Asymmetric effects of monetary policy with or without Quantitative Easing: Empirical evidence for the US

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ABSTRACT

Several rounds of Quantitative Easing since the financial crisis of 2008 have resulted in very large expansions in the monetary base of the US and other economies. This paper asks whether the effects of Quantitative Easing are subject to the asymmetries that have been established for more conventional monetary policies. Using US quarterly data from the 1950–2011 period, monetary base shocks and their effects on real GDP and industrial production are estimated. First, the paper’s findings strongly support sign asymmetry: with or without Quantitative Easing, monetary base contractions have larger effects than monetary base expansions (the effects of which are often statistically insignificant). This characterizes both permanent and temporary (four-year) shocks to the monetary base. Second, there is also evidence of size asymmetry: the effectiveness of monetary base shocks declines with their size. Size asymmetry is found for both positive and negative monetary base shocks, but it appears to be stronger for negative shocks.

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1. Introduction

The response of monetary policy to the financial crisis of 2008 and the recession of 2007–2009 has included an unprecedented expansion of the monetary base in the US and other economies. This is clearly illustrated in Fig. 1 which plots quarterly observations for the US monetary base from 1950:Q1 to 2011:Q4. It is apparent that for most of this period, in particular until the third quarter of 2008, the monetary base is growing relatively smoothly. This is dramatically changed in the fourth quarter of 2008, however, after which the monetary base is increasing at an explosive rate. By the fourth quarter of 2011, the monetary base has grown to $2.7 trillion, or more than three times its magnitude in the third quarter of 2008 ($872 billion). The monetary base is therefore increased by a factor of 3 in just three years. Fig. 2 plots the ratio of the monetary base to nominal Gross Domestic Product, effectively comparing over this time period the expansion of the monetary base with that of economic activity, as captured by GDP. For most of the pre-2008 period, the monetary base is increasing at a slower pace than nominal GDP, so the ratio gradually declines from 0.12 in 1950:Q1 to 0.06 in 2008:Q3 – though the minimum value of 0.05 is achieved in 1980. Again, what stands out is the sharp spike in the ratio beginning with 2008:Q4, raising its value to 0.17 by the end of 2011.

What has been the effect of this unparalleled monetary expansion on economic activity? A generally held view is that, by providing ample liquidity, this vigorous policy of Quantitative Easing helped prevent a repeat of the mistakes made during the Great Depression, and thus averted a deepening of the 2007–2009 recession.2

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1 I wish to thank participants at the 2012 Athenian Policy Forum Conference in Chalkidiki, Greece for helpful comments and suggestions. Errors and omissions remain mine.

By now, existing theoretical models have been modified and new ones have been developed to study the effects of such Quantitative Easing policies. It is now commonplace to distinguish between “conventional” monetary policies (that include changes in a short-term interest rate, such as the federal funds rate) and “unconventional” policies (that include Quantitative Easing). Unconventional policies are usually, though not exclusively, considered at the “zero lower bound”: situations when the short-term interest rate has been pushed down virtually to zero. A large literature has examined various mechanisms that are thought to determine the efficacy of unconventional monetary options: liquidity effects, inflationary expectations, the credit channel, signaling (commitment) effects, and portfolio effects.

Independent of this, a large number of studies have also been investigating whether the effects of monetary policy are asymmetric. In this context, asymmetry usually refers to a situation in which monetary expansions have smaller effects than monetary contractions (sign asymmetry), or large monetary shocks have smaller real effects than smaller monetary shocks (size asymmetry), though additional types of asymmetry have also been considered. As it is well known, theoretically, such asymmetries can be generated by (i) a convex aggregate supply, (ii) models that emphasize credit mechanisms, (iii) models with menu costs, or (iv) monetary authorities that respond differently to expansions than to downturns.

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3 See for example Curdia and Woodford (2011).
4 For interesting discussions, see Blinder (2010), Cecchetti and Disyatat (2010), and Nelson (2011). For the experience of economies other than the US, see Anderson, Gascon, and Liu (2010), and Kapetanios, Mumtaz, Stevens, and Theodoridis (2012).
6 This literature is vast. See Florio (2004) for a recent survey. Recent contributions that show some of the variety of monetary asymmetries that have been considered are Sensier, Osborn, and Ocal (2002), Ravn and Sola (2004), Bruinshoofd and Candelon (2005), and Lo and Piger (2005).
These asymmetries have been tested mostly in environments of conventional monetary policies. To assess the potency of policies like Quantitative Easing, it is necessary to know whether such asymmetric effects also govern the effects of unconventional monetary policies. This is the subject of the present paper.

The paper focuses on the main two types of asymmetries (sign and size) and investigates the effects of shocks to the monetary base on output and industrial production in the US. First, quarterly data are used to identify shocks to the monetary base over the period 1950–2011. Then the effects of these shocks on real GDP and industrial production are estimated.

The paper’s findings strongly support sign and size asymmetries, both with and without Quantitative Easing. First, there is clear evidence of sign asymmetry: monetary base contractions have larger effects on economic activity than monetary base expansions (the effects of which are often statistically insignificant). This is the case even when sign and size asymmetries are jointly estimated. In addition, sign asymmetry holds for output and industrial production, and characterizes both permanent and temporary (four-year) shocks to the monetary base.

Second, there is also evidence of size asymmetry: the effectiveness of monetary base shocks declines with their size. Put differently, a 100% increase in the monetary base is less than 100 times as effective as a 1% increase in the monetary base. Size asymmetry is found for both positive and negative monetary base shocks, though it appears to be stronger for negative shocks.

The rest of the paper is organized as follows. Section 2 outlines the paper’s empirical methodology, which nests sign and size asymmetries, and discusses the data. Section 3 presents the empirical results. Section 4 summarizes and concludes.

2. Empirical methodology and data

2.1. Sign asymmetry

The empirical methodology implements a modification of the approach of Cover (1992), and Karras (1996a, 1996b), and thus will be described briefly.

The estimated system consists of two equations, the first of which describes the money supply process:

\[
\Delta m_t = \alpha_0 + \sum_{i=1}^{M} \alpha_i^m \Delta m_{t-i} + \sum_{i=1}^{N} \alpha_i^y \Delta y_{t-i} + e_t^m, \tag{1}
\]

where \(m\) is the log of the monetary base, \(y\) is the log of real GDP, the \(\alpha\)'s are coefficients, and \(e^m\) is the monetary base shock. Define the positive monetary base shock as

\[e_t^+ = \max(e^m_t, 0),\]

and the negative money-supply shock as

\[e_t^- = \min(e^m_t, 0).\]

Letting \(o\) denote the log of the price of oil (a proxy for supply-side shocks), the second equation is:

\[
x_t = \beta_0 + \sum_{i=1}^{P} \beta_i^x x_{t-i} + \sum_{i=1}^{Q} \beta_i^o \Delta o_{t-i} + \sum_{i=0}^{R} (\beta_i^+ e^+_{t-i} + \beta_i^- e^-_{t-i}) + e^x_t, \tag{2}
\]

where \(x\) may stand for output growth (\(\Delta y\)) or the growth rate of industrial production (\(\Delta i\)), and the \(\beta\)'s are coefficients to be estimated. If \(\beta_i^+ = \beta_i^-\), for all \(i\), the effects of money-supply shocks are symmetric. Using (for now) the sum of these coefficients as a simple metric of effectiveness,\(^8\) the “traditional” kind of asymmetry requires \(\sum_i \beta_i^- > \sum_i \beta_i^+ \geq 0\), so that monetary contractions have larger effects than monetary expansions.\(^9\)

2.2. Including size asymmetry

We now want to allow for the possibility that large monetary shocks have different effects than small monetary shocks. To estimate these size asymmetries, we measure the size of the shock by its absolute value and specify the monetary policy effectiveness coefficients as linear functions of size:

\[
\beta_i^+ = \tilde{\beta}_i^+ + \tilde{\beta}_i^{size(+)} |e^+_{t-i}| = \tilde{\beta}_i^+ + \tilde{\beta}_i^{size(+)} e^+_{t-i}, \]

\[
\beta_i^- = \tilde{\beta}_i^- + \tilde{\beta}_i^{size(-)} |e^-_{t-i}| = \tilde{\beta}_i^- + \tilde{\beta}_i^{size(-)} e^-_{t-i}. \]

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\(^7\) Indeed it could be argued that knowing the extent of such asymmetries is even more important in the case of policies that double or triple the monetary base in a few years.

\(^8\) Alternative metrics include joint statistical significance, as well as the implied impulse response coefficients. All of these are examined formally in the next section.

\(^9\) Note that “pushing on a string”, a special case of the traditional asymmetry, would obtain if \(\sum_i \beta_i^- > \sum_i \beta_i^+ = 0\).
and

\[ \beta_i^- = \hat{\beta}_i^- + \hat{\beta}_i^{\text{size}(-)} |e_{t-i}^-| = \hat{\beta}_i^- - \hat{\beta}_i^{\text{size}(-)} e_{t-i}^- . \]

To nest the size and sign asymmetries, simply substitute the last two expressions in Eq. (2) and rewrite as

\[ x_t = \beta_0 + \sum_{i=1}^{P} \beta_i^y x_{t-i} + \sum_{i=0}^{Q} \beta_i^o o_{t-i} + \sum_{i=0}^{R} \left( \hat{\beta}_i^+ e_{t-i}^+ + \hat{\beta}_i^{\text{size}(+)} e_{t-i}^+ |e_{t-i}^+| + \hat{\beta}_i^- e_{t-i}^- + \hat{\beta}_i^{\text{size}(-)} e_{t-i}^- |e_{t-i}^-| \right) + e_t^x , \]

or

\[ x_t = \beta_0 + \sum_{i=1}^{P} \beta_i^y x_{t-i} + \sum_{i=0}^{Q} \beta_i^o o_{t-i} + \sum_{i=0}^{R} \left( \hat{\beta}_i^+ e_{t-i}^+ + \hat{\beta}_i^{\text{size}(+)} (e_{t-i}^+)^2 + \hat{\beta}_i^- e_{t-i}^- - \hat{\beta}_i^{\text{size}(-)} (e_{t-i}^-)^2 \right) + e_t^x . \] (2')

In order to test for size asymmetries we need to investigate the estimated \( \hat{\beta}_i^{\text{size}(+)} \) and \( \hat{\beta}_i^{\text{size}(-)} \) coefficients. For example, if we cannot reject the null hypothesis that \( \hat{\beta}_i^{\text{size}(+)} = \hat{\beta}_i^{\text{size}(-)} = 0, \forall i \), then the effectiveness of monetary policy shocks does not depend at all on their size. If, on the other hand, \( \sum_i \hat{\beta}_i^{\text{size}(+)} > 0 \) or \( \sum_i \hat{\beta}_i^{\text{size}(-)} < 0 \), then the effectiveness of monetary policy shocks declines with their (absolute) size, consistent with the predictions of “menu cost” theories. Note that nesting the size and sign asymmetries allows us to test whether the size effects are present in the positive shocks, in the negative shocks, or in both.

A system of Eqs. (1) and (2) (or (2')) can be estimated with the 2-step OLS procedure used by Barro (1977, 1978), or by the nonlinear least squares method used by Mishkin (1982, 1983), or by a system-wide multivariate maximum likelihood (ML) technique. The empirical section will focus mostly on the ML results, so the approach is illustrated here briefly. The log-likelihood function for the two-equation system, for example, is specified as

\[ L(\alpha, \beta, \Sigma) = -0.5 \ln |\Sigma| - 0.5(e' \Sigma^{-1} e) , \]

where \( \alpha \) and \( \beta \) are the parameter vectors of Eqs. (1) and (2), \( \Sigma = \begin{bmatrix} \sigma_{11} & \sigma_{12} \\ \sigma_{12} & \sigma_{22} \end{bmatrix} \) is the covariance matrix of the error vectors \( e^m \) and \( e^s \), and \( e' = ((e^m)', (e^s)') \). Initial values are obtained from the 2-step OLS regressions and the function is maximized with the BFGS method (a modification of the Davidson–Fletcher–Powell algorithm).

2.3. The data

All data are quarterly and obtained from the Federal Reserve Economic Data (FRED) database of the Federal Reserve Bank of St. Louis. Real GDP is used to construct the variable \( y \), the monetary base for \( m \), the Federal Reserve System’s industrial production index for \( i \), and the West Texas Intermediate spot oil price for \( o \).


3. Empirical results and discussion

3.1. Estimating sign asymmetries

We begin by estimating the system of Eqs. (1) and (2) for the four time periods defined above. Table 1 reports the estimated sums of the \( \beta^+ \) and \( \beta^- \) coefficients in Eq. (2) for output (\( x = \Delta y \)) under the assumption of eight lagged terms of the monetary base shocks in Eq. (2): \( R = 8.\(^{11}\) As expected, all estimated money terms are positive, and both \( \beta^+ \) and \( \beta^- \) coefficients are generally jointly statistically significant – i.e., the null hypotheses \( \beta_i^+ = 0, \forall i \) and \( \beta_i^- = 0, \forall i \) can be rejected in all cases (except \( \beta_i^+ = 0, \forall i \), which cannot be rejected for the Full/Short period).

Note, however, that all sums of positive coefficients, \( \sum_i \beta_i^+ \), are small and statistically insignificant. On the contrary, the sums of negative coefficients, \( \sum_i \beta_i^- \), are considerably larger and (except for the Full/Long sample) highly statistically

\(^{10}\) A long list of studies have addressed the question of significant differences in US monetary policy between the pre- and post-Volcker periods, usually in the context of the Taylor rule and the Taylor Principle. See Coibion and Gorodnichenko (2011) for a recent example. The Short/Long split is adopted to allow for structural differences due to Quantitative Easing. We also explored with other period divisions, including the Great Moderation, but without getting significant results.

\(^{11}\) Various other lag lengths were also tried, but did not alter the basic results.
significant. Moreover, and most important for our purposes, the null hypothesis $\beta^+_i = \beta^-_i, \forall i$, (the null of symmetry) can be rejected for all four samples, implying that the differences between the $\beta^+_i$ and $\beta^-_i$ coefficients are statistically significant.

These findings suggest that the output effects of monetary base shocks are indeed asymmetric and, in particular, that negative shocks have a much bigger effect on output than positive ones. Figs. 3, 4, 5, and 6 will visualize these results and clarify their implied dynamics, by plotting the responses of output and the monetary base itself to various types of monetary base shocks.

Fig. 3 reports these responses to a permanent (long-run) increase in the monetary base. The magnitude of the shock has been defined in such a way that its long-run effect is a 1% increase in the monetary base. As the left-hand side of Fig. 3 shows, this is achieved rather quickly in the Long period, but takes substantially more time in the Short period. The right-hand side graph of Fig. 3 shows the output responses to both negative and positive shocks.

As expected, positive monetary base shocks raise output, while negative shocks reduce it. Consistent with the findings of Table 1, however, these effects are clearly asymmetric: negative monetary base shocks have much larger effects on output than positive shocks.\footnote{In addition, the output responses to negative monetary base shocks are statistically significantly different from zero, while the responses to positive shocks are not.}

Interestingly, this holds both for the Long and Short samples, which implies that the asymmetry is valid regardless of whether the Quantitative Easing expansions are included. Using the point estimates, a 1% permanent increase in the monetary base has long-run output effect of 0.02% (Short sample) to 0.05% (Long sample), while a 1% permanent decrease in the monetary base has long-run output effect of $-0.18\%$ (Long sample) to $-0.25\%$ (Short sample).

Fig. 4 repeats the same exercise for the Volcker period. The general pattern of these responses is unaffected, though there is an important difference: the output effects of monetary base shocks are substantially larger. This is consistent with a view of greater potency for monetary policy in the Volcker period. The asymmetry result however is entirely robust: negative monetary base shocks generate bigger output responses than positive shocks – and this is robust for both the

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**Table 1**

Sign asymmetric effects on output: monetary base systems.

<table>
<thead>
<tr>
<th></th>
<th>Full 50:1–08:3</th>
<th>50:1–11:4</th>
<th>Volcker 79:3–08:3</th>
<th>79:3–11:4</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sum \beta^+_i$</td>
<td>0.049 (0.381)</td>
<td>0.070 (0.130)</td>
<td>0.332 (0.269)</td>
<td>0.072 (0.037)</td>
</tr>
<tr>
<td>$\sum \beta^-_i$</td>
<td>0.841 (0.321)</td>
<td>0.226 (0.132)</td>
<td>0.851 (0.262)</td>
<td>0.212 (0.067)</td>
</tr>
</tbody>
</table>

**$\chi^2$ tests**

- $\beta^+_i = \beta^-_i, \forall i$: 18.49* 67.21** 49.86** 193.3**
- $\beta^+_i = 0, \forall i$: 9.09 19.37* 24.25** 56.5**
- $\beta^-_i = 0, \forall i$: 17.18* 82.09** 54.22** 191.9**

Notes: Joint ML estimation (2-stage OLS used for starting values). Estimated standard errors in parentheses; Lag lengths: $M = N = P = Q = 4$, $R = 8$.

**Significant at 1%**.

**Significant at 5%**.
Long and Short time periods, indicating again that it holds with or without the post 2008:Q3 period. Using again the point estimates, a 1% permanent increase in the monetary base has long-run output effect of 0.1% (Long sample) to 0.2% (Short sample), while a 1% permanent decrease in the monetary base has long-run output effect of $-0.25\%$ (Long sample) to $-0.50\%$ (Short sample).

Figs. 3 and 4 assume shocks that produce permanent changes (increases or decreases) in the level of the monetary base. It is, however, unclear whether this is what the Fed intends for the Quantitative Easing that started in 2008:Q3 – and in fact there is evidence that the Fed’s exit strategy will involve (at least some) unwinding of this expansion. It is therefore interesting to consider shocks that would change (increase or decrease) the monetary base temporarily, as this may be a more realistic experiment.

Figs. 5 and 6 consider such temporary shocks that are constructed to change the monetary base for four years, achieve a peak change of 1%, and die out in the long-run. We call these “four-year” monetary base shocks. The left-hand side of Fig. 5 traces the effects on the monetary base itself for both versions of the Full period. Comparing those with the corresponding plots of Fig. 3 makes apparent the temporary nature of the “four-year” shocks: they increase or decrease the monetary base for our years by a maximum of 1%, but the change dies out in the long-run.

The right-hand side of Fig. 5 shows the output responses to these “four-year” temporary shocks for the Full period. Just like before, positive monetary base shocks raise output, while negative shocks reduce it. The main difference, of course, is that now the output effects are temporary: the shocks cause a deviation of output from the trend, but this disappears in the long-run. This is of course as expected, given the temporary nature of the monetary base expansion.

Once more, however, these effects are clearly asymmetric: negative monetary base shocks have much larger effects on output than positive shocks (the effects of which are statistically insignificant) and this holds both for the Long and Short
samples. Using the point estimates, a 1% four-year increase in the monetary base has peak output effect of 0.03% (Short sample) to 0.07% (Long sample), while a 1% four-year decrease in the monetary base has a peak output effect of −0.28% (Long sample) to −0.30% (Short sample).

Fig. 6 repeats the exercise of the four-year monetary base shocks for the Volcker period. Again, the general pattern of these responses is very similar, including the evidence of greater potency for the monetary policy in the Volcker period. The asymmetry result is again robust: negative monetary base shocks generate bigger output responses than positive shocks – even though the output effects are temporary in both cases – and this holds for both the Long and Short time periods. Using the point estimates, a 1% four-year increase in the monetary base has peak output effect of 0.2% (Long sample) to 0.15% (Short sample), while a 1% four-year decrease in the monetary base has a peak output effect of −0.4% (Long sample) to −0.55% (Short sample).

Finally, we turn to the effects on industrial production, estimating the system of Eqs. (1) and (2) with \( x = \Delta i \) and eight lags. Fig. 7 reports the estimated impulse responses to permanent and four-year monetary base shocks (only for the Volcker period to preserve space). As expected, industrial production falls sharply following a negative monetary base shock, while positive monetary base shocks are followed by much smaller (and generally statistically insignificant) increases in industrial production. This holds for both permanent and four-year shocks, with the difference that the industrial production effects of the latter are temporary.

Relying on the point estimates, a 1% four-year increase in the monetary base has peak industrial production effect of 0.2% (Long sample) to 0.3% (Short sample), while a 1% four-year decrease in the monetary base has a peak output effect of −0.8% (Long and Short samples).
that including the size variables does not change our results regarding the sign asymmetry. In particular, all estimated
the possibility that there are size asymmetries as well by estimating the system of Eqs. (1) and (2)
3.2. Estimating sign and size asymmetries
larger than those of positive shocks.

It follows that allowing for size asymmetries does not change the finding that sign asymmetries exist.

Quantitative Easing. The basic question can be expressed very succinctly: is a 100% expansion in the monetary base 100
times as potent as a 1% expansion? The answer is Yes under size symmetry, but No under size asymmetry.

Summing up the results so far, the evidence shows that monetary base shocks have asymmetric effects on output and
industrial production. Depending on the model, the effects of negative monetary base shocks are found to be several times
larger than those of positive shocks.

3.2. Estimating sign and size asymmetries

The last section has shown that sign asymmetries characterize the effects of monetary policy. In this section, we allow for
the possibility that there are size asymmetries as well by estimating the system of Eqs. (1) and (2'). The issue is particularly
important when one considers the effects of unusually large increases in the monetary base, such as those that characterize
Quantitative Easing. The basic question can be expressed very succinctly: is a 100% expansion in the monetary base 100
times as potent as a 1% expansion? The answer is Yes under size symmetry, but No under size asymmetry.

Using the format of Table 1, Table 2 reports the sums of the estimated $\hat{\beta}^+$, $\hat{\beta}^-$, $\hat{\beta}^{size(+)}$, and $\hat{\beta}^{size(-)}$ coefficients in Eq. (2')
for output ($x = \Delta y$) and industrial production ($x = \Delta I$) under the assumption of eight lags ($R = 8$). The first thing to note is
that including the size variables does not change our results regarding the sign asymmetry. In particular, all estimated $\hat{\beta}^+$
and $\hat{\beta}^-$ terms are positive, and again the $\hat{\beta}^-$ terms are statistically significant and substantially larger than the $\hat{\beta}^+$ terms.
It follows that allowing for size asymmetries does not change the finding that sign asymmetries exist.

Now, we turn to the results on size. All the estimated $\hat{\beta}^{size(+)}$ and $\hat{\beta}^{size(-)}$ terms in Table 2 are negative and statistically
significant, indicating that the effectiveness of monetary base shocks declines with their (absolute) size, as expected. It is
worth noting that the $\hat{\beta}^{size(-)}$ coefficients are substantially larger, suggesting that the size asymmetry may be stronger for
the negative monetary base shocks.

4. Conclusions

This paper has investigated two types of asymmetric effects of monetary base shocks on US output, unemployment, and
industrial production. Quarterly data from 1950–2011 have been used to identify monetary base shocks and their effects
for various periods, including the episodes of Quantitative Easing after 2008:Q4. The paper’s empirical findings support the
following conclusions:

(i) There is clear evidence of sign asymmetry: monetary base contractions have larger effects on economic activity than
monetary base expansions (the effects of which are often statistically insignificant). This holds for both output and
industrial production, and continues to be the case even when sign and size asymmetries are jointly estimated.
(ii) Sign asymmetry characterizes both permanent and temporary (modeled here as four-year) shocks to the monetary base.
(iii) There is also evidence of size asymmetry: the effectiveness of monetary base shocks declines with size. Put differently,
a 100% increase in the monetary base is less than 100 times as effective as a 1% increase in the monetary base.
(iv) Size asymmetry characterizes both positive and negative monetary base shocks, though it appears to be stronger for
negative shocks.
(v) There results are robust to whether the Quantitative Easing period is included in the sample or not.

| Table 2 |

| Sign and size asymmetric effects on output: monetary base systems (Full sample). |

<table>
<thead>
<tr>
<th>Real GDP</th>
<th>Industrial production</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sum \hat{\beta}^+$</td>
<td>0.0775 (0.1551)</td>
</tr>
<tr>
<td>$\sum \hat{\beta}^-$</td>
<td>0.5334 (0.1462)</td>
</tr>
<tr>
<td>$\sum \hat{\beta}^{size(+) -}$</td>
<td>-0.0195 (0.0084)</td>
</tr>
<tr>
<td>$\sum \hat{\beta}^{size(-) -}$</td>
<td>-0.1178 (0.0599)</td>
</tr>
</tbody>
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<table>
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<tr>
<th>$\chi^2$ tests</th>
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</thead>
<tbody>
<tr>
<td>$\hat{\beta}^+$ = 0, ∀i</td>
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<tr>
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</tr>
<tr>
<td>$\hat{\beta}^{size(+)} = 0, ∀i$</td>
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<tr>
<td>$\hat{\beta}^{size(-)} = 0, ∀i$</td>
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Notes: Joint ML estimation (2-stage OLS used for starting values). Estimated standard errors in
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** Significant at 1%.
* Significant at 5%.
References


