Table 1: Growth in Output and the Factors of Production					
average annual growth rates					
	87-10	87-95	95-00	00-07	07-10
Output	2.8	2.9	4.9	2.6	-0.8
Capital	1.8	1.9	2.4	1.8	0.8
Hours	0.5	1.4	2.0	0.0	-3.2
Output per Hour	2.3	1.5	2.9	2.6	2.4
Capital per Hour	1.3	0.5	0.4	1.8	4.0
"Technology"	1.8	1.3	2.8	2.1	1.0
comprising					
Multifactor Productivity	1.0	0.5	1.5	1.4	0.5
Labor Composition (sc)	0.3	0.4	0.2	0.2	0.5
Capital Composition (sc)	0.5	0.4	1.0	0.4	0.1

The Bureau of Labor Statistics has a Multifactor Productivity program that models output using a production function very much like the one we have used in our study of the long run. (Estimates are produced for many industries; those above are for the largest aggregate available, called the Private Business Sector, which is not quite as comprehensive as total economy GDP.) One difference is that the labor input is hours worked, rather than just the number of workers. (So instead of looking at living standards – i.e. output per person or worker – directly, we are looking at labor productivity. Living standards can be decomposed into labor productivity and some labor market and demographic variables, with labor productivity being by far the most important component.) Another difference is that the labor and capital inputs are adjusted for "composition". This results from an attempt to give more productive workers and more productive types of machinery more weight in the construction of the overall input indexes. Multifactor productivity is then calculated residually as the part of output that is not accounted for by the two inputs and their compositions. The two composition components and multifactor productivity would all be soaked up in one way or another by our "technology" variable *A*. This is appropriate in a sense, since increases in the composition/quality of capital can reflect technological improvements embodied in new equipment, while increases in the composition/quality of labor can reflect an increase in hours worked by those with specialized training and those who are organized in such a way as to take the best advantage of the technological paradigm. (It's not standard to conceptually lump the three things together like I'm doing, but it will serve our purposes here adequately.)

Notice that the growth rates for output per hour are equal to the growth rates for output minus the growth rates for hours. This corresponds with the growth rate rules we talked about in class. (I fudged the calculations of the growth rates a tiny bit so that this approximation should, for the most part, work exactly to one decimal place.) Likewise for capital per hour.

Over the entire 1987-2010 period for which data are available, output per hour grew at 2.3 per cent per year, the capital-labor ratio grew at 1.3 per cent per year, and the composite “technology” measure grew at 1.8 per cent per year. The full Solow model that we studied predicts that, when the economy is in its steady state, the growth rate of output per worker (and also the growth rate of capital per worker) will be equal to the growth rate of technology. That prediction is therefore not borne out in the data. Why? There could be a lot of reasons. For one, it’s possible (even likely) that the economy is not in a steady state, but is rather converging slowly but steadily to one. At the same time, our model (even if we were to incorporate the more comprehensive production function used by the BLS) probably misses a lot of relevant aspects of reality. For one thing, our assumption of fixed, exogenous growth rates of labor and technology is a stringent one. It is likely that, in contrast, many aspects of individuals’ decisions and behavior affect the factors of production and the technological paradigm simultaneously.

Nonetheless, it is often the case that growth in “technology” (broadly conceived) is close to output per hour growth. For the overall 1987-2010 period, growth in the composite technology measure accounted for about 81% of growth in output per hour (i.e. 1.8 percentage points of the 2.3 per cent per year growth rate of output per hour over this period). (The rest of growth in output per hour is accounted for by growth in capital per hour, which needs to be scaled by a parameter from the production function to get everything to add up correctly; but this involves details that we don’t need to get into here.) In the 1995-2000 sub-period, which was a time of rapid growth and is often referred to as the dawning of the “new economy”, technology growth accounted for over 95% of growth in output per hour. (During this sub-period, capital composition was growing especially rapidly, indicating that the large contribution from technology was being driven to a large extent by technological change embodied in capital investments. This corresponds with the large investments in IT machinery, equipment, and software that many businesses were making at this time.)

A couple of other interesting little things can be pointed out. First, output-per-hour growth was actually quite robust during the recessionary sub-period of 2007-2010. In contrast, on the GDP per capita and household income graphs, there were clear drops over this period. The difference can be explained by the use of hours in the present tables. Falling output and rising population mean that GDP per capita must fall; but falling output can be associated with rising output per hour as long as the drop in hours worked is large enough, which it certainly was in this case. The implication of the population rising at the same time that total hours worked were falling is that average hours and/or the proportion of the population employed must have been falling a lot over this sub-period, both of which do usually occur in recessions.

Second, even though hours fell a lot over this sub-period, labor composition grew at a fairly substantial pace. This suggests that those who lost their jobs or worked fewer hours than usual were primarily those receiving less weight in the calculation of the overall input indexes. As alluded to above, the weights are motivated by a desire to reflect the differing productivities of various groups of workers; so workers receiving a low weight are those identified as being less productive. This often includes workers with low education, skills, and training, who, it is reasonable to suppose, come disproportionately from low-income households. In other words, it looks like workers with lower incomes were the first to lose their jobs and/or working time in the most recent recession. This is all in line with the observation suggested by the graph on household incomes: low-income households suffer to a greater degree than other households during recessions (at least in terms of their market income before adding any income received through government transfers).

If you're curious about these data and methods, besides checking out the documentation provided by the BLS, you might also be interested in the classic book *Productivity and U.S. Economic Growth* by Dale Jorgenson, Frank Gollop, and Barbara Fraumeni, and a more recent discussion of sources of growth, "A Retrospective Look at the U.S. Productivity Growth Resurgence", by Dale Jorgenson, Mun S. Ho, and Kevin Stiroh (*Journal of Economic Perspectives*, Winter 2008).

Note: All calculations were based on the indexes of real value added, total hours, productive capital stock, labor composition, capital composition, and multifactor productivity, as well as the labor and capital shares, provided by the Bureau of Labor Statistics in the detailed tables corresponding with the Multifactor Productivity Trends, 2010 news release of March 21, 2012. Percentage growth rates have been approximated by log differences.