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Electricity Use as an Indicator of U.S. Economic Activity

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Abstract[1]

We argue for the resurrection of an old idea: electricity use as an indicator of U.S. economic activity. Our analysis relies on associations–the 40-year correlation between growth rates in real GDP and electricity use can be as high as 89% –and intuition. Electricity use and economic conditions should move together. The vast majority of goods and services are still produced using electricity; services may require less electricity, but they still require some. Electricity use also has other strengths –it is broad-based and the data are available weekly, possibly hourly by 2015.

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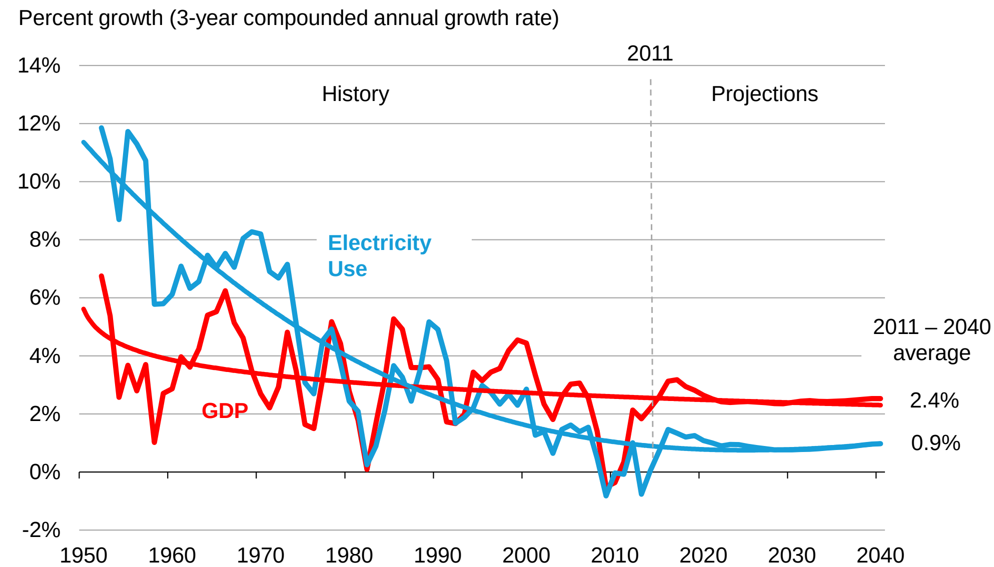
Introduction

Rising and falling weight is an important indicator of overall health when considered together with nutrition and physical activity. Increases and decreases in electricity use should serve a similar role for the economy. But this no longer seems to be the case [Figure 1]. Nick Akins, Chief Executive of American Electric Power, calls it a new world –electric utility executives have had to abandon their century-old assumption that the use of electricity tracks overall economic conditions (Smith, 2014). Has the relationship between electricity use and U.S. economic activity changed to the point where one is no longer informative about the other?

Figure 1. U.S. electricity use and economic growth, 1950-2040



Source: EIA, Annual Energy Outlook 2013

In this paper we show that the relationship still exists. Although it has changed over time, there remains a strong correlation between growth in electricity use and gross domestic product (GDP). Electricity use also moves with other economic statistics such as employment and sales during U.S. recessions. Based on these associations we argue for the return of an old idea, using electricity as an indicator of U.S. economic activity. Electricity use also has other strengths –it is broad-based, as electricity is vital to the production of goods and services throughout the economy; and the data is available weekly, possibly hourly by 2015.

Electricity use and economic conditions should move together: electricity is needed to produce the vast majority of goods and services. Just as 3D printers need energy to make necklaces, so do natural gas traders need it to power the computers they use to buy and sell futures contracts. It is the difficulty in accounting for how that use has changed over time–due to government regulations, improvements in production processes, and better energy efficiency–that makes comparisons between changes in electricity and GDP difficult.

Difficult but not impossible. As divergent as the series in Figure 1 appear, there is still a correlation of over 66% from 1950-2013. Beginning the series in the mid-1970s, after much of the transition from an industrial to a service-based economy was underway, the correlation rose to over 76%. Moving to monthly data, varying the electricity use series, and accounting for changes in energy intensity over time can increase this correlation to nearly 90%. Certainly, correlation is not causation –but 40 years sure is a hint; a hint that electricity use can be an indicator of current U.S. economic activity.

This is common for developing countries, where economic data are not believed to be reliable.[2] Yet, it is rarely used in this context in developed countries, particularly the United States. For example, the business cycle dating committee of the National Bureau of Economic Research (NBER) uses personal income, employment, industrial production, and manufacturing and trade sales in dating expansions and contractions of the U.S. economy.[3] Various Federal Reserve Banks and the Conference Board have also created indexes out of these and other economic variables to serve as indicators, and none consider electricity use.

If other direct statistics of economic activity are available, why look at an indirect one such as electricity use? Three reasons: it is comprehensive, available weekly, and makes use of energy data. No other indicator, with the exception of GDP or gross output (GO), has such broad coverage of the economy. Electricity use data is available with a two month delay from the Electric Power Monthly (EPM) of the U.S. Energy Information Administration (EIA).[4] This can be supplemented with weekly data from the Edison Electric Institute (EEI).[5] And EIA hopes to make hourly electric use data available during 2015. Finally, to our knowledge none of the popular indicators or indexes of economic activity consider energy. There may be important information available in energy data that is otherwise missed.

In the remainder of this paper we expand on these ideas. We begin by showing that electricity use and U.S. GDP are still related, and then compare electricity use with standard economic indicators around recessions dated by the NBER. We then outline our methods, describe the data, and provide some examples before concluding with suggestions for future research.

Electricity use and real GDP

Real GDP is one of the broadest measures of economic activity available. Although imperfect, it attempts to quantify the value of all market-based production of goods and services in the U.S. economy every quarter. Because producing the vast majority of goods and services requires electricity, movements in electricity usage should correspond to growth and contraction of the economy.

The difficulty is that electricity use also changes for other reasons, primarily because the structure of the economy evolves, but also due to seasonal variation when looking at quarterly or monthly data. Such recent changes have led some to conclude that electricity use is no longer informative about economic conditions. In this section we show that the co-movement between growth electricity use and real GDP is still strong.

Sample period and measure of electricity use

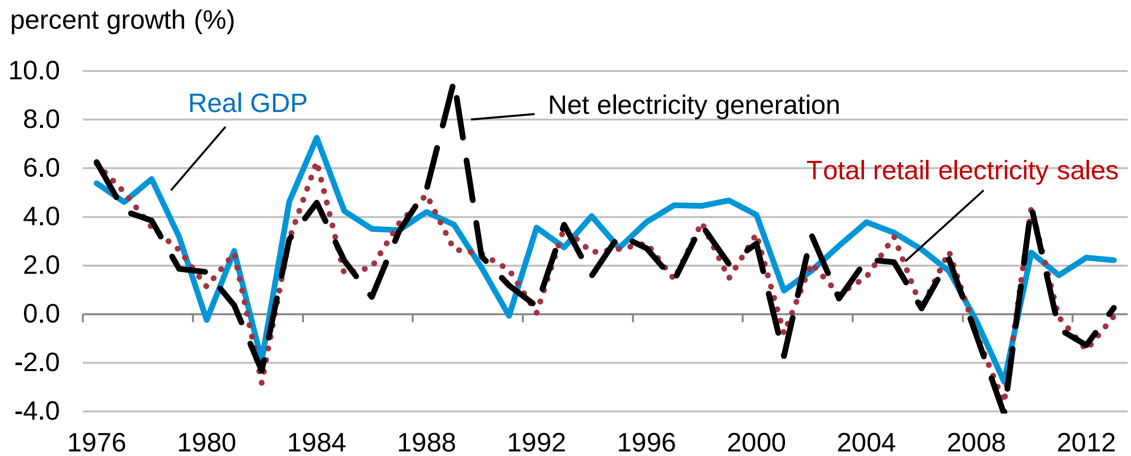
The structure of the U.S. economy is much different today than in 1950, when Figure 1 begins. In 1950 services accounted for roughly 60% of real GDP, today that value is closer to 80% (Buera and Kaboski, 2012). These changes are reflected in the declining trend of electricity use –over time the same growth

[2] China stands out here, see for example: http://blogs.wsj.com/chinarealtime/2014/01/20/what-chinas-electricity-usage-says-about-growth/.
[3] See http://www.nber.org/cycles/recessions.html for details on each variable.
[4] See http://www.eia.gov/electricity/monthly/.
[5] A subscription is required, see http://www.eei.org/Pages/default.aspx.

in real GDP has been associated with smaller growth in electricity. It takes less electricity to produce an architectural plan that sells for $10000 than it does to produce a vehicle of the same value.

But the steepest falls in the trend growth rate of electricity use occurred during the 1950s and 1960s as the share of services in the U.S. economy began to grow. Eliminating this time period removes the largest differences between the series [Figure 2, real GDP and net electricity generation]. Although they do not move perfectly together [the correlation from 1976-2013 is 66%], there is no longer a clear divergence in the trends. The service share of the U.S. economy continued to increase until the turn of the century, suggesting that the largest modifications in the relationship between electricity use and GDP occurred in the 1950s, 1960s, and early 1970s.

Figure 2. U.S. electricity use and economic growth, 1976-2013



Source: EIA, BEA

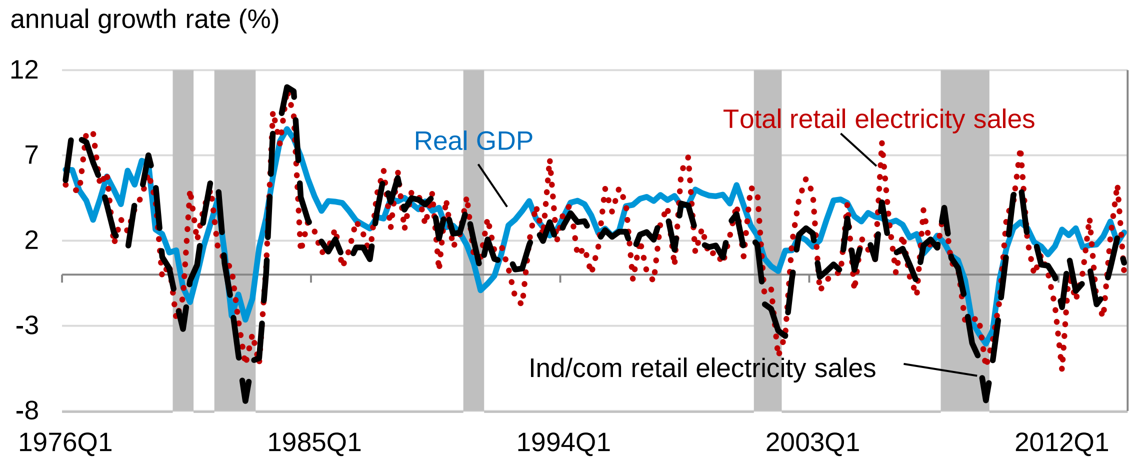
Figure 2 also distinguishes between the series standing-in for electricity use. Retail electricity sales are an alternative to the net electricity generation series plotted in Figure 1. Retail sales have a stronger annual correlation with growth in real GDP than net generation since the mid-1970s, at over 76%. Because of this we use retail electricity sales from this point forward. However, the final results using net electricity generation are not substantially different from those based on retail sales in most instances. We also show the results beginning in 1976 to use as much data as possible. But beginning in later time periods only improves the correlations shown below.

End-use sectors and seasonality

Annual data makes it is easier to pick out trends, but not necessarily to relate economic activity with electricity use. Most commonly-used indicators of economic activity are available monthly, and real GDP is available quarterly. Electricity use data is also available monthly, and Figure 3 plots growth in total retail electricity sales against growth in real GDP since 1976.[6] The electricity data are annual growth rates calculated based on quarterly averages of the monthly data.

[6] The monthly electricity retail sales data is available starting in 1975.

Figure 3. U.S. electricity use and economic growth, 1976Q1-2014Q2, recessions shaded



Source: EIA, BEA

The total retail electricity sales series is more volatile than real GDP since the 1970s. Interestingly, the correlation falls to 55% from 1976-2014Q2 (Table 1; it is 76% using annual data from 1976-2013).

Table 1. Electricity use correlations with real GDP, 1976Q1-2014Q2

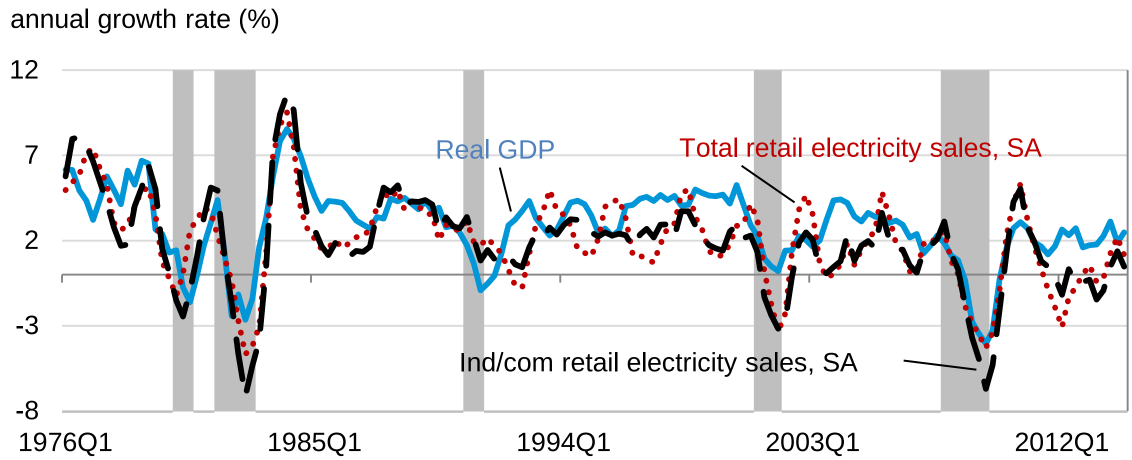
Electricity use series	Contemporaneous	Electricity use lagged 1 quarter	Electricity use lagged 2 quarters
Total, no adjustment	0.55	0.53	0.41
Industrial/Commercial, no adjustment	0.77	0.68	0.47
Total, seasonally adjusted	0.66	0.62	0.49
Industrial/Commercial, seasonally adjusted	0.80	0.70	0.49
Total, intensity and seasonally adjusted	0.86	0.77	0.60
Industrial/Commercial, intensity and seasonally adjusted	0.89	0.78	0.56

Source: EIA.

This association can be improved by using only retail electricity sales from the industrial and commercial sectors [Figure 3]. Because most electricity use associated with economic activity occurs in these sectors, it appears to give a clearer picture of economic activity. With this switch the correlation jumps to nearly 78%. And the correlation when growth in industrial/commercial electricity use lags that in real GDP by one quarter is over 68%.

Calculating annual growth rates in electricity use simultaneously removes any trend in the series and seasonal movements. Yet it is possible that information is lost because seasonal changes are treated the same as variations due to economic activity. An alternative is to seasonally adjust the data first, average the monthly data to quarterly, then calculate annual growth rates. With seasonal changes removed, the idea is that any movements around the trend growth of electricity sales reflect economic activity [Figure 4]. We seasonally adjust both electricity series using regression analysis (as described in the Method, Data, and Illustration section below).

Figure 4. U.S. electricity use and economic growth, 1976Q1-2014Q2, recessions shaded



Source: EIA, BEA

Seasonally adjusting the total retail electricity sales series before calculating annual growth rates reduces its volatility. It also improves its correlation with growth in real GDP up to 66% –still below the value with annual data, but a substantial improvement from the case where no seasonal adjustment is made before calculating growth rates. The correlation between growth in industrial/commercial retail electricity sales and real GDP improves slightly as well because of seasonal adjustment, from 78% to 80%. Because of these improvements we use only the series that are seasonally adjusted below.

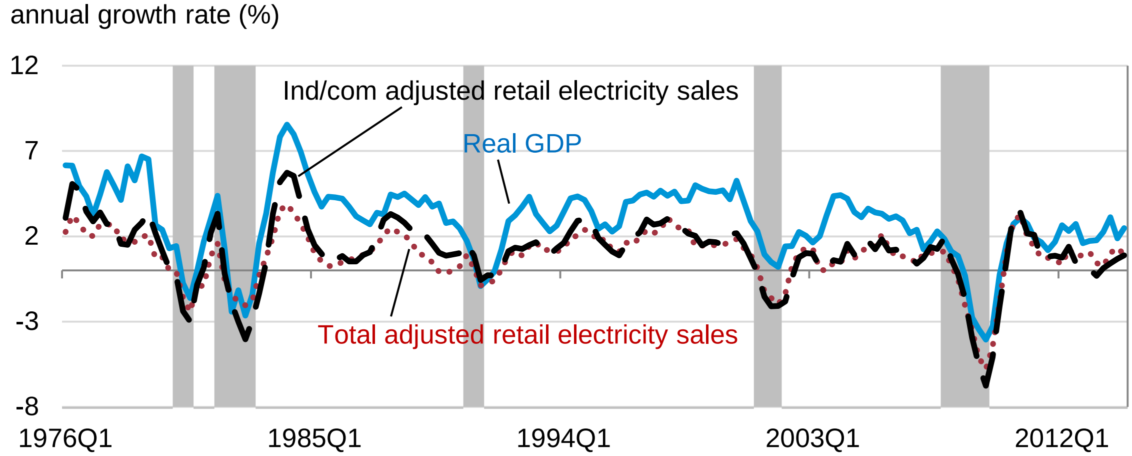
Accounting for electricity intensity

The adjustments made to this point show how the correlation between measures of growth in electricity use and real GDP can be improved. They have not, however, attempted to account for how electricity use has changed throughout the U.S. economy over time.

The most direct way to get at such changes is through electricity intensity –the ratio of electricity use to a measure of production. Variations in electricity intensity over time reflect the changing nature of electricity use in the economy, whether due to government regulations, improvements in production processes, or better energy efficiency.

Figure 5 shows annual growth rates of the retail electricity series after accounting for electricity intensity (and seasonally adjusting the series as above). This is done using regression analysis (as described in the Method, Data, and Illustration section below). The electricity intensity measure we use is the ratio of total retail electricity sales to industrial production in the U.S. manufacturing sector. We chose this measure because it is available monthly, and that it focuses on the use of electricity in an energy-intensive sector of the U.S. economy over time.

Figure 5. U.S. electricity use and economic growth, 1976Q1-2014Q2, recessions shaded



Source: EIA, BEA

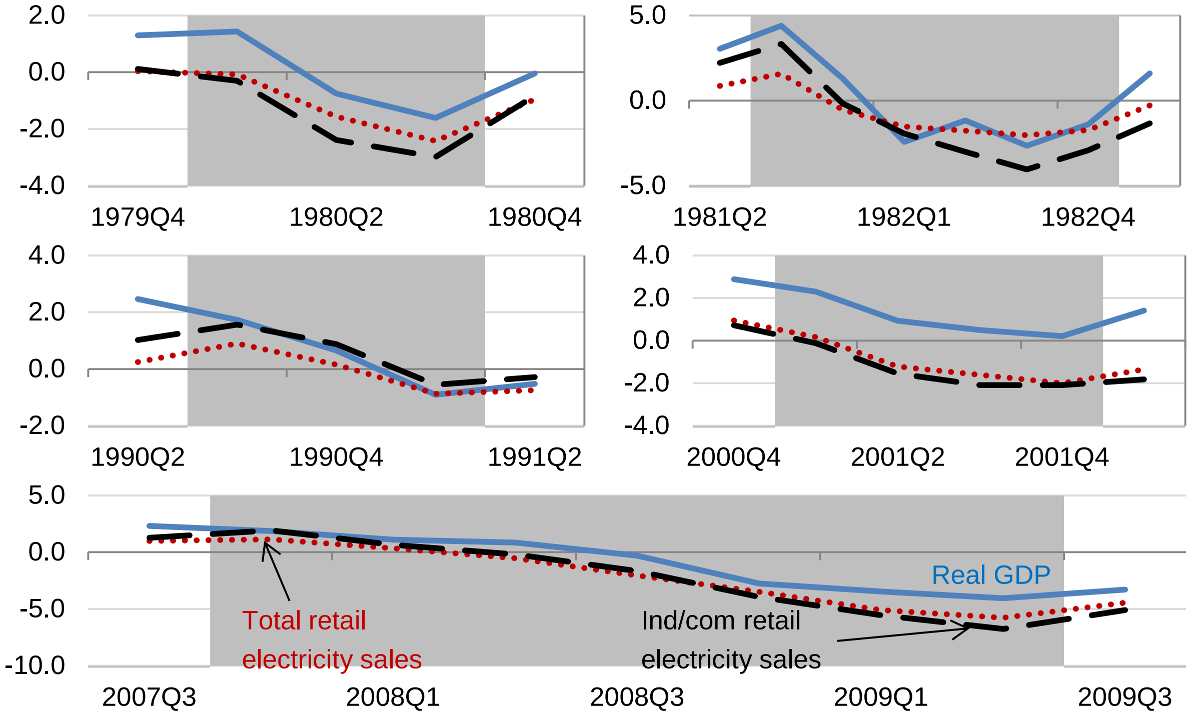
The adjustment for energy intensity substantially improves the correlation between growth in real GDP and electricity use, irrespective of the series. The correlation between total retail electricity sales and real GDP jumps to 86%; it is 89% between industrial/commercial electricity sales and real GDP. The lagged correlations also stand out [Table 1]. With either electricity use series lagged one quarter, the correlations are just below 80%, and even lagged two quarters they are around 60%.

Recessions

Correlation between electricity use and GDP during normal times is all well and good –but do they move together during downturns in the economy? Figure 6 shows that they do, at least during the previous five NBER-dated recessions (shaded).

In each of the past five recessions annual growth in both total and industrial/commercial retail electricity sales has moved closely with annual growth in real GDP. It also appears that growth rates in both electricity use series turn up before the end of each recession. They turn down once the recession has begun, with the exception of the recession that began in 2001.

Figure 6. U.S. electricity use and economic growth during the last five NBER-dated recessions

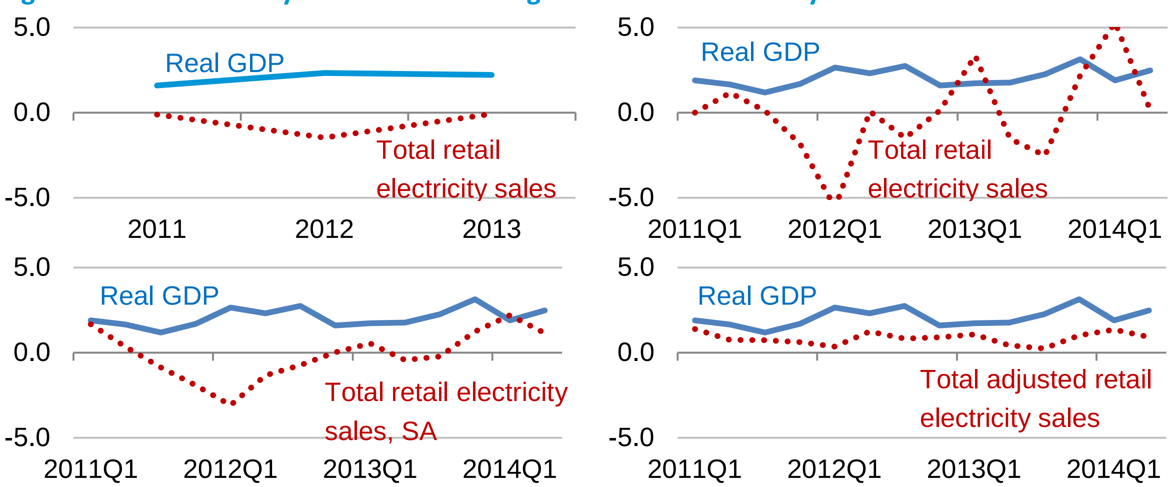


Source: EIA, BEA

Recent history

Few dispute the well-documented relationship between growth in electricity use and real GDP in the past. But the concern is with recent changes in this relationship, in the way that electricity is now used throughout the U.S. economy. Figure 7 shows growth in real GDP and various total retail electricity series from 2011 to the second quarter of 2014 using the same scale (annual data ends in 2013).

Figure 7. U.S. electricity use and economic growth in recent history



Source: EIA, BEA

The top-left panel plots the annual data with no adjustments made to retail electricity sales. There does appear to be a divergence in the growth rates, although sales do turn up in 2013. Moving to unadjusted annual data (top-right panel) adds more volatility, and a clear separation between the series disappears.

Seasonally adjusting the data before calculating growth rates (bottom-left panel) reduces some of this volatility in recent retail electricity sales, and does not reflect a clear divergence. The series move apart in 2012 but come back together by 2014. Adjusting for energy intensity as well as seasonality (bottom-right) shows a steady relationship between growth in retail electricity sales and real GDP.

Summary

We have documented the association between growth in electricity use and real U.S. GDP annually since 1950, and quarterly since 1976. In terms of the annual data, excluding the 1950s, 1960s, and early 1970s, and substituting retail electricity sales for net electricity generation improves the correlation between growth in electricity use and real GDP by ten percentage points.

The correlations based on monthly data are higher when the electricity use series are first adjusted. Instead, if annual growth rates are calculated on the original data, co-movement between growth in total retail electricity sales and real GDP falls substantially. This can be improved by using only industrial and commercial retail electricity sales, and further gains are possible by first seasonally adjusting either series and then calculating annual growth rates.

The strongest correlations, however, result from adjustments for both seasonal variation and energy intensity. Using the ratio of total retail electricity sales to industrial production in the manufacturing sector as the measure of energy intensity raises the correlations above 86%, up to 89% for industrial and commercial retail electricity sales.

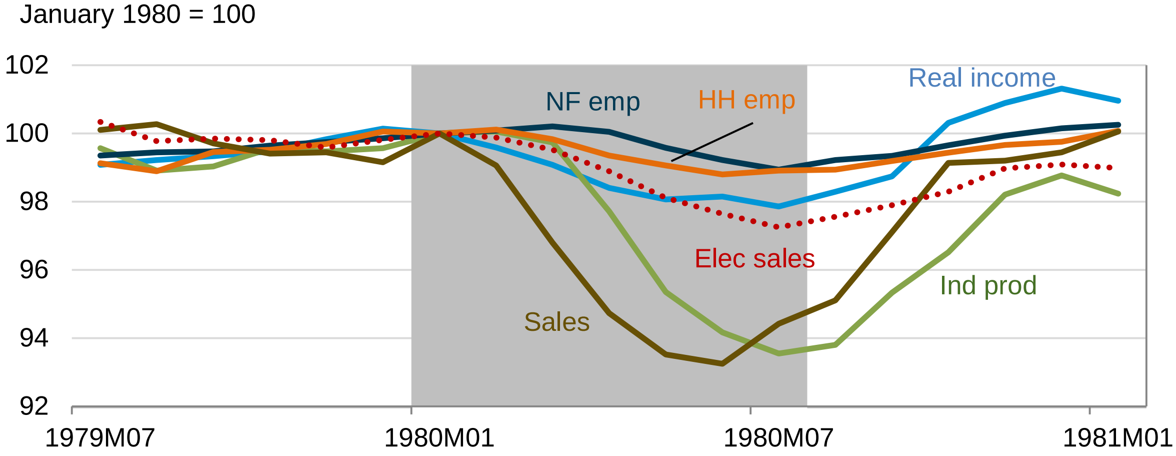
In addition, in each of the past five recessions annual growth in both total and industrial/commercial retail electricity sales has moved closely with annual growth in real GDP. Finally, growth rates of the adjusted total retail electricity sales series do not appear to diverge from real GDP in recent history.

Electricity use and other coincident indicators

Real GDP is the most commonly-used economic indicator, but it is only available quarterly and released with some delay. There are many other standard indicators which are available monthly (or even weekly), and in this section we compare some of these with total retail electricity sales (Elec Sales) during the last five U.S. recessions.

The statistics we use are traditional coincident indicators, those that the NBER considers when dating business cycles: real personal income (real income), household and non-farm employment (HH Emp, NF Emp), industrial production (Ind Prod), and manufacturing and trade sales (Sales). The next five figures show the behavior of these variables and total retail electricity sales six months before, during, and six months after recessions using spider charts (Lahiri and Yao, 2012). In these charts the value of each series is normalized to 100 at the peak of the business cycle as determined by the NBER committee (NBER, 2014).

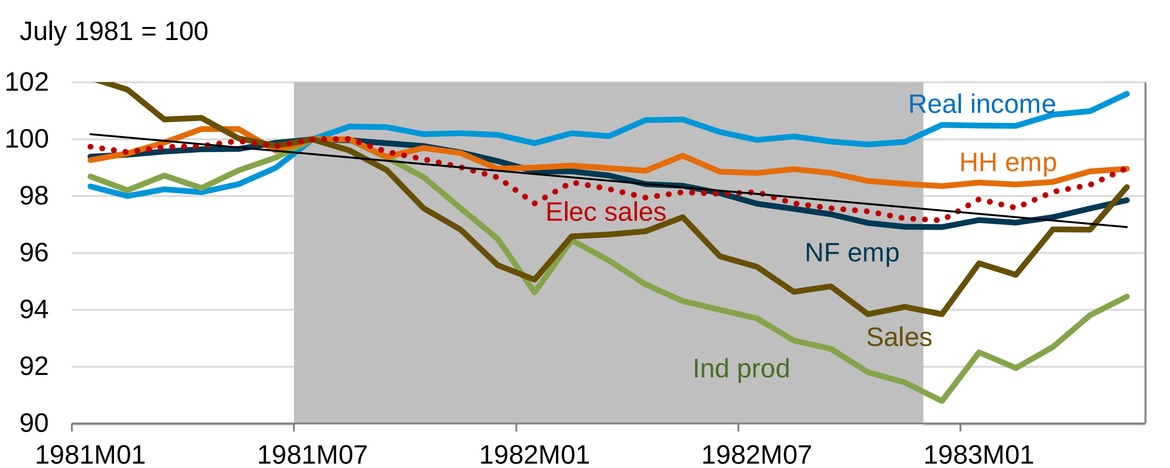
Figure 8. Coincident indicators before, during, and after recession (shaded) dated January to July 1980



Source: EIA, BEA, BLS, Federal Reserve, NBER

During the recession that began in 1980, electricity sales had a similar shape to household employment towards the beginning, but moved more like real personal income towards the end [Figure 8]. The depth of the fall in retail electricity sales is between that of the employment and income series and those for manufacturing and trade sales and industrial production. During the 1981 recession, retail electricity sales moved almost exactly with non-farm employment, similar to the shape of household employment [Figure 9].

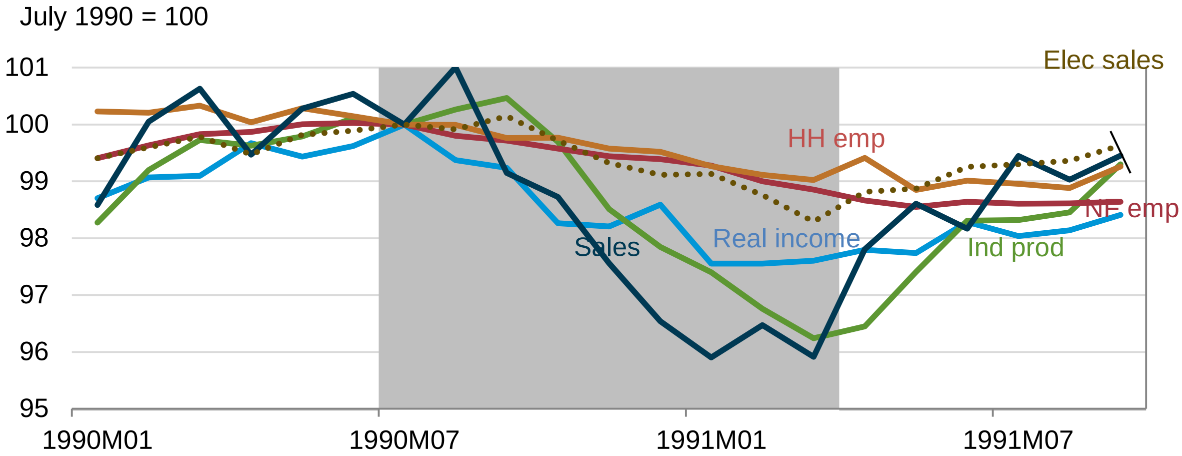
Figure 9. Coincident indicators before, during, and after recession (shaded) dated July 1981 to November 1982



Source: EIA, BEA, BLS, Federal Reserve, NBER

Here, the depth of the fall in electricity sales is less than the fall in non-farm employment, manufacturing and trade sales, and industrial production, but larger than the falls in household employment and real income. A similar pattern continues during the 1990-1991 recessions [Figure 10]. Although more volatile than during the first two recessions shown above, retail electricity sales track the employment series well, falling by slightly more. The dip in retail electricity sales is smaller than the declines in manufacturing and trade sales, industrial production, and real income.

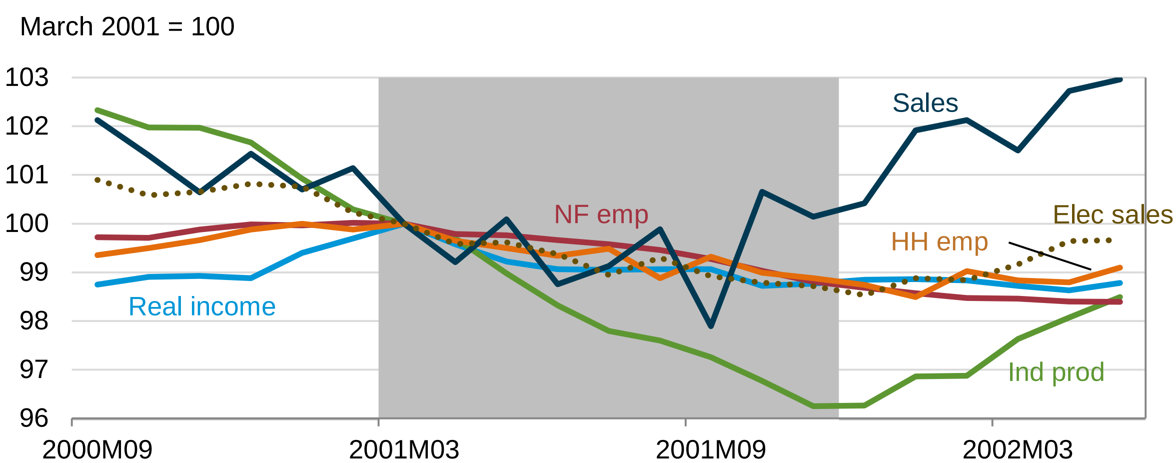
Figure 10. Coincident indicators before, during, and after recession (shaded) dated July 1990 to March 1991



Source: EIA, BEA, BLS, Federal Reserve, NBER

Electricity sales again move with both employment series during the 2001 recession [Figure 11]. In this case manufacturing and trade sales do not drop as much as industrial production, and show more volatility than the other series. Electricity sales appear to turn up just after the trough of the recession.

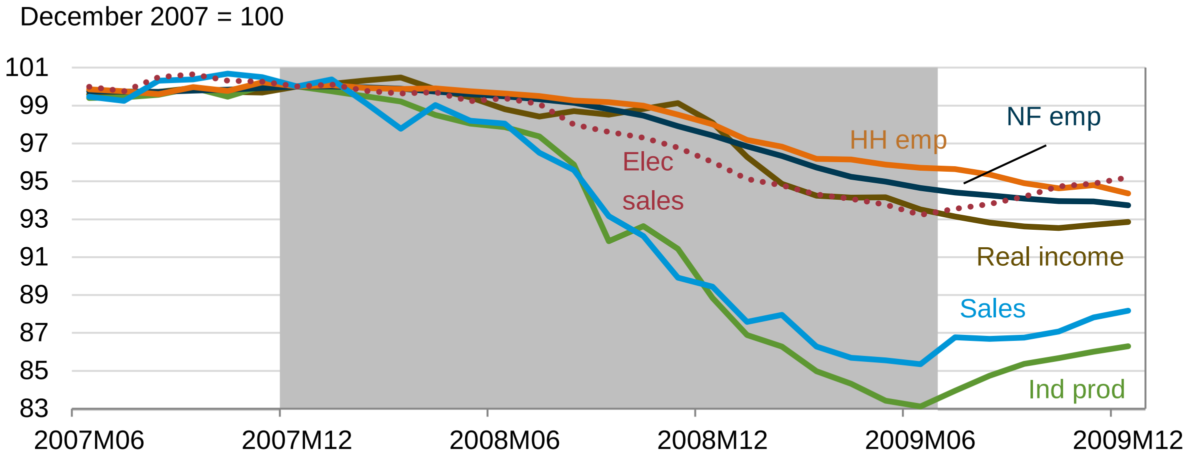
Figure 11. Coincident indicators before, during, and after recession (shaded) dated March to November 2001



Source: EIA, BEA, BLS, Federal Reserve, NBER

Retail electricity sales diverge more from the other indicators during the recession of 2008-2009. Both industrial production and manufacturing and trade sales show large declines, while income and employment fall by less. Retail electricity sales decline to levels similar to real income, but turn up earlier, just before the recession ends. Manufacturing and trade sales and industrial production turn up at this point as well, while employment and income continue to fall.

Figure 12. Coincident indicators before, during, and after recession (shaded) dated December 2007 to June 2009



Source: EIA, BEA, BLS, Federal Reserve, NBER

Taken together, what story do the spider charts tell? In general, total retail electricity sales move similar to other coincident economic indicators during recessions. There are differences. Movements in retail electricity sales tend to coincide with different measures of employment in the depth of their declines and shape. But the electricity data turn up around the same time as manufacturing and trade sales and industrial production.

Method, data, and illustration

The various electricity use series presented above differ in the underlying definitional concept and in how they are adjusted. In this section we discuss the data and methods in detail. We also illustrate how the adjusted series can be calculated as data become available.

Adjustment method

Our starting assumption for the monthly data is that electricity use over time can be divided between three unobserved components: an underlying trend; a cycle; and seasonal variation. The trend is determined by factors such as energy efficiency, population growth, the structure of the economy, culture, and anything else that influences the steady rate of growth in electricity use. The cycle is our object of interest and consists of movements around the trend. We assume these movements coincide with short-term ups and downs of the economy. Seasonality reflects higher or lower demand for electricity due to changes in weather that occur at regular times each year.

Our goal with adjustment is for the annual growth rates of the series to reflect cyclical movements around the trend. We use five different types of series above:

i. Calculate annual growth rates from raw annual data;
ii. Average raw monthly data to quarterly and calculate annual growth rates;
iii. Seasonally adjust the raw monthly data, average to quarterly, and calculate annual growth rates;
iv. Adjust raw monthly data for seasonality and electricity intensity, average to quarterly, and calculate the annual growth rates;
v. Adjust raw monthly data for seasonality and electricity intensity.

In the final three adjustments above we estimate the trend of the series using a regression model that allows parameters to vary over time.[7] The regression model for the third adjustment estimates the trend after accounting for seasonality, while the trend for the fourth and fifth are based on a model that accounts for both seasonality and electricity intensity.[8] The resulting trend series are either aggregated to quarterly by averaging over three months before the annual growth rates is calculated, as in the third or fourth adjustments above, or left at a monthly frequency as in adjustment five above.

Data

The data we use are available from various sources and begin at different time periods. Real GDP is taken from the U.S. Bureau of Economic Analysis (BEA) and is available quarterly. The BEA is also the source for the monthly real personal income and real manufacturing and trade sales data. Both household and non-farm employment are available each month from the U.S. Bureau of Labor Statistics (BLS).

The industrial production series (total and manufacturing) are released each month by the Federal Reserve Board. And the electricity use data are all taken from EIA. Net electricity generation is available from the Monthly Energy Review (MER), while retail electricity sales (total and industrial/commercial) come from the EPM.

Each series has a delay between the time period covered and the time of release. Real GDP is available roughly one month after the end of a quarter. The electricity use data has about a two month delay between the end of a month and release of that month's data, while that delay is about three months for manufacturing and trade sales, and one month for personal income. The employment and industrial production series are usually available within two weeks after the end of the reporting month.

Only retail electricity sales are needed to construct the unadjusted or seasonally adjusted series. But using the data on industrial production to construct the intensity and seasonally adjusted series can help to raise the correlation between electricity use and real GDP as discussed above.

Illustration

In this sub-section we construct an example to illustrate the construction of an economic indicator based on electricity use data. The example is based on data available on the 20th of September 2014 – total (and industrial/commercial) retail electricity sales through June 2014 (released on the 3rd of September 2014); weekly electric output data from EEI available for the week ending on the 13th of September 2014 (available by the 18th of September 2014); and manufacturing industrial production through August 2014 (released on the 15th of September 2014). Real GDP growth for the third quarter of 2014 becomes available on the 30th of October 2014.

In this example we want to calculate the adjusted retail electricity sales series through August 2014. To do this, we first total the EEI data to monthly and then calculate the average annual growth rates from

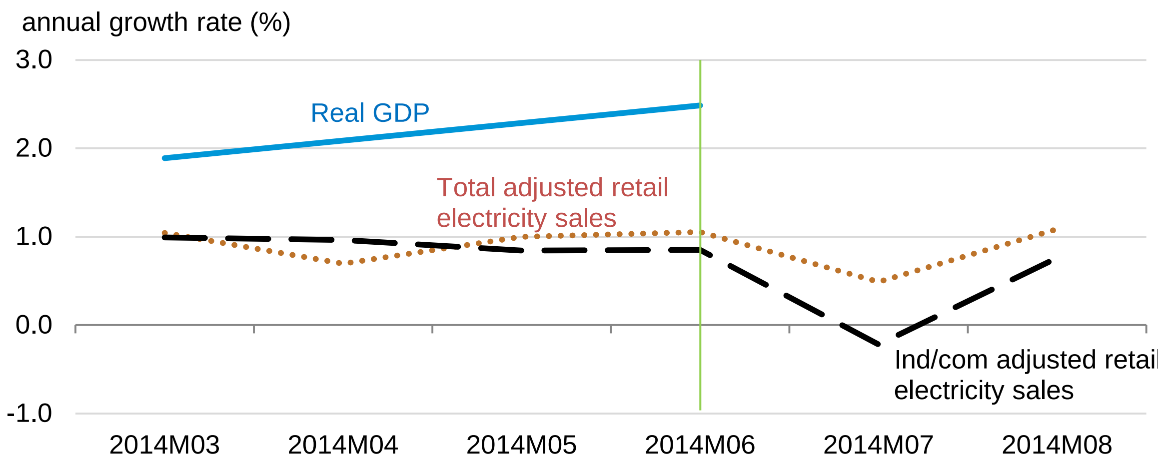
[7] These models are commonly referred to as unobserved components or structural time series models (Harvey, 1987). We use the SSM Toolbox of Peng and Aston (2011) for the estimations.

[8] The trend component is specified as a random walk, the seasonal component is trigonometric with time-varying parameters, and energy intensity is also associated with time-varying parameters. The extracted trend component is obtained using the Kalman smoother.

July 2013 to July 2014 and from August 2013 to August 2014.[9] We then grow both total and industrial/commercial retail electricity sales data from the EPM at the annual EEI growth rates for July and August of 2014.

Next, we estimate the monthly trend by accounting for both seasonality and electricity intensity. The electricity intensity measure is the ratio of total retail electricity sales to industrial production in manufacturing. The industrial production series is available through August 2014. The total retail electricity sales series is calculated by growing the total retail sales data from the EPM by EEI growth rates for July and August of 2014.

Figure 13. U.S. electricity use and real GDP growth, from March 2014 to August 2014



Source: EIA, BEA

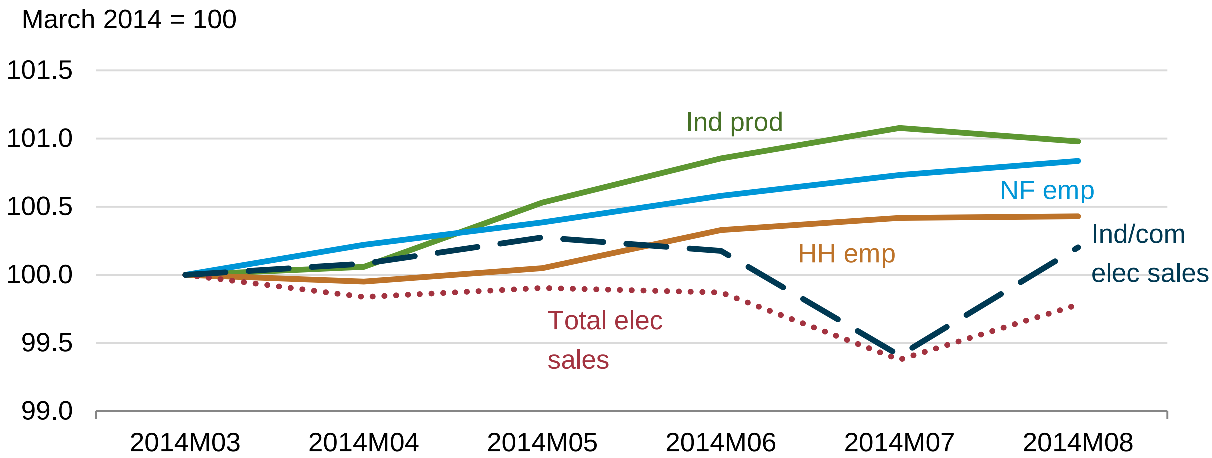
Annual growth rates of adjusted retail sales and real U.S. GDP from March of 2014 are displayed in Figure 13.[10] There are only two real GDP data points during this time period, and these coincide with 2014M03 (2014Q1) and 2014M06 (2014Q2). Trajectories of the GDP and retail sales series differ, with real GDP growth trending up through the middle of 2014 and both electricity series remaining flat. Does this indicate that 3rd quarter GDP should be expected to flatten out as well?

To answer this we can also compare with other monthly indicators available through August 2014 as plotted in Figure 14 (manufacturing and trade sales and real income are unavailable). March 2014 is normalized to 100 for consistency with Figure 13.

[9] To deal with weeks that overlap months, we first convert the EEI data to daily frequency by assuming each day of the week has the same value, but that the week sums to the total in EEI's original data. We then sum up for each month.

[10] Unadjusted and seasonally adjusted series are not shown but display the same pattern for both total and industrial/commercial retail electricity sales.

Figure 14. Coincident indicators from March 2014 to August 2014



Source: EIA, BEA, BLS, Federal Reserve, NBER

Total retail electricity sales paint a slightly different picture of economic activity since March 2014 than the other standard indicators. The others, including industrial/commercial retail electricity sales, all show slight improvement, whereas total retail electricity sales are flat through August 2014 (though rising). Neither electricity series contradicts an economy that is growing at a steady pace, although they do show a slowing in July 2014.

Future research

Our analysis is focused on association and intuition, and leaves many questions unanswered. Four areas are particularly interesting:

1. Moving to weekly data and comparing with other weekly indicators of economic activity. EEI produces weekly data (going back to the 1990s) and EIA hopes to have hourly data available sometime in 2015.
2. Testing electricity use as a leading indicator of economic activity, including pairing it with other leading indicators to test whether it improves explanatory power.
3. Forecasting short-term movements in real GDP with electricity use.
4. Improving our measure of energy intensity in estimating the adjusted series.

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