Aggregate Transactions as High-Frequency Indicators of Economic Activity

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We thank the Interac Organization, and in particular Eric Chue, for supplying us with the data on debit card transactions, and Bryan Campbell and Steve Murphy, who provided vintage macroeconomic data through CIRANO

Outline

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– National accounts data and forecasts

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Measuring and forecasting macro aggregates

- We have very precise, frequent, timely information on financial variables; by contrast GDP, arguably the single most important measurement in economics, is poorly and infrequently measured, and it takes months to get this poor quarterly measure, then we revise it
- standard errors of revisions to GDP, consumption, non-durables expenditure are all very substantial
- forecasts of changes are very poor even two quarters ahead (rmsfe comparable to that from use of unconditional mean as forecast)
- this situation has not improved in generations, while electronic data recording has produced massive improvements in data quality in other areas

Can we exploit other data sources?

- Every electronic transaction (credit, debit) is now recorded and stored somewhere.
- However, these data are private property and involve trade secrets.
- Fortunately, the Interac organization at least is aware of the research value of these numbers, and has agreed to provide us (subject to a non-disclosure agreement) with daily transaction values from the point at which they began daily recording, late in 1999.
- Unfortunately, other obvious sources of these daily transaction data have not yet shown the same public spirit. We are persevering.

The Interac data

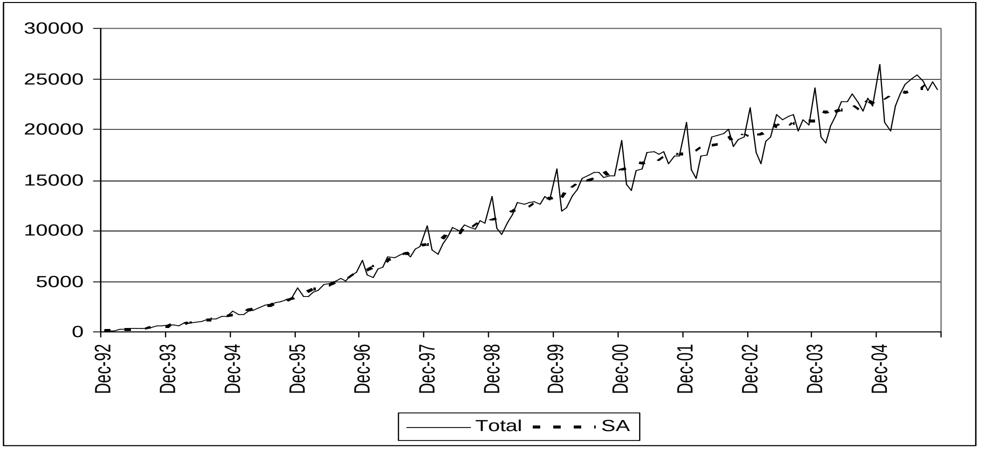
- Pilot projects for debit card terminals were launched in Canada in 1991; Canadians are the most intensive users of this means of payments: debit card transactions per inhabitant in 2003 were 81.7 in Canada, 74.6 in Sweden, 71.2 in the Netherlands, 70.6 in France, 63.4 in the U.S., and 56.7 in the UK. (Source: Interac Organization). 86 per cent of Canadians own a debit card, and in 2004, 47 per cent of transactions were conducted with debit cards, compared to 29 per cent with cash, 20 per cent with credit cards and fewer than 4 per cent with cheques.
- Much less intensively used in the US; the number transactions using electronic means of payments (which includes both credit and debit card transactions) only exceeded the number of cheque payments for the first time in 2003.
- In Canada, debit card purchases represented 10 per cent of the economy's expenditures, or about 17 per cent of total household expenditures

- Figure 1: total monthly debit card transactions (vertical scale divided by a random number) Note: (i) transactions exhibit a strong seasonal pattern (ii) monthly transactions have shown very rapid growth, far exceeding that of the overall economy, with transactions increasing from about 1.5 million in December 1992 to 215 million in November 2005.
- We obtain the debit card series adjusted using X11-ARIMA, the same procedure used to adjust the National Accounts data. The resulting seasonally adjusted debit card series is also shown in Figure 1, again divided by a randomly chosen constant.

FIGURE 1

Re-scaled debit card transaction values

Raw and seasonally adjusted, Dec 1992–Nov 2005

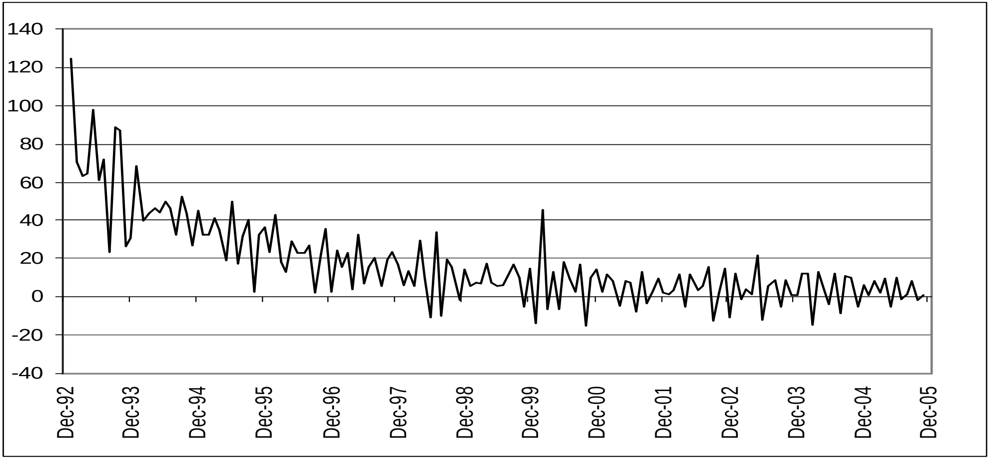


- The real economy grew by about 50% between 1992 and 2005, yet debit card transactions grew by over 14,000%. In Figure 2 we plot the annualized growth rate of monthly debit card transactions.

Figure 2

Monthly growth rate of debit card transaction values

Seasonally adjusted, Jan 1993–Nov 2005



This trend may impede inference on the value of debit data. However, there are a number of ways in which we can correct for the growth rate in the adoption of debit card technology:

– quadratic growth rate

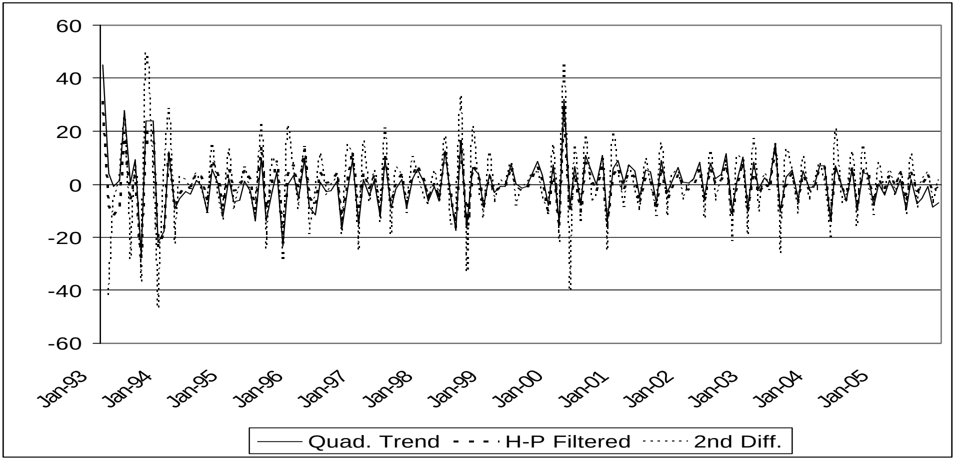
– an estimated trend can be removed using a Hodrick-Prescott filter.

– changes in the growth rates of debit card transactions, instead of changes in the levels, can be analyzed.

In Figure 3 we plot the three series that emerge from the above corrections.

FIGURE 3

Debit card transaction growth rates, adjusted for rate of technology adoption, Jan 1993–Nov 2005



Application 1: predicting data revisions and forecasts

(ie Improving measurements and forecasts)

National accounts data

- Campbell and Murphy (2007) make available a data base which stores values of a number of macroeconomic quantities, including real GDP and several of its components such as aggregate and non-durable consumption expenditures. These quarterly data are available from the first quarter of 1971 through the latest published quarter, hereafter T)
- stored in the form of an upper triangular matrix, i.e. entries are of the form $x_{t|\tau}$ where x is a variable of interest, t is the date to which a measurement applies, and τ is the date at which a measurement is recorded, with $\tau \geq t$. The main diagonal of the matrix therefore contains first-release estimates, $x_{t|t}$, while entries of the form $x_{t|\tau}$, $\tau > t$, indicate the estimate of the value for date t that is current at some date τ which is after t. The sequence of values $x_{t|\tau}$, $\tau = t, t+1, \ldots T$ typically contains the first release, at least two revisions, and occasional further changes resulting from base-year adjustments.

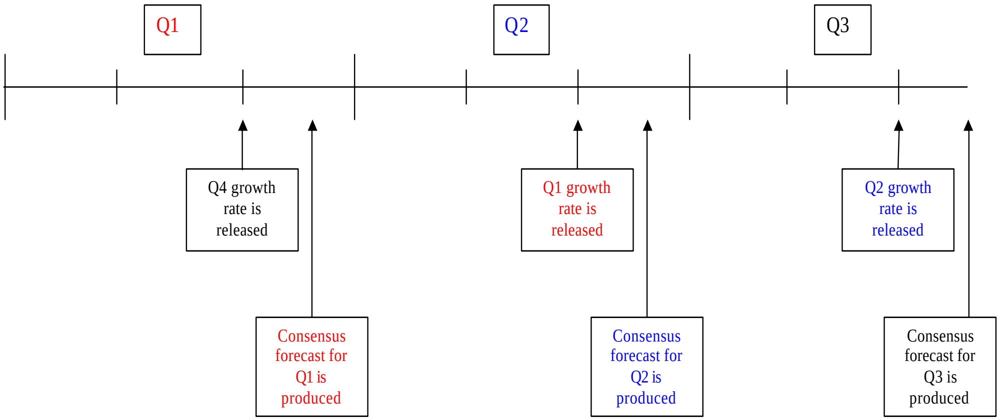
Measurement and forecasting errors to predict

- Let $N_{k,t}$ denote the officially-reported quarterly growth rate of any national accounts variable, where t is the quarter to which the growth rate pertains and k is the release number (or vintage) of the series, e.g. if N represents GDP and t is 2005Q4, then $N_{1,2005Q4}$ denotes the first official estimate of the growth rate of GDP in 2005Q4.
- consensus forecasts are produced by Consensus Economics Inc., as the mean of fifteen forecasts produced by a sample of forecasters. Quarterly forecasts are produced for GDP and personal expenditure (and consumer price inflation, not treated here). The consensus forecast for a given quarter, as indicated in Figure 4 below, is produced approximately two weeks before the end of that quarter.

  item- Figure 4 records the timeline for forecasts and data releases.

Figure 4

Timeline of forecasts and data releases



Consider the error

$$E_{k,t} = (N_{k,t} - C_t) = (N_{1,t} - C_t) + (N_{k,t} - N_{1,t}), \tag{1}$$

where C_t represents the consensus forecast of a particular quantity of interest measured at time t.

- We attempt to predict both $E_{k,t}$ for different values of k (forecast error prediction) and also the revisions $(N_{k,t} - N_{1,t})$

Table 1: Descriptive Statistics: Observed Errors

Sample: 2001:1 to 2005:3

Error	National Accounts Variable (*N*)								
	GDP			Consumption			Non-Durables		
	Mean	Std Error	RMSE	Mean	Std Error	RMSE	Mean	Std Error	RMSE
Measurement Errors: Quarterly Annualized Growth Rates									
$N_{2,t} - N_{1,t}$	0.069	0.396	0.391	0.351	0.551	0.641	0.151	0.900	0.888
$N_{3,t} - N_{1,t}$	0.011	0.452	0.440	0.366	0.508	0.615	0.055	0.929	0.906
$N_{4,t} - N_{1,t}$	-0.007	0.525	0.511	0.334	0.525	0.611	-0.109	0.991	0.971
Measurement Errors: Year-over-Year Growth Rates									
$N_{2,t} - N_{1,t}$	-0.005	0.163	0.159	0.105	0.177	0.201	0.009	0.245	0.239
$N_{3,t} - N_{1,t}$	-0.010	0.195	0.190	0.100	0.260	0.273	-0.043	0.250	0.247
$N_{4,t} - N_{1,t}$	0.031	0.226	0.222	0.104	0.354	0.360	-0.081	0.291	0.295
Consensus Errors: Year-over-Year Growth Rates									
$N_{1,t} - C_t$	-0.022	0.467	0.455	0.182	0.512	0.530	N/A	N/A	N/A
$N_{2,t} - C_t$	-0.028	0.463	0.452	0.287	0.506	0.570	N/A	N/A	N/A
$N_{3,t} - C_t$	-0.032	0.470	0.459	0.283	0.475	0.542	N/A	N/A	N/A
$N_{4,t} - C_t$	0.008	0.479	0.466	0.286	0.530	0.590	N/A	N/A	N/A

Note: RMSE = Root Mean Squared Error

Error prediction

- Caveat: we presently use only five years of data since Statistics Canada made the change to chain-weighted indices for major national accounts variables such as GDP; measurement and revision processes before that time are not directly comparable, although it may prove that they have sufficient structure in common to allow us to learn something about the current process. The short period does not permit out-of-sample forecasting; our consensus forecast data are also available only relatively recently, beginning in 1999.
- The results that follow, therefore, should be viewed as exploratory and suggestive.
- We fit linear models of the form:

$$\epsilon_t = \beta_0 + \beta_1 D_t + \beta_2 \Delta R_{t-2} + \beta_3 \Delta R_{t-3} + \beta_4 \epsilon_{t-1} + u_t \tag{2}$$

where...

· ϵ_t is any one of the measurement or consensus forecast errors described above.

· D_t is one of the three transformed debit card series discussed in Section 2.2.

· $\Delta R_{t-2}, \Delta R_{t-3}$ are real short-term interest rates lagged by 2 or 3 quarters, respectively.

Estimation results for variants of equation (2) are presented in Tables 3–5 for specifications chosen by the Schwarz information criterion (SC).[1] Table 3 record results for quarterly measurement errors $N_{kt} - N_{1t},\ k = 2, 3, 4$, Table 4 for the corresponding annual measurement errors, and Table 5 for the consensus forecasts errors $N_{kt} - C_t,\ k = 1, 2, 3, 4$.

[1]Recall that we consider three different debit card transformations and several different vintages of measurement errors.

Table 3: Estimated Parameters for the Q/Q Measurement Errors

Sample: 2001:1 to 2005:3

Variable	GDP			Consumption			Non-Durables		
	$N_{2,t}-N_{1,t}$	$N_{3,t}-N_{1,t}$.	$N_{4,t}-N_{1,t}$	$N_{2,t}-N_{1,t}$	$N_{3,t}-N_{1,t}$	$N_{4,t}-N_{1,t}$.	$N_{2,t}-N_{1,t}$	$N_{3,t}-N_{1,t}$	$N_{4,t}-N_{1,t}$.
Constant	0.10 (1.56)	-0.01 (-0.35)	0.04 (1.14)	0.47 (3.66)	0.90 (6.25)	0.82 (7.32)	0.03 (0.14)	-0.06 (-0.29)	-0.20 (-0.87)
$Debit_t$	-0.04^{H} (-0.92)	0.08^{D} (4.97)	0.02^{D} (1.37)	--	--	-0.07^{D} (-2.69)	0.17^{Q} (1.77)	0.16^{Q} (1.82)	0.12^{Q} (1.33)
$Debit_{t-1}$	-0.16 (-3.26)	-0.05 (-3.13)	-0.11 (-6.32)	--	--	--	--	--	--
ΔR_{t-1}	0.10 (1.70)	0.32 (6.05)	0.21 (3.60)	-0.32 (-3.80)	-0.48 (-5.04)	-0.60 (-6.31)	--	--	--
ΔR_{t-2}	-0.19 (-1.89)	-0.12 (-2.77)	-0.14 (-2.43)	0.23 (2.36)	--	--	--	--	--
ΔR_{t-3}	--	0.25 (6.93)	0.35 (9.06)	--	--	--	--	--	--
$Error_{t-1}$	-0.19 (-0.84)	0.17 (3.13)	0.57 (7.52)	0.37 (2.07)	-0.23 (-0.96)	-0.16 (-1.06)	--	--	--
$Error_{t-2}$	--	0.63 (9.53)	0.15 (1.20)	-0.58 (-4.58)	-0.72 (-4.50)	-0.37 (-2.40)	--	--	--
$Error_{t-3}$	--	-0.36 (-8.18)	-0.33 (-4.02)	0.24 (1.51)	-0.53 (-3.72)	-0.88 (-5.95)	--	--	--
$\overline{R}^2$	0.29	0.82	0.75	0.24	0.40	0.43	0.13	0.09	0.02
SC	-1.71	-2.70	-2.32	-1.06	-1.26	-1.12	-0.15	-0.04	0.16

Note: D = Second-differenced, H = H-P filtered, Q = Quadratic trend.

Table 4: Estimated Parameters for the Y/Y Measurement Errors
Sample: 2001:1 to 2005:3

Variable	GDP			Consumption			Non-Durables		
	$N_{2,t}-N_{1,t}$	$N_{3,t}-N_{1,t}$.	$N_{4,t}-N_{1,t}$	$N_{2,t}-N_{1,t}$	$N_{3,t}-N_{1,t}$	$N_{4,t}-N_{1,t}$.	$N_{2,t}-N_{1,t}$	$N_{3,t}-N_{1,t}$	$N_{4,t}-N_{1,t}$.
Constant	0.00 (0.13)	0.01 (0.47)	0.02 (0.60)	0.08 (4.28)	0.07 (1.82)	-0.00 (-0.10)	-0.02 (-0.36)	-0.04 (-1.22)	-0.12 (-1.91)
$Debit_t$	0.00^D (0.26)	0.06^D (4.16)	0.11^H (3.99)	-0.04^D (-6.19)	-0.04^D (-2.58)	-0.02^Q (-0.68)	0.04^Q (1.79)	0.05^Q (2.21)	0.06^Q (2.48)
$Debit_{t-1}$	0.05 (3.84)	0.05 (3.61)	--	--	--	0.10 (1.74)	--	--	--
ΔR_{t-1}	0.15 (5.20)	0.06 (4.70)	-0.03 (-0.60)	-0.14 (-6.39)	-0.10 (-1.88)	-0.12 (-1.99)	--	-0.01 (-0.19)	--
ΔR_{t-2}	--	--	-0.12 (-3.20)	0.14 (7.83)	0.15 (3.24)	0.17 (3.77)	--	0.17 (4.60)	--
ΔR_{t-3}	--	--	--	--	0.04 (0.83)	--	--	--	--
$Error_{t-1}$	-0.23 (-1.46)	--	0.51 (2.87)	0.57 (5.73)	0.45 (2.90)	0.82 (6.92)	--	0.76 (4.29)	--
$Error_{t-2}$	0.48 (2.63)	--	--	-0.13 (-1.72)	--	-0.48 (-3.10)	--	--	--
$Error_{t-3}$	-0.10 (-0.66)	--	--	--	--	--	--	--	--
$\overline{R}^2$	0.52	0.49	0.47	0.81	0.39	0.56	0.09	0.56	0.16
SC	-3.59	-3.56	-3.25	-4.55	-2.57	-2.16	-2.71	-3.05	-2.44

Note: D = Second-differenced, H = H-P filtered, Q = Quadratic trend.

Table 5: Estimated Parameters for the Y/Y Consensus Errors

Sample: 2001:1 to 2005:3

Variable	GDP				Consumption			
	$N_{1,t}-C_t$	$N_{2,t}-C_t$.	$N_{3,t}-C_t$	$N_{4,t}-C_t$	$N_{1,t}-C_t$	$N_{2,t}-C_t$.	$N_{3,t}-C_t$	$N_{4,t}-C_t$.
Constant	-0.03 (-0.23)	0.13 (1.65)	0.13	0.05 (0.54)	0.29 (4.08)	0.46 (5.27)	0.44 (4.67)	0.23 (2.18)
$Debit_t$	0.17^H (2.37)	0.14^Q (2.27)	0.16^Q (2.35)	0.27^H (3.32)	--	-0.05^D (-1.33)	-0.09^D (-3.85)	0.08^Q (2.59)
$Debit_{t-1}$	--	-0.19 (-3.76)	-0.20 (-3.59)	--	--	-0.12 (-3.47)	-0.13 (-3.71)	--
ΔR_{t-1}	--	0.09 (0.97)	0.10 (1.09)	0.03 (0.26)	0.02 (0.10)	-0.13 (-0.96)	-0.18 (-1.48)	--
ΔR_{t-2}	--	--	--	--	-0.24 (-2.79)	-0.35 (-4.07)	-0.33 (-4.27)	--
ΔR_{t-3}	--	--	--	--	-0.27 (-2.52)	--	--	--
$Error_{t-1}$	--	0.67 (4.43)	0.65 (4.81)	0.26 (1.71)	-0.49 (-3.02)	-0.25 (-1.61)	-0.10 (-0.84)	--
$Error_{t-2}$	--	--	--	--	-0.01 (-0.06)	0.17 (1.09)	0.06 (0.30)	--
$Error_{t-3}$	--	--	--	--	-0.11 (-0.52)	-0.35 (-2.46)	-0.43 (-3.80)	--
$\bar{R}^2$	0.11	0.48	0.48	0.38	0.38	0.36	0.41	0.04
SC	-1.44	-1.66	-1.64	-1.54	-1.39	-1.28	-1.39	-1.12

Note: D = Second-differenced, H = H-P filtered, Q = Quadratic trend.

- the specifications chosen by SC retain debit transactions in 23 of 26 cases, and in most of these cases debit transactions or their lags show statistically significant effects by conventional tests on the regression parameter. The three cases in which transaction information is not retained in the SC-minimizing specification concern total consumption errors in each case.
- a varying but typically substantial (around one third) proportion of the variation of these errors is fitted by the regression specification. The fitting of GDP measurement and forecast errors is particularly good.

Application 2: quantifying effects of extreme events

- Note that this is essentially impossible with quarterly data unless we observe a truly huge event

High-frequency analysis of selected shocks

September 11 terrorist attacks

- The terrorist attacks of September 11 2001 had, of course, no direct impact in Canada apart from the diversion of some flights because of closed U.S. airspace. However, the magnitude and visibility of the attacks suggest a possible disruption of activity well outside directly affected areas.
- To measure the extent of the drop in transactions on September 11 relative to what they could have been, we standardize the observed transactions around this date as follows:

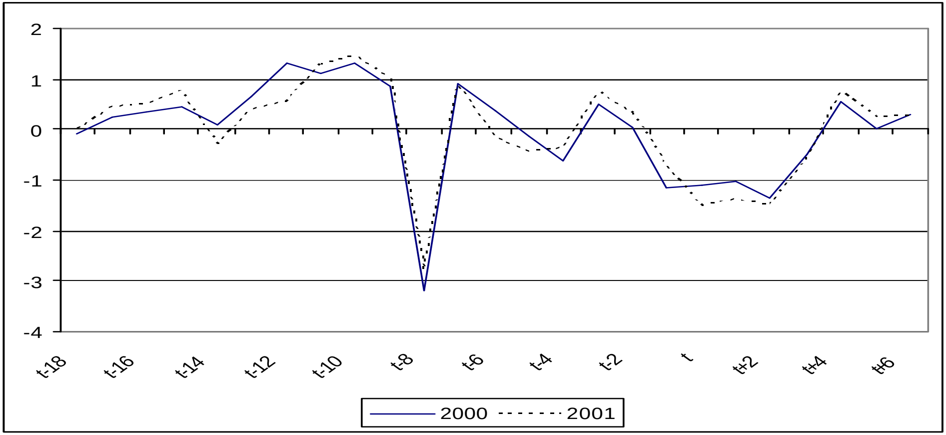
$$Z_t = \frac{D_t - \overline{D}}{\hat{\sigma}} \tag{3}$$

where D_t is the value of debit card transactions at time t, $\overline{D} = \frac{1}{3}\sum_{i=2}^{4} D_{t-7i}$, and the standard error is $\hat{\sigma} = \left[\frac{1}{24}\sum_{i=1}^{25}(D_t - \overline{D})^2\right]^{1/2}$.

- Since transactions regularly vary according to the day of the week, we subtract the mean of observed transactions for that particular day. Furthermore, since a holiday observation occurs shortly prior to 9/11 (i.e. Labour Day), we compute this mean using the data from 2, 3 and 4 weeks prior (i.e. 14, 21 and 28 days before). This standardization is done for both 2000 and 2001.
- In Figure 5 we plot the standardized values for both 2000 and 2001. Given that transactions vary greatly with each day of the week, the comparison between 2001 and the equivalent period in 2000 is made relative to Labour Day: Time t in the graphs represent the 8^{th} day after Labour Day (note that this is the same day of the week in each case, as Labour Day is always a Monday. In 2001 this corresponds to 11 September; in 2000, t represents 12 September.

Figure 5

Standardized transaction values in the vicinity of September 11 (date t), 2001 and 2000



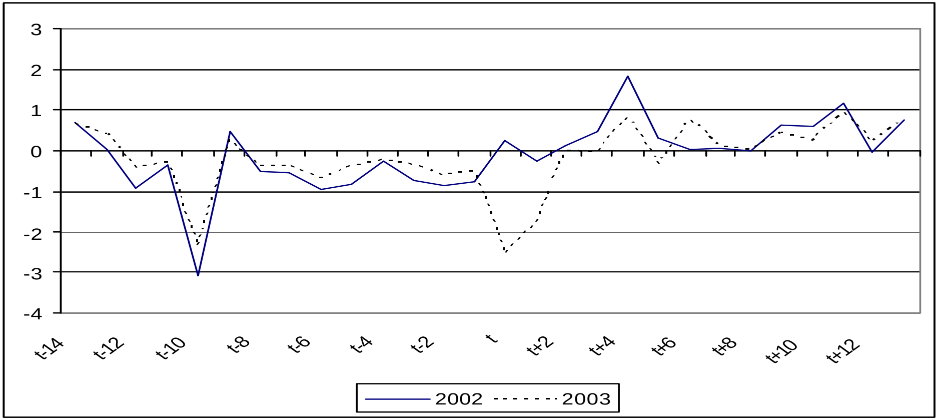
- the difference between the two years' standardized values is well within one standard error, and indeed the September 11 2001 value is only slightly more than one standard error below the mean. That is, the estimated direct impact of the terrorist attacks in terms of lost or postponed consumption *in Canada* was relatively small in absolute terms, and well within the range of normal variation. While the September 11 attacks no doubt had very substantial effects on economic activity which would be observable in data specific to New York State or, of course, New York City, we can discern little impact in Canadian data.

The blackout of August, 2003

- Around 4:00 PM on Thursday August 14, 2003, a power outage affected nearly 50 million households throughout most of Ontario and several U.S. states. Power was gradually restored over the next 48 hours, but the effect of the outage lingered for over a week as businesses and government were urged not to resume normal operations in an effort to conserve energy so as not to place stress on the fragile power grid.
- For comparison in analyzing the impact of the blackout, in Figure 6 we plot standardized transactions, computed as described above, relative to the third quarter of 2002, in which there were no major shocks. Time t in this graph represent the 10^{th} day after the Civic Holiday.

Figure 6

Standardized transaction values in the vicinity of the blackout, August 14 (date t), 2003 and 2002



- On the day of the blackout we see that transactions in 2003 dropped sharply relative to their equivalent 2002 levels. We also observe that the relative gap was largely closed by *t+2*, indicating that following the drop on 14 August and 15 August, debit card transactions returned to their (relative) equivalent 2002 levels on Saturday, 16 August. However, 2003 transactions lingered below their 2002 levels up to 19 August, likely reflecting the fact that normal business activities did not fully resume in some areas for about one week following the blackout.
- The difference (of over two standard errors) between the standardized values for 2002 and 2003 in Figure 6 at times t and *t+1* translates into a net loss of about 1.9 million debit card transactions, or about 28% of a single day's transactions for a typical Thursday or Friday in August of 2003 (the 2003 value is also over 2 standard errors below the mean). Of course, in the absence of electricity some transactions would have been conducted using cash instead of debit cards.

Some tentative conclusions

- It must be possible to do better than quarterly survey measures, available three months later, then heavily revised, on our most important aggregates
- High-frequency transactions data are a potential avenue for doing so, but the private-good nature of the data is a barrier
- Nonetheless, even with only debit card data covering a portion of transactions and a smaller proportion of value, there are indications that some revisions and forecast errors are predictable, ie that this information can lead to early estimates of aggregates which improve the accuracy of early-release estimates and short-term forecasts. However, results are mixed and tentative.

- We can also quantify clearly the effects of some extreme shocks, and can address the question of whether, and if so over what period, 'lost' economic activity is recouped
- We would expect much higher predictive and explanatory value if we could obtain comparable credit-card transaction data, which with debit would then account for a large and increasing proportion of transactions and of value.