. program.

The model's parameters and structure likely can be improved, as discussed below. Nonetheless, the approach, equations and reference modes developed and the results obtained to date suggest greater benefits may yet be achieved through refining the model and asking further questions of it. For example, as mentioned above, Kiley suggested alternatives in designing the C.A.R.S. incentives that he claimed would better support environmental protection aims or concerns. With additional inputs to model structure and data, such alternative “what more” versions of proposed lawmaking likely could be examined in advance of legislative action.

A principal limitation of this research lay in our limited ability to retrieve empirical data that likely would have refined the models and improved upon and increased the number of reference modes with which the simulation was compared. While we are grateful to the university sources with which we have been associated for their grants provided to purchase auto industry data, others likely have access to more numerous and perhaps higher quality data. In a sense, this helps to support the argument made by Labedz et al. (2011) that prospective legislative impact statements be developed under government auspices. Undoubtedly, the greater resources of a dedicated legislative learning office and of interested private stakeholders would support more complete data retrieval, develop more comprehensive models, and make even greater contribution to knowledge management among lawmakers.

Clearly, we chose not to test each hypothesis laid out in the Introduction. Our data access constraints suggested that building and testing our limited model was a prudent program, sufficient for a first test of the P.L.I.S. proposal. We would welcome the opportunity to build more, and hope to test H1 in a next stage.

Our limited access to automakers’ decision processes about inventories and production plans, let alone their then-current financial, operational and competitive considerations (as also experienced by Shahabuddin, above), posed another challenge in developing model structure relating to the left side of figure 5. Much of this information is confidential or proprietary, but likely it is more knowable or better estimable by a government office acting under lawmakers’ authority. Much of it is variable across the set of automakers too, and access to additional proprietary databases likely would lead to improvements upon our version.

Such limitations notwithstanding, we conclude that the P.L.I.S. approach to legislative knowledge management, including its application of systems thinking and system dynamics approaches, is viable and deserving of future research, support and funding. As the second author and his co-authors observed, P.L.I.S. would be central in an iterative feedback process that carefully assembles a dynamic systems model from the claims of interested parties as legislation is proposed, then traces the operation of the system in order to validate (some of) those claims in the years following its enactment. Lessons learned through this recursive process would be available to guide subsequent amendments of that law, but more importantly could guide systemic discussion of future legislative proposals that bear similar designs, as for example with other targeted economic stimulus measures. Legislative models may be developed transnationally, so that a government may call upon other nations’ prior experience, systemic learning, successes and shortcomings while crafting its own laws. In a specific case, the American experience with C.A.R.S. might add to models of the Abwrackprämie and other European auto substitution precedents mentioned in the Introduction, and might have learned from their systemic models if those had been available.

The Senate of the United States has just approved an early stride into the use of broader feedback analyses. In an approved amendment to the concurrent budget resolution for the government’s 2014 fiscal year, it would require the CBO to estimate revenue changes in connection with certain bills “that incorporates the macroeconomic effects of the policy being analyzed” (S.CON.RES.8, 2013).

Not only legislators and their constituents would benefit from the P.L.I.S. approach. It offers to provide invaluable “what if”, “what else” and “what more” guidance to guide legislators in better lawmaking. It offers to challenge the sense of civic powerlessness before powerful interests, causes and symbols that Stone validates within the “art” of public policy making. It goes without saying (but still we will) that holistic thinkers and integrative scientists and professionals would enjoy greater opportunities to deploy their talents in global support of systems thinking, that integrative fifth discipline of essential organizational learning. The Tax Foundation certainly sees these possibilities. “Additionally, Congress should look to outside groups … to independently estimate the effects of tax changes. An open discussion of the various models, and their underlying assumptions, would greatly improve the tax writing process.” (McBride, 2013).

References

Arenas F. 2012. Stocks of knowledge and organizational performance. In Proceedings of the 30th International System Dynamics Conference, St. Gallen, Schweiz.

Bird C. 2010. Car Loans: How Long Should They Be? *Cars.com*. July 9, 2010, retrieved March 3, 2013.

Bismarck OEL v. 1867. Interview (11 August 1867) with Friedrich Meyer von Waldeck of the St. Petersburgische Zeitung. Reprinted in *Fürst Bismarck: neue Tischgespräche und Interviews*, **1**: 248.

Blinder A. 2008. A modest proposal: eco-friendly stimulus. *The New York Times*. July 27, 2008.

"C.A.R.S.". 2009. United States. Supplemental Appropriations Act (Pub. L. 111-32, H.R. 2346, enacted June 24, 2009). Title XIII, Consumer Assistance to Recycle and Save Program.

Congressional Budget Office. ("CBO"). 2009. United States Congress. Cost Estimate for H.R. 2454, American Clean Energy and Security Act of 2009. June 5, 2009, retrieved November 23, 2009 from http://www.cbo.gov/ftpdocs /102xx/doc10262/hr2454.pdf.

Congressional Record. 2009. United States. Congress. House of Representatives. Remarks of Congresswoman Betty Sutton, D-OH. 111 Cong. Rec. H6348.

Council of Economic Advisors. United States. 2009. Economic Analysis of the Car Allowance Rebate System ("Cash for Clunkers"). September 10, 2009.

Crain Communications, Inc. 2012. United States automotive industry new vehicle inventory and sales data, Ward's Automotive Group custom data. 2005-2012 US Sales by model line and 2005-2012 US Inventory by model line. Purchased April 26, 2012.

Ewing J. 2009. Car-scrapping plans -- Germany's lessons. *Der Spiegel Online.* May 7, 2009, retrieved March 24, 2010.

Fu L. 2009. Cash for clunkers: bad for environment?, *My Fox Chicago.* August 4, 2009, 8:39 PM CDT, retrieved August 12, 2009.

General Accounting Office. United States. 2003. Report to the Committee on Finance, U.S. Senate, Vehicle Donations: Benefits to Charities and Donors, but Limited Program Oversight.

Glaeser E. 2009. Program has clunky reasoning. *Boston Globe.* August 8, 2009.

Global System Dynamics and Policies project, (2009), GSD partner directly informs Estonian parliamentary policy. http://www.globalsystemdynamics.eu/index.php. Retrieved 2010-12-06.

H.R. 2751. United States. Congress. Consumer Assistance to Recycle and Save Act (as introduced in House) 111th CONGRESS 1st Session June 8, 2009.

Joyce C. 2009. Critics say 'Clunkers' program isn't very green. *NPR's All Things Considered.* August 3, 2009, retrieved August 11, 2009.

Kiley D. 2009. How to rewrite cash for clunkers legislation. *Bloomberg Business Week*. Posted July 29, 2009, retrieved March 15, 2013.

Labedz CS, Cavaleri SA, Berry GR. 2011. Interactive knowledge management: putting pragmatic policy planning in place. *Journal of Knowledge Management* **15**(4), 551-567.

Lindblom CE. 1980. *The Policy-Making Process.* Prentice-Hall: Englewood Cliffs, N.J.

Lyneis J. 2000. System dynamics for market forecasting and structural analysis. *System Dynamics Review* **16**(1): 3-25.

McBride W. 2013. Senate votes to require CBO to use macroeconomic revenue analysis. *TaxFoundation.org.* March 25, 2013. Retrieved May 29, 2013, from http://taxfoundation.org/blog/senate-votes-require-cbo-use-macroeconomic-revenue-analysis.

McCullagh D. 2009. Cash for clunkers does little to help the environment. *CBSnews.com.* August 5, 2009. Retrieved August 22, 2009, from http://www.cbsnews.com/blogs/2009/08/05/ business/econwatch/entry5217824.shtml.

Miravete EJ, Moral MJ. 2009. Qualitative effects of Cash for Clunkers programs. *Centre for Economic Policy Research Discussion Paper* DP7517.

National Environmental Protection Act ("NEPA"). 1970. United States. Pub. L. 91-190, 42 U.S.C. 4321-4347, January 1, 1970, as amended by Pub. L. 94-52, July 3, 1975, Pub. L. 94-83, August 9, 1975, and Pub. L. 97-258, §4(b), Sept. 13, 1982.

National Highway Transportation Safety Administration ("NHTSA"). 2011. United States. Department of Transportation. Summary of Fuel Economy Performance. NVS-220. April 28, 2011.

Norusis MJ. 2007. *SPSS 9.0 Guide to Data Analysis*. Prentice Hall: Upper Saddle River, NJ.

Rahmandad H, Sterman JD. 2012. Reporting guidelines for simulation-based research in social sciences. *System Dynamics Review* **28**(4): 396-411.

S.CON.RES.8. United States. Section 416 of S.CON.RES.8 (113th Congress), the Concurrent Budget Resolution passed by the Senate. March 23, 2013.

Senge PM. 2006. *The Fifth Discipline: The Art and Practice of the Learning Organization.* Doubleday: New York.

Shahabuddin S. 2009. Forecasting automobile sales. *Management Research News* **32**(7): 670-682.

Shogren E. 2009. Charities lament 'Cash For Clunkers' program. *NPR All Things Considered.* July 14, 2009, retrieved August 19, 2009.

Sterman JD. 2000a. Learning in and about complex systems. *System Dynamics Review* **10**(2-3): 291-330.

Sterman JD. 2000b. *Business Dynamics: Systems Thinking and Modeling for a Complex World*. McGraw Hill Higher Education: Boston, MA.

Stone D. 2002. *Policy Paradox: The Art of Political Decision Making.* WW Norton & Company, Inc: New York.

Ventana Systems. 2003. Vensim: The Ventana Simulation Environment. Harvard, MA.

Walther G., Wansart J., Kieckhäfer K., Schnieder E. Spengler T.S. 2010. Impact assessment in the automotive industry: mandatory market introduction of alternative powertrain technologies, *System Dynamics Review* **26**(3): 239-261.

Westley C. 2009. The “I Hate the Poor” Act of 2009: Who Really Benefits from Cash for Clunkers Program. *Foundation for Economic Education.* Retrieved August 22, 2009 from http://fee.org/articles/hate-poor-act-2009/.

Fig. 2 CLD presenting non-policy-intended consequences of C.A.R.S. [restated here for readability]

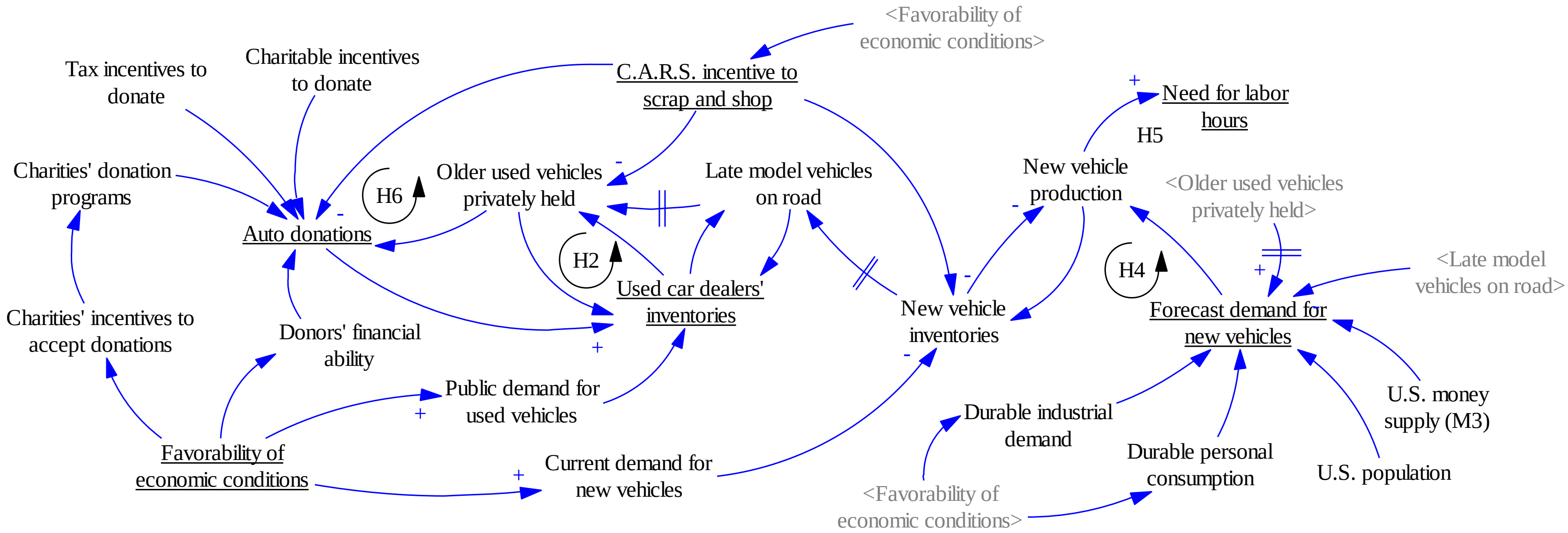

Figure 5. The complete S&F model for simulation