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Full Employment and Competition in the Aspen Economic Model: Implications for Modeling Acts of Terrorism

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Full Employment and Competition in the Aspen Economic Model: Implications for Modeling Acts of Terrorism

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Abstract

Acts of terrorism could have a range of broad impacts on an economy, including changes in consumer (or demand) confidence and the ability of productive sectors to respond to changes. As a first step toward a model of terrorism-based impacts, we develop here a model of production and employment that characterizes dynamics in ways useful toward understanding how terrorism-based shocks could propagate through the economy; subsequent models will introduce the role of savings and investment into the economy. We use Aspen, a powerful economic modeling tool developed at Sandia, to demonstrate for validation purposes that a single-firm economy converges to the known monopoly equilibrium price, output, and employment levels, while multiple-firm economies converge toward the competitive equilibria typified by lower prices and higher output and employment. However, we find that competition also leads to churn by consumers seeking lower prices, making it difficult for firms to optimize with respect to wages, prices, and employment levels. Thus, competitive firms generate market "noise" in the steady state as they search for prices and employment levels that will maximize profits. In the context of this model, not only could terrorism depress overall consumer confidence and economic activity but terrorist acts could also cause normal short-run dynamics to be misinterpreted by consumers as a faltering economy.

Acknowledgments

Dr. Richard J. Pryor founded Aspen and initiated our current line of research. We also thank Craig Jorgensen for software enhancements that enabled our current findings, and Rhonda Reinert for editorial assistance.

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Full Employment and Competition in the Aspen Economic Model: Implications for Modeling Acts of Terrorism[1]

1.0 Introduction

Acts of terrorism have the potential to create significant economic impacts across the country and across economic sectors. For example, an attack that creates widespread fear and reduces confidence across all consumers would have pervasive effects in many sectors of the economy, just as the attacks on September 11, 2001, are still being felt in the airline and travel industries in 2004. Likewise, an attack that targets specific productive sectors of the economy could create output and employment conditions that, when viewed in conjunction with the terrorism, could fuel an otherwise unfounded reduction in confidence in the economy.

To gain a fundamental understanding of the social and economic drivers of terrorism-based economic impacts, we are developing, in two distinct phases, a microeconomic model of economic demand and supply subject to terrorism-related impacts. For the first phase, described herein, we developed a model of how microeconomic firms and employment adjust endogenously to changes in demand and in the number of firms. For the second phase, we are introducing consumer confidence, as represented by the preferences to consume, to invest savings in safe investments, or to invest savings in riskier but higher-yield investments. Additionally, we are introducing specific economic and social mechanisms for how terrorist-based shocks can propagate through the economy. The combined model will be able to simulate the effects of terrorist shocks on economic demand and supply sectors.

In our phase-one model, households earn income and consume goods to maximize utility. The *reservation wage* required to entice each household to enter the labor market varies across households, and the productivity rate of firms is constant across firms. Under this framework, our model allows us to infer the following logic: Some households produce more utility by not working for a firm if their *direct* personal utility productivity is greater than the utility that is generated *indirectly* by going to work, getting income, purchasing goods from firms, and then consuming those goods.[2] Full employment is

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[1] This work is funded by the Advanced Scientific Computing program of the U.S. Department of Homeland Security.

[2] This is related to the notion of a household's trade-off between work and leisure. Leisure can be considered as a form of consumption for the household; that is, more leisure makes the household better off. However, spending time at work rather than at leisure generates income, which allows the household to consume goods and services. Households that can generate more utility from leisure will stay at home, while those that generate more utility from consumption will go to work. As described in Section 2, we model that switching point as a function of the ratio of wages to the price of produced goods.

defined as the level at which those who are willing and able to work for firms are employed.

Firm-based production has become the societal norm in most cultures since firms typically have production technologies superior to home-based productions and these firms can acquire labor and capital in amounts and proportions that make them more productive or efficient. Productive efficiency creates higher per capita product, which can be distributed among workers, owners of capital, and consumers. These benefits result in higher real output, wages, and profits, and a higher standard of living.

In our model, actual employment is a combined function of households' willingness to work (which collectively defines the labor supply curve) and firms' productivity rates (which provide the production feasibility curve and related labor demand curve). Supply and demand in the goods market are functions not only of the price of goods in the market but also of the amount of labor that households are willing to supply to firms at the current wage rates and goods prices.

Two particular market equilibria are known and calculated herein, but the short-run dynamics of firms and households trying to reach these equilibria are not. In the simulations, firms producing and selling goods take available employment as given in the short run. Households, considering whether to work, take final goods prices as given. These and other short-run assumptions create "noise" for employment and prices, which can make equilibrium unattainable.

This report is organized as follows. Section 2.0 describes our model of labor markets and goods markets. We first formulate a model of household utility maximization and then calculate both the labor supply function of all households and the goods demand that results from their income. Next, we formulate the firm profit-maximization problem and the related goods-supply function and labor-demand function. Finally, we calculate the goods-market and labor-market equilibria.

Section 3.0 describes two sets of Aspen agent simulations: the single-firm monopoly case and the multiple-firm competitive case. We discuss how both sets of simulations illustrate the dynamics of how the economies converge to long-run equilibrium and how they adjust in the short run. Section 4.0 summarizes and describes the phase-two work.

2.0 Model

We model a two-market, multiperiod, closed economy composed of F firms and H households. Each household generates utility, either by consuming purchased goods or by generating utility at home with its own internal productivity. Goods are purchased in the goods market with wages earned by working at one of the firms. Each firm generates profits by using labor, purchased in the labor market, to produce a good and then by selling that good in the goods market.

In this model of short-run decisions, utility is defined by current consumption; households do not save for the future. In subsequent papers, we will model long-run decisions regarding life-cycle savings and consumption.

2.1 Households

Each household is a single potential laborer endowed with its own internal productivity, ρ_h, which represents the quantity of goods the household can produce for its own consumption each time period if it chooses *not* to work for a firm. The population of households has internal productivity rates uniformly distributed over the interval $[\rho_{min}, \rho_{max}]$.

Each household tries to maximize its utility each time period by consuming either home-produced goods or firm-produced goods. If consuming at home, its product is ρ_h. If consuming purchased goods, it will have earned a wage, w, from the firm and purchased q goods at price p in the market. Since its income-constraint equation is $p \times q_h \le w$, a household that works will be able to purchase and consume $q_h = w/p$ goods. The household's problem is then to select the consumption that solves

$$\max \mathrm{U}_h(\cdot) = \begin{Bmatrix} \frac{w}{p}, & \frac{w}{p} \ge \rho_h \\ \rho_h, & \frac{w}{p} < \rho_h \end{Bmatrix} = \max(\frac{w}{p}, \rho_h)\,. \qquad (1)$$

Labor Supply

Labor supply is defined by the number of households willing and able to work for firms. Given the uniform density function of internal productivities, $[\rho_{min}, \rho_{max}]$, the labor supply can be defined as

$$L^s = L^s(\frac{w}{p}) = \int_{\rho_{min}}^{\rho_{max}} f_h(\frac{w}{p})\ d\rho\,, \qquad (2)$$

where

$$f_h(\frac{w}{p}) = \begin{Bmatrix} \frac{H}{(\rho_{max} - \rho_{min})}, & \frac{w}{p} \geq \rho_h \\ 0, & \frac{w}{p} < \rho_h \end{Bmatrix}.$$

Substituting,

$$\begin{aligned} L^s(\frac{w}{p}) &= \int_{\rho_{min}}^{\frac{w}{p}} \frac{H}{(\rho_{max} - \rho_{min})} d\rho + \int_{\frac{w}{p}}^{\rho_{\max}} 0 \ d\rho \\ &= H \left[\frac{\frac{w}{p} - \rho_{min}}{\rho_{max} - \rho_{min}} \right]. \end{aligned} \tag{3}$$

Figure 1 illustrates this supply function.

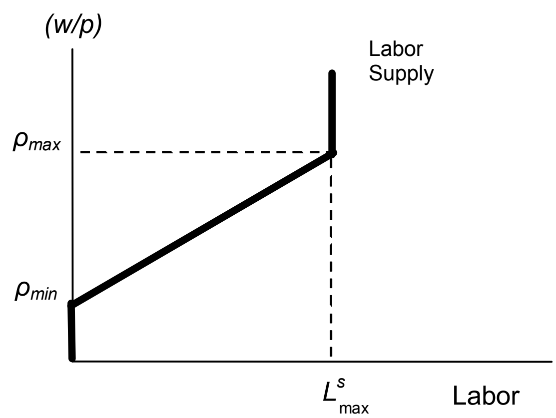

Figure 1. Labor supply function.

Full employment is defined as the condition where all households for which $\rho_h < (w/p)$ are employed by firms and the remaining are not employed by firms.

Goods Demand

Since each household maximizes utility by maximizing consumption, each household will purchase all it can, i.e., *w/p*. Goods demand follows as

$$
\begin{aligned}
G^D = G^D(\frac{w}{p}) \quad &= \sum_{h=0}^{H} q_h \\
&= \left(\frac{w}{p}\right) L^s(\frac{w}{p}) \\
&= \left(\frac{w}{p}\right) \text{ H } \left[\frac{\frac{w}{p} - \rho_{min}}{\rho_{max} - \rho_{min}} \right].
\end{aligned}
\tag{4}
$$

2.2 Firms

Each time period, firms use labor l_f to produce output, using the production technology

$$
q_f = q_f(\rho_f, l_f) = \rho_f \times l_f, \tag{5}
$$

where ρ_f represents the conversion of labor to goods.

Labor is purchased in the labor market at the fixed rate w. (We could also model w as varying, but this would add complexity to the equilibrium and market dynamics that is outside the scope of this work.) The produced goods, on the other hand, are sold in the goods market at price p_f as determined by the firm. The firm's problem is to select the price that maximizes profits, i.e.,

$$
\begin{aligned}
\max \pi_f \quad &= p_f q_f - w l_f \\
&= p_f \rho_f l_f - w l_f \\
&= (p_f \rho_f - w) l_f.
\end{aligned}
\tag{6}
$$

If we impose the condition that a firm will only produce if $\pi_f > 0,$ then we must have the condition $(p_f \rho_f - w) > 0,$ or $\rho_f > \frac{w}{p_f}.$ If so, the firm will try to produce infinite profits by hiring infinite labor. Summarizing, optimal firm production is then

$$
\hat{q}_f = q_f(\frac{w}{p}) = \left\{ \begin{matrix} +\infty, & \frac{w}{p_f} < \rho_f \\ 0, & \frac{w}{p_f} \geq \rho_f \end{matrix} \right\}, \tag{7}
$$

the goods supply function in the goods market is

$$G^S = \sum_{f=1}^{F} \hat{q}_f, \tag{8}$$

and the labor demand function in the labor market is

$$L^D = \sum_{f=1}^{F} \hat{l}_f. \tag{9}$$

2.3 Market Equilibrium

For market clearing, we have the necessary conditions $G^D = G^S$ and $L^D = L^S$. We consider two specific cases: a single-firm monopoly economy and a multiple-firm competitive-market economy. To provide a reference point, we also compute some properties for the socially optimal economy, where firms have zero expected profits and all laborers that are willing and able to work are employed by firms.

Case 1: Single Firm

In the context of our model, a single firm will know, given Equation (1), what the labor response will be to the price it offers in the market.[3] The firm's problem, therefore, can be reformulated as

$$\begin{aligned} \max \pi_f &= p_f q_f - w l_f \\ &= p_f \rho_f l_f - w l_f \\ &= (p_f \rho_f - w) l(\frac{w}{p}) \\ &= (p_f \rho_f - w)\ H \left[\frac{\frac{w}{p} - \rho_{min}}{\rho_{max} - \rho_{min}} \right]. \end{aligned} \tag{10}$$

Sufficient conditions for maximum profit are that (1) first-order conditions with respect to price p equal zero and (2) second-order conditions are strictly less than zero. It can be shown that

$$\frac{d\pi}{dp} = 0 \quad \Leftrightarrow \quad \hat{p} = w\sqrt{\rho_f \rho_{min}} \tag{11}$$

and

[3] In our simulations, the agents do not actually know the employment response, but as shown below, the functional forms of our market equations allow firms to correctly "discover" the employment response.

$$\frac{d^2\pi}{d^2p} < 0 \quad \Leftrightarrow \quad -2\hat{p}\rho_f\rho_{\min} < 0, \qquad (12)$$

the latter of which holds for all positive values of p, ρ_f, and ρ_{min}. The price $\hat{p}$ is then the profit-maximizing price.

Case 2: Multiple Firms

The economy with multiple firms is a little more complicated. Instead of each household always purchasing from a single firm, each household randomly selects a firm, where firms with lower prices have higher probabilities of being selected. Specifically, if a firm has a price that is one-half of another firm's price, then it has twice the probability of being selected by a household. Formally, a firm with price p_f has a purchase probability of

$$\text{Prob[household selecting firm } f\text{]} \;=\; \left(\frac{1}{\sum_{f=1}^{F} p_f}\right)\frac{1}{p_f}. \qquad (13)$$

In this case, a firm competing with other firms in the market has *expected demand* for its product:

$$\begin{aligned} \hat{q}_f = \mathrm{E}[q_f] \quad &= \{\text{prob of being selected}\} \times \{\text{expected demand if selected}\} \\ &= \left(\frac{1}{\sum_{f=1}^{F} p_f}\right)\frac{1}{p_f} \times H\left[\frac{\frac{w}{E[p]} - \rho_{min}}{\rho_{max} - \rho_{min}}\right], \end{aligned} \qquad (14)$$

where E[p] is the expected value of the price each household expects to see in the goods market, computed as the weighted average of all prices in the market. Since all firms are identical, in equilibrium all of the firms should be charging the same price and have the same expected demand.[4] As with the monopoly case, it can be shown that first-order and second-order conditions are necessary and sufficient for equilibrium:

$$\frac{d\pi}{dp} = 0 \quad \Leftrightarrow \quad \hat{p} = w\sqrt{\frac{1}{F}\rho_f\rho_{min}}, \qquad (15)$$

and

$$\frac{d^2\pi}{d^2p} < 0 \quad \Leftrightarrow \quad \frac{-2w^2}{p^3} < 0, \qquad (16)$$

[4] For an example of a case where heterogeneous firms have different prices in Nash equilibrium, see Ehlen 2004.

the latter of which holds for all positive values of w and p. By inspection, not only is it the case that if *all* firms are at prices not equal to $\hat{p}$ that they will move toward $\hat{p}$, but also if the firms are at different prices from each other that they will collectively move toward $\hat{p}$. Finally, note that a firm will only make a profit if its per-unit revenue is greater than its per-unit cost, i.e.,

$$\frac{\hat{p}\rho_f l_f}{\rho_f l_f} > \frac{w l_f}{\rho_f l_f} \;\Rightarrow\; \hat{p} > p_{min} = \frac{w}{\rho_f}. \tag{17}$$

Limit Case: Socially Optimal Equilibrium

The impact of competition on profits is bound in the limit by the socially optimal equilibrium. While case 2 is more competitive than case 1, firms are still earning positive profits, implying that potential new firms, seeing profit opportunities, could enter the market. Economically speaking, socially optimal implies zero profits for all firms, and the economy achieves full employment. To compare case 1 and case 2 with a known limit equilibrium, we need to calculate the number of firms necessary to create an economy where expected firm profits are zero.

Inspecting Equation (15), the equilibrium price decreases monotonically with increasing F. Using the definition of p_{min} in Equation (17), the number of firms required for competitive equilibrium is

$$F = \rho_f^3 \rho_{min}. \tag{18}$$

The condition $\hat{p} = \frac{w}{\rho_f}$ then defines the socially optimal equilibrium case.

Figure 2 illustrates long-run demand and supply in the goods market. These curves are directly linked via the price-wage ratio represented on the vertical axis and intersect at outputs $Q = 0$ and $Q = Q^*$. Due to the functional forms of the utility and profit functions, the socially optimal equilibrium output level is Q^*, and the corresponding equilibrium price is p_{min} (from Equation (17). For any $p' > p_{min}$, a surplus is created where Q_B units of goods are produced but only Q_A units are purchased by households. A monopoly will set such price greater than p_{min} to maximize $Q_B - Q_A$. Under competition, firms charging any $p' > \hat{p}$ will be undercut by competitors until the market price declines to the competitive equilibrium at $\hat{p}$. Under perfect competition, $\hat{p} = p_{min}$ and $Q_B - Q_A = 0$.

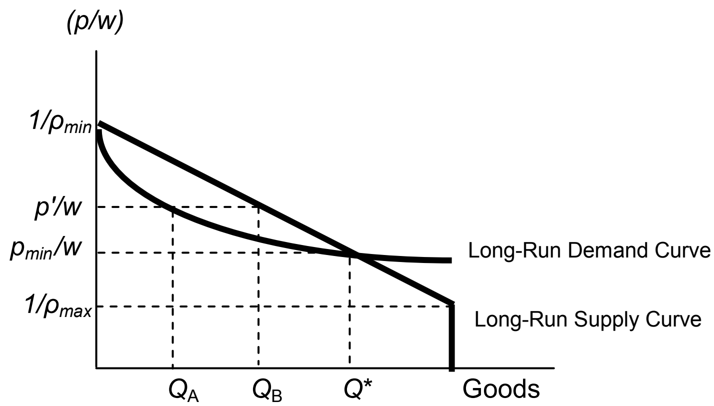

Figure 2. Long-run demand and supply curves in the goods market.

3.0 Simulations

To investigate whether the economy "discovers" its monopoly or competitive equilibrium and, if so, how this process occurs, we conducted a series of Aspen[5] agent simulations for the single-firm and multiple-firm cases. In both cases we used the socially optimal economy as comparative, limit conditions. The parameters for the two cases are given in Table 1.

Table 1. Simulation Parameters

Parameter		Case 1 Monopoly	Case 2 Monopolistically Competitive	Socially Optimal Competition
Households				
	Number	100	100	---
	Internal productivity	[1.0, 2.5]	[1.0, 2.5]	[1.0, 2.5]
Firms				
	Number	1	5	8+
	Productivity	2.0	2.0	2.0
	Wage rate offered	50.0	50.0	50.0
Calculated Optima				
	Equilibrium price ($\hat{p}$)	70.7	31.6	25.0
	Equilibrium employment (L^s)	29	64	80

3.1 Agent Rules/Mechanics

Households

Each household monitors wages and prices every time step. If an unemployed household *h* with internal productivity ρ_h observes that $(w/p) > \rho_h$, then that household applies for employment. If an employed household with internal productivity ρ_h observes that $(w/p) < \rho_h$, then that household quits its job and leaves the labor market. Each employed household attempts each time period to spend its entire savings from wages on the purchase of goods for consumption.

Firms

Each firm employs an algorithm for setting the price of the goods that it sells in the goods market. This algorithm essentially searches for the price that maximizes current-period profits by averaging its price and profit performance over time. We chose this algorithm for its ability to converge for this particular exercise. (Typically, Aspen employs more complex learning algorithms, e.g., Slepoy and Pryor 2002.)

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[5] For details on the structure and uses of the Aspen model, see Basu et al. 1996 and Basu and Pryor 1997.

Each firm also runs a simple algorithm to determine the production that will maximize its profits, and then tries to access the labor necessary to produce that amount of output. This algorithm continues to scale its labor force in a certain direction (up or down) so long as the firm's profits are increasing.

If the firm reaches a local maximum, it oscillates about that number of employees while perpetually searching nearby for an employment level that will increase its profits. Finally, each firm purchases any excess inventory of goods that it was unable to sell in the goods market.

3.2 Simulation Results

Case 1: Single Firm

For validation, we demonstrate that all simulation variables quickly converge to their calculated equilibriums in the one-firm case. As shown in Figure 3, the monopoly firm converges its labor demand to 29, well below full employment of 80, which is the number of people willing and able to work at that (*w/p*) ratio. Said another way, the firm underemploys since it is getting higher profits at lower output levels. It charges a price near the expected monopoly price of $70, which is well above the p_{min} price of $25 (Figure 4).

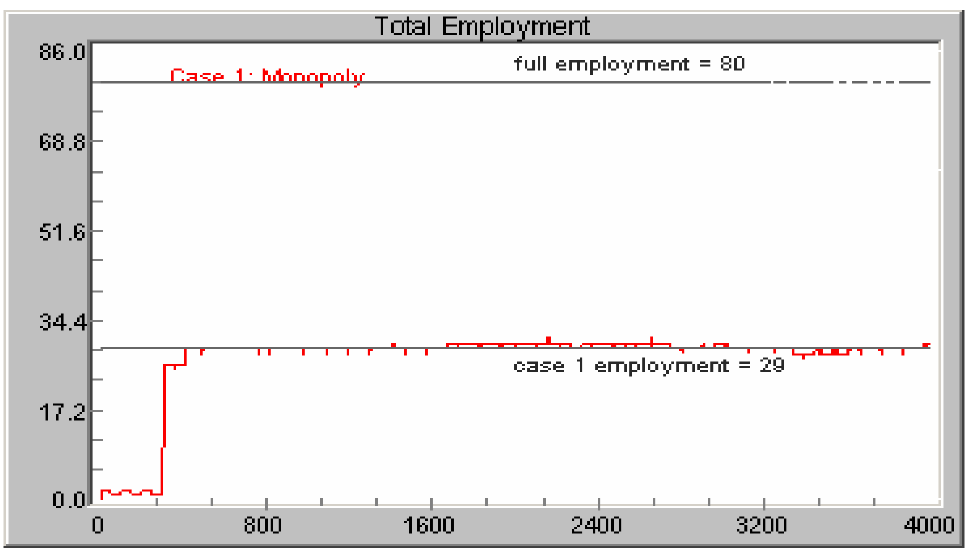

Figure 3. Monopoly case: Total employment.

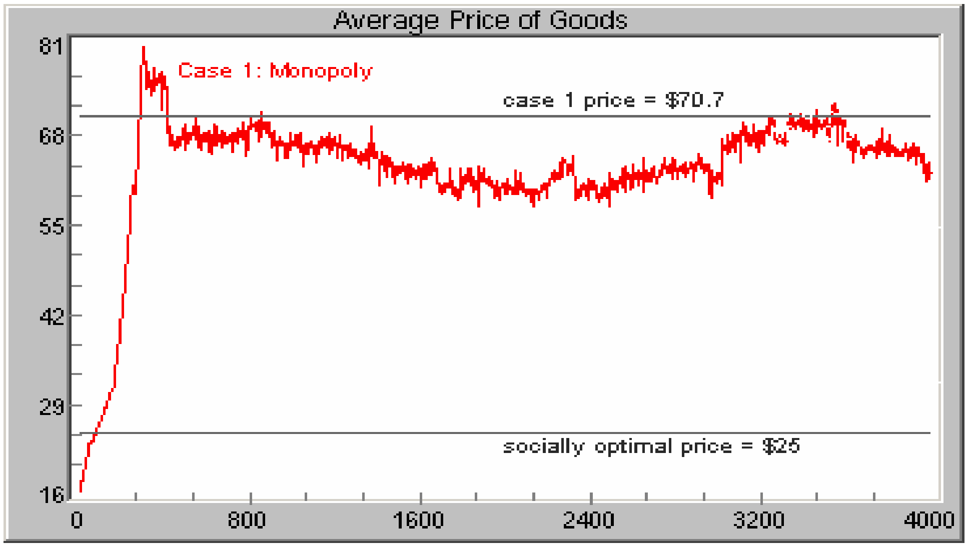

Figure 4. Monopoly case: Market price.

By restricting output, the firm makes a profit of 36 units (Figure 5), while those households that participate in the labor market collectively purchase 22 units (Figure 6).

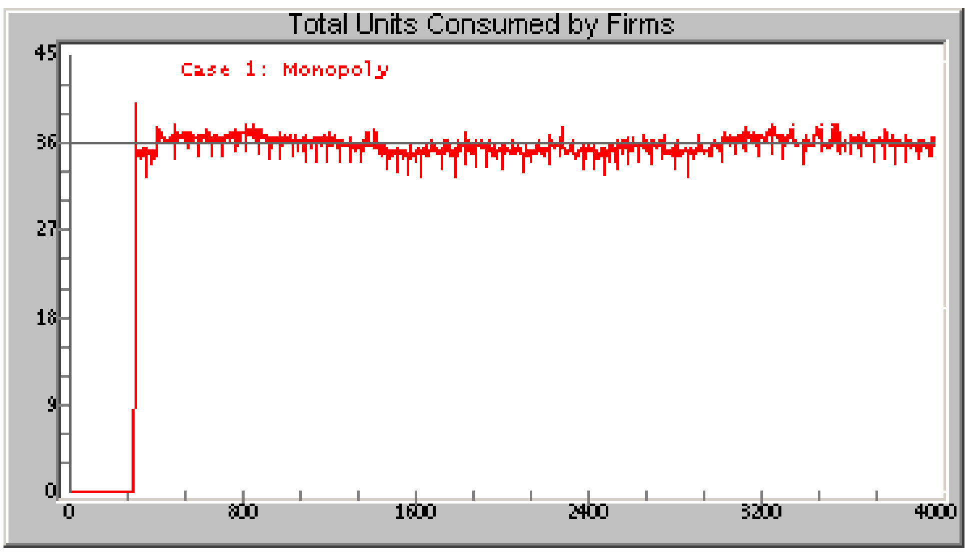

Figure 5. Monopoly case: Firm profits.

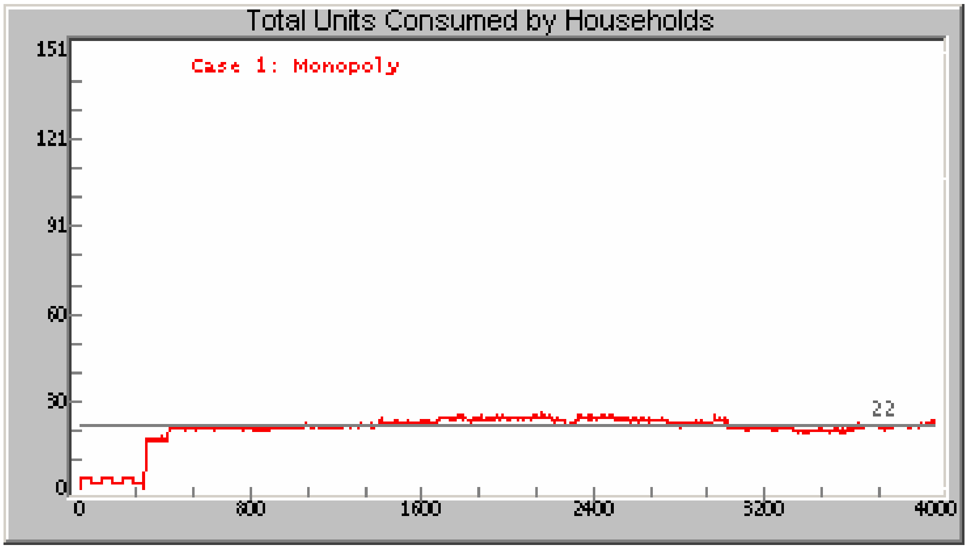

Figure 6. Monopoly case: Units consumed.

Households that work for the firm produce two units of goods per time step (based on the firm productivity rate) but consume only 0.75 units, or 38% of their marginal product (Figure 7).

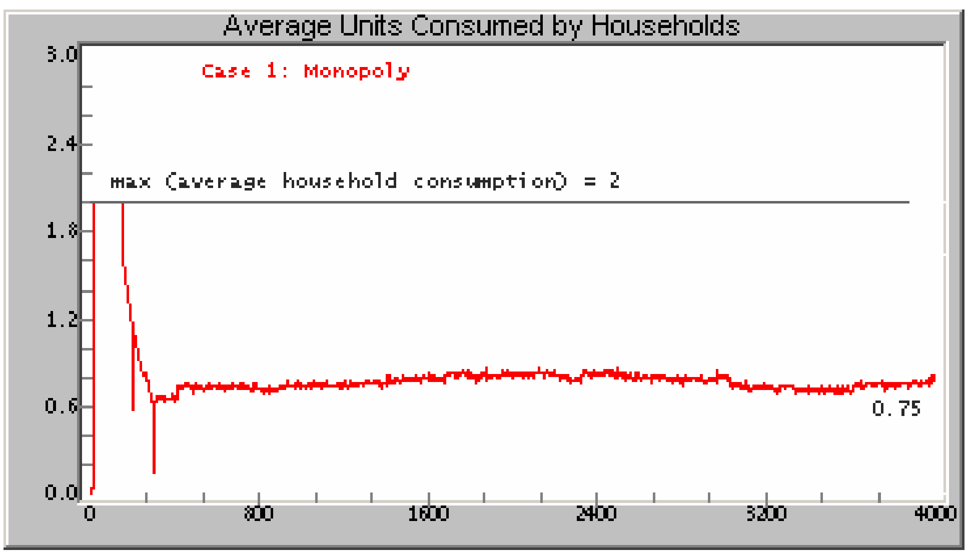

Figure 7. Monopoly case: Average units consumed.

Case 2: Multiple Firms

In the second case, we ran the same simulations but with five firms instead of one. In the following graphs (Figures 8 through 13), green represents this competitive case, and red represents the previous monopoly case. In the competitive case, we find that firms collectively employ more labor than in the monopoly case. The number of employees converges near (slightly above) the expected competitive employment level of 64 (Figure 8), and the price converges slightly below the competitive price of $31.60 (Figure 9).

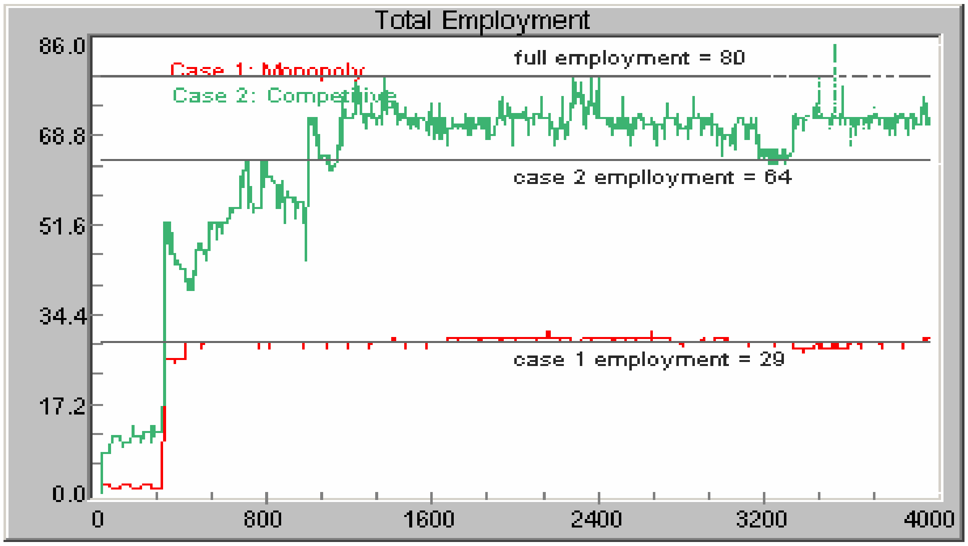

Figure 8. Competitive case: Total employment.

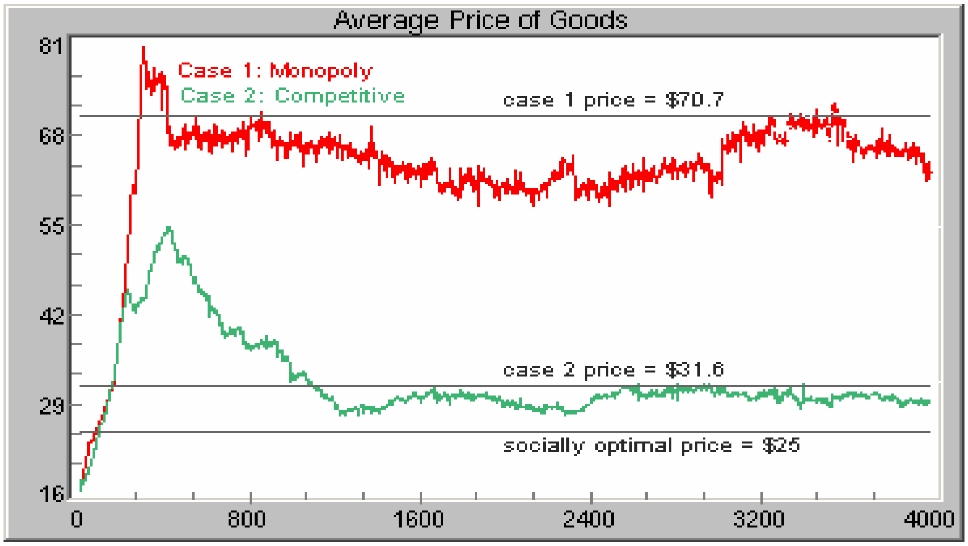

Figure 9. Competitive case: Average price.

Comparing the two cases, we find in the competitive case that firms collectively generate lower profits (about half) than in the monopoly case (Figure 10) and that they also employ more laborers and provide higher real wages to the households than in the monopoly case (Figure 11).

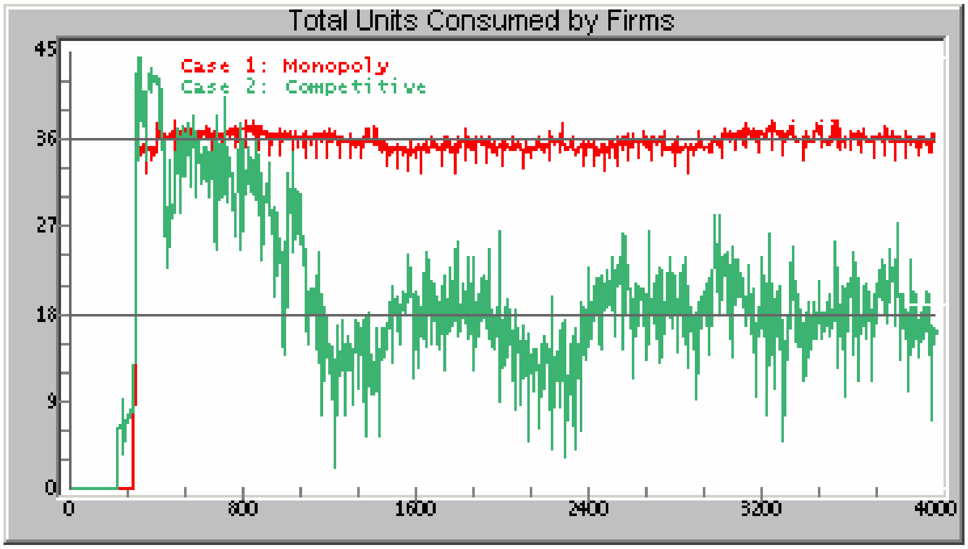

Figure 10. Competitive case: Firm profits.

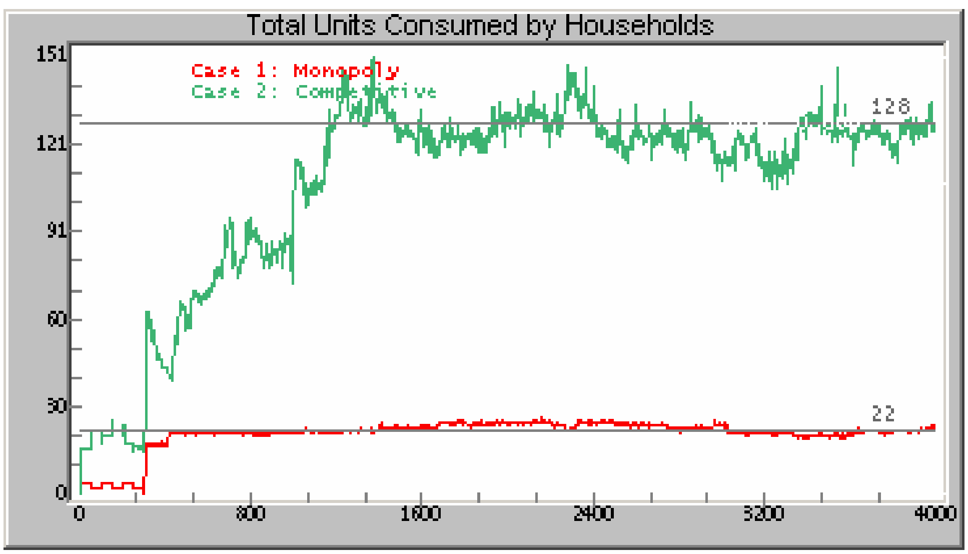

Figure 11. Competitive case: Units consumed.

We also find that under competition each household's real wage is more than double the wage earned under the monopoly case (Figure 12). In the competitive case, households retain 1.75 units per time step (87% of marginal product), compared with 0.75 units (38% of marginal product) in the monopoly case.

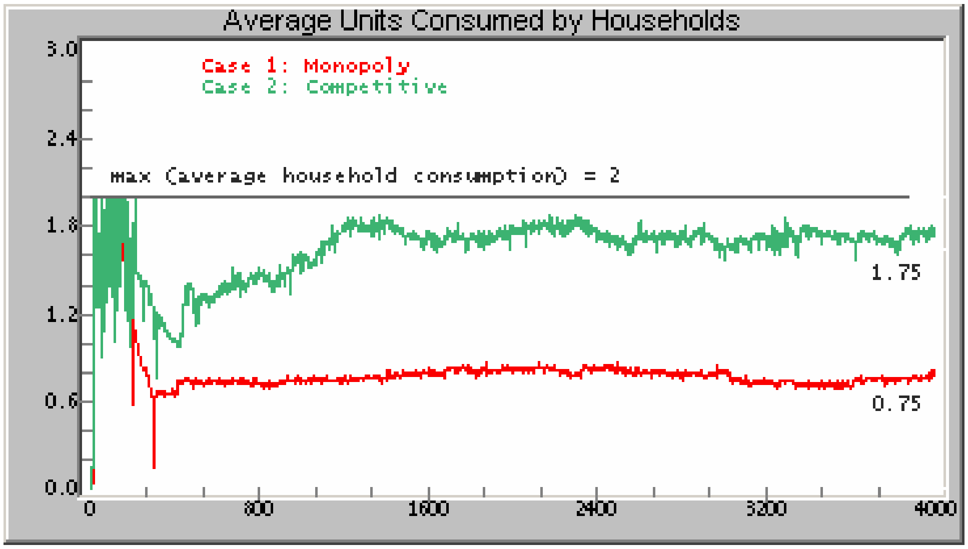

Figure 12. Competitive case: Average units consumed.

3.3 Discussion

In this economy, a fundamental role of the firm(s) is to allow households with lower-than-average personal productivities to contribute to, and get returns from, higher-productivity activities offered by firms. Per capita income increases for these lower-than-average households. Increasing the number of firms will increase the returns to households; output and employment increases, prices decrease, and households buy more goods.

In the single-firm economy, the firm gets fairly accurate short-run, if not long-run, information about the number of goods it can sell and about the available labor force. In contrast, as seen in the multiple-firm figures, the multiple-firm economy can have significant "noise" in both markets. More firms are asynchronously assuming their employment is fixed; employment shifts in and out of firms and *across* firms, making employment response difficult to interpret. Compare the total employment levels displayed previously in Figure 8: while monopoly employment quickly approaches equilibrium, the competitive employment fluctuates significantly over almost half of the time steps.

Similarly, multiple firms are trying to experiment on price and reacting to the perceived demand response to their price. If the noise created by experimentation is high, the signal-to-noise ratio will be low, making convergence to equilibrium more difficult.

Similarly, in the multiple-firm economy, as each firm is individually searching for an optimal price, the ever-changing set of prices from the *other* firms creates noise in the first firm's interpretation of the effect of its price change on its demand. This uncertainty propagates back through production, employment, and ultimately its demand again.

In this model, the firms have a memory of several time steps and use moving averages of several time steps to estimate the success of their pricing and employment choices. We also experimented with very shallow memories in which the firms looked only at the last time period. In those simulations, we often found that the firms would repeatedly overcompensate and that the markets would diverge into unexpected corner solutions. We found that simple smoothing avoids some of the divergence issues encountered in other discrete simulations (e.g., Arifovic 1994), leads to more reasonable and robust results, and probably provides a more realistic firm behavior.

Firms most directly experience the bottom-line impact of noise in their profits, which we observe in Figure 10. We can see that the monopoly profits quickly converge to equilibrium, whereas the competitive profits suffer from both short-run noise and long-run oscillations. We illustrate this contrast more precisely in Figure 13, which plots the average of the firms' standard deviation of profit (from Figure 10) for the 50 most recent time steps. We see that the average standard deviation of profit is on average seven fold higher in a competitive market than in a monopoly market.

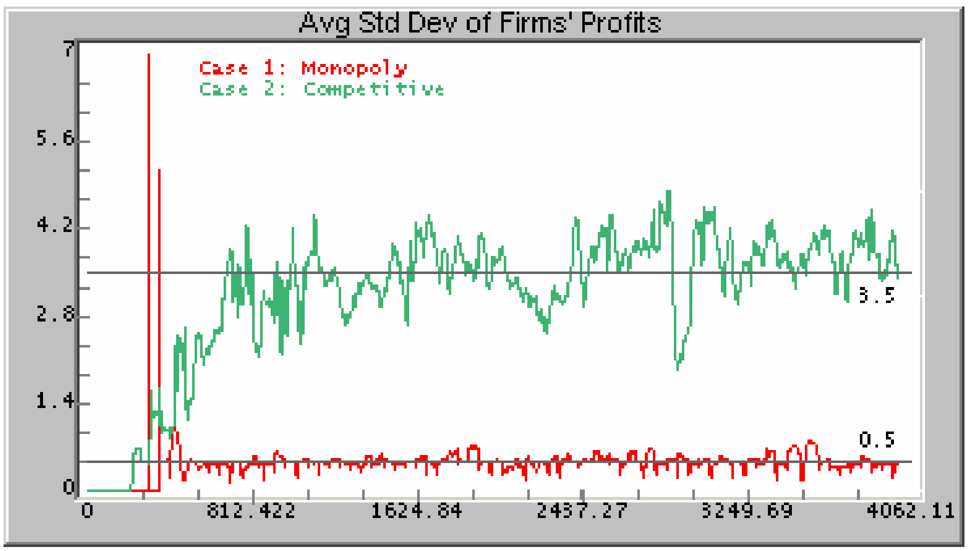

Figure 13. Variability in firms' profits: Monopoly and competitive cases.

While a terrorist attack arguably has direct impacts on households' willingness to consume particular goods (or goods at all), such an attack could also create noise in markets that could easily be interpreted as economic instability or downturn. Consider an attack where a significant fraction of firms in an industry were disabled for a period of time. Endogenously, as implied by this model, output and employment could decrease and prices could increase sharply, as the remaining firms have a clearer picture of their customer-response functions. Furthermore, as the disabled firms return and rush to regain market share, the ensuing noise in prices, output, and employment could be interpreted by still-uneasy consumers as a floundering economy, thereby perpetuating a lack of confidence and poor performance in the embattled sector. The mechanics of such perpetuating perceptions needs to be better understood.

The comparison of the two sets of simulations also illustrates how competitive markets can, given constant demand, be "self-healing": if during a disruption several firms are incapacitated, the remaining firms can use the new-found market power to increase profits, get clearer information on (an increased) demand, and stabilize until the incapacitated firms return. From this model, however, returning firms imply increased noise in goods and labor markets, creating instabilities.

In general, this work demonstrates the nature of competition and full employment in a closed economy in which income effects are pervasive and the goods' supply curve is explicitly tied to work effort. By capturing these output and employment features of the macroeconomy, we have demonstrated the appropriateness of agent-based models for microbased macroeconomic analysis, particularly the ability to define computable equilibria and analyze the conditions under which these equilibria are stable within "small" fluctuations.

4.0 Summary and Next Steps

4.1 Summary

In this report we describe an agent-based model of full employment in a productive economy. Households enter the labor force depending on the returns to working, and firms set prices that maximize profits given this level of employment. The equilibrium conditions of two specific cases were analyzed, the first in which there is a single monopoly firm in the goods market and the second in which there are five firms.

We ran simulations of these two cases, each with a distinct computable equilibrium to which the simulations converged. This comparison of single-firm and multiple-firm markets demonstrates the traditional finding that a firm that would otherwise restrict output and charge monopoly prices is forced to competitive behavior in the presence of other firms. Our model finds this to be true (1) with a *constant-returns-to-scale* production technology, which removes any effects of firm size, and (2) with constant wages, which remove any effects of labor-demand market power on the part of firms. Competition leads to higher total production and consumption, with lower total producer surplus and higher average consumer surplus. Competition, however, also increases the "noise" in markets, making it more difficult for firms to get accurate demand signals.

Comparing the two sets of simulations, competitive markets can have significant goods and labor market noise that confounds competition; one can easily imagine a firm in a socially optimal economy (see definition above) so confused by market signals that it "accidentally" fails. In the context of a terrorist attack, which is designed to propagate systemic fear and uncertainty across many people, accidental failures could be misinterpreted as terrorist-caused failures. Such false attribution, commonplace in financial markets, could perpetuate a reduction in consumer confidence throughout the economy.

4.2 Next Steps

To complete our general model of consumer confidence and terrorism-related shocks to the economy, two additional Aspen components are being developed.

Modeling Economic Confidence

Current work focuses on introducing time horizons into the decision process of both household and firm Aspen agents and on reintroducing financial markets to Aspen to better understand the role of confidence on full employment.

Modeling Economic Shocks and Adjustments

Since our Aspen simulations converge to the calculated equilibria, they provide a useful baseline for modeling the impacts of economic shocks and adjustments. In the case of shocks, we can study the behavior of an economy as it diverges from, and returns to, a known full-employment level. In the case of adjustments, we can study the transition of the economy as it moves to a new full-employment level. We also intend to model the impact of shocks on confidence and expectations as well as the secondary effect on short-run and long-run employment. As we develop increasingly complex models, we will continue to derive computable equilibria that validate agent behavior.

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