Is Lumpy Investment Relevant for the Business Cycle?

Julia K. Thomas[1]

University of Minnesota

and

Federal Reserve Bank of Minneapolis

January 2001 SENSITIVITY APPENDIX

[1]Department of Economics, University of Minnesota, 1035 Heller Hall, 271 - 19th Avenue South, Minneapolis, MN 55455; jkt@atlas.socsci.umn.edu. I am grateful to Marianne Baxter, Robert Chirinko, Robert Hall, Andrew John, Timothy Kehoe, Aubhik Khan, John Leahy, Edward Prescott, Stanley Zin, and, in particular, Robert King for helpful comments and suggestions. I also thank participants in seminars at the Board of Governors, Boston College, Calgary, Carnegie Mellon, Federal Reserve Bank of Philadelphia, GSB-Chicago, Houston, Minnesota, Virginia, the Wharton School, the February 1999 NBER Economic Fluctuations and Growth meetings, the 1999 Midwest Macroeconomics, Society for Economic Dynamics and NBER Summer Institute meetings, as well as two anonymous referees. Any remaining errors are my own.

Appendix

(available from author upon request)

Robustness

In this appendix, I explore the sensitivity of my results to changes in parameter sets and functional forms. The nine panels of tables 7 and 8 revisit the results of tables 3 and 4 under sensitivity experiments within three broad categories. First, as the sole difference in the lumpy investment versus benchmark neoclassical environments arises from underlying fixed costs of capital adjustment, I consider four alternatives for these costs. Panel 1 provides results under a ten-fold rise in the upper support for the cost distribution, while panels 2 and 3 correspond to alternative curvature properties, replacing the linear CDF of the uniform distribution with a concave ($\Psi = -1.5$), then convex ($\Psi = -.25$) curvature assumption. In panel 4, the denomination of costs in labor units is replaced by direct output costs, with trend growth eliminated to prevent plants outgrowing their effects.

Results for the benchmark versus state-dependent adjustment economies' quantities remain quite close in each of these four panels. Their differences are most pronounced when the upper support is raised, but even these are on the order of one percent. In this case, the maintained similarity is achieved by a marked reduction in interest rate volatility in the state-dependent adjustment economy, with its relative variance falling about 8.5 percent below that in the benchmark economy. While the constant adjustment economy generally continues to exhibit close dynamics, its performance is most affected in the cases of raised upper support and convex curvature. In these instances, the steady-state plant distribution has much greater dispersion than previously, with about 50 percent of plants operating with capital aged 3 years or beyond, and long delays until full adjustment. (In the $B = .02$ case, maximum delays to investment rise from 5 to 22 years, and only 15 percent of plants invest each year.) The associated reduction in steady state adjustment fractions of low-numbered plant groups makes changes in adjustment timing more central to the dynamics of the state-dependent adjustment economy, and leaves the constant adjustment model more constrained by its fixed adjustment hazard than before. Consistent with this reduced flexibility in investment demand, constant adjustment interest rates become much less volatile, with a 57 percent reduction in variability relative to the benchmark. Similar features hold in table 8, where the greatest difference across the benchmark and state-dependent adjustment economies is a stronger interest rate - output correlation in the latter.

Panels 5-7 represent alternative specifications for momentary utility, allowing for variations in the representative household's elasticities of intertemporal substitution and labor supply. The former is achieved by adopting Rogerson and Wright (1988) preferences, which allow for variations in σ while maintaining the indivisible labor assumption. For the latter, momentary utility is replaced by $u(c, L) = \log(c) + s_{\mathsf{L}} \log(L)$. In each instance, the discount factor and the parameter governing the preference for leisure are allowed to adjust so that the steady state interest rate is maintained at 6.5 percent and steady state hours remain at $N = .20$.

When the intertemporal elasticity of substitution is varied from unity in panels 5, ($\sigma = .5$,) and 6, ($\sigma = 2$), the distinctions in aggregate quantity dynamics remain essentially imperceptible for benchmark and state-dependent adjustment economies, with the constant adjustment economy following closely behind. The greatest differences continue to occur with respect to interest rates, with constant adjustment exhibiting about 30 percent less variability than the benchmark in the $\sigma = .5$ case. In panel 7, divisible labor ($\eta < \infty$) has predictable consequences in dampening the cycle and raising wage variability. For our purposes, reduced labor supply responsiveness is relatively more constraining for the economies with flexible investment timing, narrowing differences in outcomes for the constant adjustment model relative to the other two models.

The final two panels vary capital's share of output, γ, while holding labor's share constant at $\nu = .58$. While this alters both capital's relative importance in production and the degree of plant-level returns to scale, results in panels 8 and 9 reveal that the latter has the greater effect. Specifically, as plant-level returns fall farther away from one ($\gamma = .2$), the effectiveness of the trade-off between intensive and extensive margin adjustment is reduced. While the state-dependent adjustment economy simply relies more heavily on changes in the number of investors to keep pace with the benchmark economy's dynamics, there is no such possibility when adjustment rates are fixed. Thus, under constant adjustment, with the earlier onset of diminishing returns for each investing plant, the cycle is more dampened, and interest rates are substantially less volatile, relative to the other two economies.

Three conclusions may be drawn from this discussion. First, the comparative results of the paper are generally robust. The lumpy-investment economy with state-dependent adjustment rates remains resilient in its ability to reproduce the cyclical behavior of the benchmark economy. Second, in each instance, differences in interest rate dynamics are largely responsible for these similarities in quantities. Third, in some cases, (panels 1, 3, and 8,) quantity gaps between the constant adjustment economy and the benchmark grow in importance, accompanied by substantially greater differences in price behavior. We may infer from this that, under some specifications of adjustment costs and technology, changes in plant-level investment timing become more central in maintaining sufficient flexibility in investment demand as to allow the state-dependent adjustment economy's close match with the benchmark.

Table A-1: Relative Standard Deviations under Alternative Parameter Sets*

			Y	I	N	C	w	r
	cost cdf	**B**	1.85	3.303	0.577	0.492	0.492	0.096
1)	**B=.02**	**SD**	1.84	3.279	0.567	0.496	0.496	0.089
		CA	1.75	3.040	0.506	0.534	0.534	0.061
	cost cdf	**B**	1.85	3.303	0.577	0.492	0.492	0.096
2)	Y**= -1.50**	**SD**	1.85	3.304	0.576	0.492	0.492	0.095
		CA	1.82	3.226	0.556	0.503	0.503	0.083
	cost cdf	**B**	1.85	3.303	0.577	0.492	0.492	0.096
3)	Y**= -.25**	**SD**	1.86	3.323	0.579	0.489	0.489	0.095
		CA	1.77	3.104	0.524	0.522	0.522	0.067
	cost unit	**B**	1.86	4.089	0.579	0.491	0.491	0.096
4)	x **from Y**	**SD**	1.85	4.086	0.579	0.491	0.491	0.095
		CA	1.82	3.965	0.554	0.504	0.504	0.080
	prefs	**B**	1.81	4.656	0.537	0.492	0.593	0.081
5)	s **=0.5**	**SD**	1.81	4.665	0.536	0.493	0.594	0.079
		CA	1.75	4.374	0.494	0.463	0.606	0.063
	prefs	**B**	1.88	2.537	0.597	0.631	0.431	0.106
6)	s **=2**	**SD**	1.88	2.532	0.595	0.632	0.432	0.104
		CA	1.86	2.513	0.587	0.636	0.438	0.095
	prefs	**B**	1.68	3.242	0.449	0.503	0.594	0.098
7)	h**(N)**	**SD**	1.68	3.243	0.448	0.504	0.594	0.097
	finite	**CA**	1.66	3.176	0.435	0.513	0.603	0.085
	k-share	**B**	1.72	4.428	0.483	0.585	0.585	0.086
8)	g**=.20**	**SD**	1.72	4.433	0.482	0.585	0.585	0.083
		CA	1.66	4.137	0.440	0.608	0.608	0.056
	k-share	**B**	1.93	2.853	0.625	0.445	0.445	0.101
9)	g**=.41**	**SD**	1.93	2.852	0.625	0.445	0.445	0.100
		CA	1.92	2.836	0.619	0.448	0.448	0.098

* The first column of reported values, headed "Y", gives percent standard deviations for output in the benchmark, state-dependent adjustment and constant adjustment models for each alternative parameter set. The remaining columns are standard deviations relative to the standard deviation of output. An H-P filter, with weight 100, has been applied to each model.

Table A-2: Contemporaneous Correlations with Output under Alternative Parameter Sets*

			I	N	C	w	r
1)	cost cdf B=.02	B	0.973	0.946	0.924	0.924	0.889
		SD	0.974	0.948	0.932	0.932	0.899
		CA	0.981	0.960	0.964	0.964	0.914
2)	cost cdf Y= -1.50	B	0.973	0.946	0.924	0.924	0.889
		SD	0.973	0.946	0.925	0.925	0.892
		CA	0.976	0.950	0.938	0.938	0.904
3)	cost cdf Y= -.25	B	0.973	0.946	0.924	0.924	0.889
		SD	0.974	0.947	0.924	0.924	0.895
		CA	0.980	0.957	0.957	0.957	0.912
4)	cost unit x from Y	B	0.968	0.945	0.922	0.922	0.891
		SD	0.968	0.945	0.923	0.923	0.895
		CA	0.972	0.950	0.940	0.940	0.908
5)	prefs s =0.5	B	0.919	0.872	0.392	0.896	0.805
		SD	0.919	0.872	0.390	0.897	0.810
		CA	0.931	0.887	0.529	0.927	0.832
6)	prefs s =2	B	0.993	0.980	0.993	0.962	0.931
		SD	0.993	0.981	0.993	0.963	0.933
		CA	0.993	0.982	0.994	0.967	0.941
7)	prefs h (N) finite	B	0.973	0.945	0.932	0.969	0.893
		SD	0.973	0.946	0.932	0.969	0.896
		CA	0.976	0.950	0.943	0.974	0.908
8)	k-share g=.20	B	0.953	0.923	0.948	0.948	0.802
		SD	0.953	0.923	0.949	0.949	0.808
		CA	0.963	0.936	0.967	0.967	0.800
9)	k-share g=.41	B	0.980	0.954	0.907	0.907	0.917
		SD	0.980	0.954	0.907	0.907	0.918
		CA	0.981	0.955	0.912	0.912	0.920

* B: Benchmark; SD: State-dependent adjustment; CA: Constant adjustment.