E C O N O M I C S   B U L L E T I N

Analyzing the impact of prenatal care on infant health: do we have useful input and output measures?

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Abstract

Recent work raises questions about the input and output measures typically used to estimate the impact of prenatal care on infant health: self-reported prenatal care may generate biased estimates of the impact of prenatal care on infant health, and birthweight may be a narrow measure of infant health that leads to underestimation of the impact of prenatal care on delivery outcomes. We link data from a prenatal care clinic, the associated hospital and the relevant birth certificate records to analyze these measurement issues. We conclude that low birthweight is not meaningful measure of infant health for the purpose of estimating the relation between prenatal care and delivery outcomes. In addition, the discrepancy between provider-reported and self-reported care is substantial, the correlation between these two measures is low, and the estimated relationship between prenatal care and infant health is not robust with respect to reliance on self-reported vs. provider-reported care.

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1. Introduction

Datasets derived from birth-certificate records are widely used to estimate the impact of prenatal care on delivery outcomes. Recent papers raise concerns about the quality of this data, and indicate that data-quality issues may lead to biased estimates of this impact. We link hospital, prenatal clinic and birth-certificate records for a sample of mother-infant pairs, to analyze the implications of relying on birth-certificate data to measure prenatal care utilization and infant health.

Data derived from birth-certificates include two measures of prenatal care utilization (self-reported prenatal care visits and start-month), and two measures of infant health (a continuous birthweight variable, and a dichotomous variable indicating low birthweight). While some studies augment this data by linking the birth-certificate information to other data sources, the input and output measures derived from birth-certificates constitute the central focus of most prenatal care impact analyses (Conway and Deb 2005, Evans and Lien 2005, Joyce 1999, Rosenzweig and Schultz 1983, Baldwin, et. al 1998). The inaccuracy of self-reported prenatal care is well-known, but analysts argue that this data is, nonetheless, useful for policy analysis as long as the inaccuracy does not bias the analytical results (Schoendorf and Branum 2006, Bradford, et. al 2007, Kressin et. al 2003).

Recent papers, however, raise questions about the validity of the assumption that self-reported prenatal care utilization data can yield unbiased results. The critical issue is whether the accuracy of birth-certificate records varies across demographic groups. Forrest and Singh (1987) compare three sources of data on prenatal care utilization (Vital Statistics, National Natality Survey, National Survey of Family Growth), and conclude that there are statistically significant differences in data quality across demographic subgroups, but differences across these subgroups are small relative to the differences across data sources. Similarly, Reichman & Schwartz-Soicher (2007) report that the sensitivities of prenatal care utilization vary significantly across demographic groups, but the magnitudes of the differences are small.

Despite these reassuring results, two recent papers conclude that self-reported data introduces significant bias into the estimation of the impact of prenatal care on infant health; however, the two papers do not agree on the direction of that bias. Penrod and Lantz (2000) conclude that self-reported data introduces a bias that attenuates the magnitude of the estimated impact, while Reichman, et al.(2006) conclude that self-reported data introduces a bias that works in the opposite direction.

Reichman, et al. (2006) also note that birthweight is a narrow measure of infant health, that may not encompass the full set of infant health conditions potentially mitigated by prenatal care. If prenatal care potentially impacts other conditions, in addition to preventing low birthweight, then reliance on birthweight as the primary measure of infant health will lead to underestimation of the value of prenatal care.

We link hospital, prenatal care clinic and birth-certificate data to examine three issues:

1. The degree to which low birthweight is a good proxy for infant health,
2. Characteristics of the discrepancy between self- and provider-reported care, and
3. The impact of alternate measures of prenatal care and infant health on the estimated relationship between prenatal care and infant health outcomes.

2. Data

2.1 The Dataset

We link data from three sources: a tertiary care hospital that includes a neonatal intensive care unit, a subsidized prenatal care clinic associated with the hospital, and birth-certificate records. The dataset includes all single live births that (i) occurred in the hospital from 2000-2002, and (ii) were preceded by either prenatal care provided by the associated clinic or no care. Cases were removed from the data if the infant was transferred to a larger hospital for specialized care or if the mother had surgery that was unrelated to the delivery (such as trauma-related surgery). The hospital administrative data includes maternal age and insurance status, infant and maternal Diagnostic Related Group (DRG), infant and maternal diagnoses reported as International Classification of Diseases (ICD-9) codes, and the marginal cost of providing hospital care for the infant. The administrative data used here is the source for the relevant hospital discharge data.

The clinic data includes the number of visits and the duration of time between the first prenatal care visit and the delivery. The birth-certificate data includes the self-reported number of visits and prenatal care start month, maternal demographic characteristics, and infant birthweight. Of the available hospital records, 85% were linked to prenatal clinic records. Of the matched hospital and clinic records, 68% were matched to birth-certificate records. The resulting sample includes 2076 mother-infant pairs.

Our focus on data from a single hospital and its associated prenatal care clinic presents both advantages & disadvantages. Reliance on a single provider minimizes unobserved variation that could stem from differences in provider practice patterns, quality of prenatal care, community demographic characteristics, or the availability of relevant social support services. This permits us to use the marginal cost of the infant's hospital stay as a broad measure of infant health because it measures the resources employed to provide care with minimal variation in medical practice patterns or hospital accounting practices. The single-provider dataset, however, also imposes a potential limitation. The provider-reported prenatal care includes care provided by our sample clinic, ignoring the possibility that patients may have received care from multiple sources. Anecdotal evidence from the clinic, however indicates that this is probably not a major issue in this sample because the subject clinic is a primary source of care for Medicaid patients, and the clinic is subsidized by the hospital to provide care for low-income patients.

Reichman, et al. (2006) analyze similar issues using a dataset that includes maternal and infant diagnoses from abstracted medical records, rather than administrative data. While abstracted medical records provide a greater range of demographic or diagnosis variables, they do not include the marginal cost of treating the infant during the infant's hospital stay. The administrative data used in our study does include this marginal cost, which provides a broad measure of infant health.

Our sample is not representative of the United States population: young, low-income, and Hispanic mothers are over-represented in our sample. Our conclusion that the measurement problems can lead to biased results is therefore indicative of the importance of additional investigation of these measurement issues, but it cannot be generalized to the population as a whole.

2.2 Output Measures: Birth-certificate data include two widely-used measures of infant size: a continuous birthweight variable, Weight, and a dichotomous variable to indicate birthweight less than 2500 grams, LBW. The administrative data includes four additional measures of infant health.

- The hospital administrative data includes ICD-9 code 765, which encompasses both the infant's birthweight and the infant's health condition. This code identifies infants with "Disorders relating to short gestation and low birthweight" and notes that this code "Usually implies" a birthweight of less than 2,500 grams. Infants with this code are identified in our study by the dichotomous variable ICD9-765. In contrast, the birth-certificate data classifies any infant who weighs less than 2,500 as LBW, without regard to health status.
- ICD-9 codes also provide information about additional infant diagnoses: congenital abnormalities (ICD-9 codes 740-759), maternal causes of perinatal morbidity and mortality (ICD-9 codes 760-763), slow fetal growth (ICD-9 code 764), high birthweight (ICD-9 code 766), and other conditions originating in the perinatal period (ICD-9 codes 767-779).
- Three Diagnostic Related Group (DRG) codes indicate preterm delivery (386-388), which are used to create a dichotomous variable, Preterm.
- The marginal cost of providing hospital care for the infant provides a broad measure of infant health because this variable, which is computed by the hospital activity-based cost accounting system, measures the direct cost of the resources used to provide care for each infant. Overhead and indirect expenses are not included, the single-provider dataset minimizes variations in practice patterns and community infrastructure, and the infant ICD-9 codes account for infant congenital abnormalities.

2.3 Input Measures: We define four measures of prenatal care inputs: provider-reported visits and duration, and self-reported visits and duration. We focus on duration of prenatal care, rather than the start month, to facilitate interpretation of our results: increases in both duration and visits reflect increased quantities of care. We define the variable, Duration, to be the number of months between the prenatal care start-date and the delivery. We do not use gestational age to adjust the duration variable for premature deliveries, due to published concerns about the accuracy of the gestational age variable.

2.4 Exogenous Variables: The variable Year in the final regressions accounts for the impact of inflation on the infant's marginal cost. Maternal demographic characteristics included in the data set are: maternal age and education (completion of high school or not), insurance status (self-insured, covered by Medicaid or other government program, or privately insured), race/ethnicity (black, Hispanic), and the presence of exogenous diagnoses (pre-existing maternal hypertension, pre-existing factors indicating a high-risk pregnancy, other pre-existing maternal diagnoses, and infant congenital abnormalities).

3. Analyses and Results

3.1 Does the LBW variable provide a good proxy measure for infant health?

We regress the natural log of marginal cost, lnMC, on the alternate measures of infant health (Weight, LBW, ICD9-765, Preterm, and a set of infant diagnoses) to assess the degree to which LBW provides a good proxy for infant health (see Table 1). The relationships between lnMC and the infant size measures are statistically significant, but the explanatory power is low (the R-squared statistics range from .02 to .06). Adding the infant diagnoses variables, however, increases the R-squared statistic to .18. We conclude that infant size does not provide a broad measure of infant health, because infant health is also affected by other diagnoses that may be potentially impacted by prenatal care.

We also consider the relation between the numeric LBW classification system and the medical ICD9-765 systems (see Table 2).[1] Of the 95 infants classified as LBW, 68 are not coded as ICD9-765, and two-thirds of these 68 infants are female. Among the LBW infants, marginal cost is significantly higher for infants categorized as ICD9-765. This treatment cost difference is consistent with the fact that all of the infants classified as ICD9-765 were categorized as premature (DRG 386, 387 or 388), while almost half (43) of the 95 infants categorized as LBW are coded as normal newborns (DRG 391).

3.2 Does self-reported care provide a good proxy measure for provider-reported care?

We examine two aspects of the relationship between self-reported and provider-reported prenatal care. First, we estimate the ordinary least squares (OLS) regression equation:

$$S_i = a + \beta P_i + \varepsilon$$

where S_i represents self-reported prenatal care, P_i represents provider-reported prenatal care, and i indexes the two prenatal care measures, Duration and Visits.

The relationships between self-reported and provider-reported Visits and duration are weak. Ordinary least squares (OLS) estimation yields:

- Self-reported duration = 5.73 + .32*provider-reported duration + ε; R^2 = .10, and
- Self-reported Visits = 7.31 + .44*provider-reported Visits + ε; R^2 = .15,

where ε is an error term. These estimated equations imply that self-reported care is approximately equal to provider-reported care when the number of Visits is 13, and the duration of care is 8 months. Self-reported care exceeds provider-reported care when providers report care below these levels, and the self-reported care is understated when

[1] LBW infants constitute 4.6% of our sample. For comparison, the nationwide LBW rate for single live births is 6.0%. (CDC National Vital Statistics System) The sample rate is reasonable, given the over-representation of young and Hispanic births in our sample.) The hospital data codes 3% of infants as ICD9-765.

providers reported higher levels of care. Thus, the relationship between self-reported and provider-reported care suggests that new mothers know the "correct" numbers and are motivated to state these "correct" numbers. (See Figure 1.) The estimated coefficients of the provider-reported variables are statistically significant at the 1% level; however the R-squared statistics for the regression equations are low.

Second, we use OLS estimation to test the null hypotheses that the discrepancies between self-reported and provider-reported measures of prenatal care are not correlated with maternal demographic or health characteristics, provider-reported care, or infant health. These discrepancies, which are computed as

$$D_i = S_i - P_i. \qquad \text{Equation (1)}$$

are substantial. The average number of self-reported Visits, 10.5, exceeds the average number of provider-reported Visits, 7.2, by nearly 50 percent. Similarly, the average self-reported duration of prenatal care, 6.7 months, is more than double the average provider-reported duration, 3.1 months.

OLS regressions of the Visit and Duration discrepancies on maternal characteristics, provider-reported care, and infant health indicate that these variables account for 19% and 26% of the variations in the Duration and Visits discrepancies (Table 3). The Duration discrepancy is significantly related to the diagnosis of high-risk pregnancy, marginal cost of the infant's hospital stay, and provider-reported care. The Visits discrepancy is significantly associated with maternal education, race/ethnicity, diagnoses of pre-existing hypertension and high-risk pregnancy, and provider-reported care.

The gap between self-reported and provider-reported Visits is larger for mothers with pre-existing hypertension, but this diagnosis is not significantly related to the Duration discrepancy (See Table 3). This pattern suggests that mothers may be including all visits that occur during the pregnancy as "prenatal care". Roohan, et al. (2003) have previously discussed the possibility that the discrepancy between self-reported and provider-reported Visits could reflect lack of clarity about the definition of prenatal care, rather than reporting error. Their discussion focused on a slightly different issue: that a mother might count, as the first prenatal care visit, an office visit in which the pregnancy is confirmed, while providers would not categorize this visit as "prenatal care".

3.3 Is the estimated infant health production function robust with respect to the alternate measures of prenatal care inputs and outputs?

We estimate an infant health production function similar to those reported in the literature, to analyze the impact of using alternate measures of prenatal care inputs and outputs. Infant health is assumed to be a function of prenatal care, maternal health, and maternal demographic variables:

$$H = \beta_0 + \beta_1 P_i + \beta_2 X + \varepsilon \qquad \text{Equation (2)}$$

Where: H measures infant health, P_i measures the quantity of prenatal care, X is vector of exogenous variables measuring maternal health and demographic characteristics and time, and ε is a random error term.

Consistent with Reichman, et al., we use Ordinary Least Squares (OLS), rather than Two Stage Least Squares (2SLS) estimation, due to (a) concerns about the quality of the available instrumental variables and (b) evidence indicating that the impact of typically unobserved variables is minor. Estimation of Equation (2) is straightforward when provider-reported data is available. To estimate Equation (2) with self-reported data, we substitute Equation (1) into Equation (2):

$$H = \beta_0 + \beta_1 S_i + \gamma D + \beta_2 X + \varepsilon \qquad \text{Equation (3).}$$

Because information about D is not typically available when self-reported data is used, Equation (3) is estimated as Equation (4), in which D is an omitted variable:

$$H = \beta_0 + \beta_1 S_i + \beta_2 X + \varepsilon \qquad \text{Equation (4).}$$

Estimation of β_1 in Equation (4) will be unbiased if the missing variable, *D*, is not correlated with *H, S* or *X*. We therefore investigate the issue of bias by estimating the relationship between D and these variables, and by comparing the estimates of β_1 in Equations (1) and (4).

Table 4 reports estimates of the infant health production function specified in Equation (1), using both self-reported and provider-reported Visits to measure prenatal care inputs and both low birthweight (LBW) and marginal cost to measure infant health. The coefficient of provider-reported Visits is not statistically significant, regardless of whether LBW or lnMC is used to measure infant health. In contrast, the coefficient of self-reported Visits is statistically significant for both measures of infant health. We do not report results for self-reported and provider-reported Duration, because neither of these measures has a statistically significant coefficient.

Application of the Park Test to the log scale OLS residuals indicates that we cannot reject the null hypothesis of homoscedasticity for both self-reported and provider-reported visits. In addition, the residuals in both equations are leptokurtic, with kurtosis equal to 18.9 for self-reported visits and 19.1 for provider-reported visits. Following Manning and Mullahy (2001) and Manning, Basu and Mullahy (2005), we conclude that log scale OLS is the appropriate estimation strategy for this data.

This finding, that self-reported Visits are significantly associated with infant health while provider-reported Visits are not, is not consistent with the typical assumption that self-reports provide a more noisy signal than provider-reports. This suggests two hypotheses for further research:

- Self-reported care could provide a more meaningful measure of care than provider-reported care if the visits that are not counted by providers (as "prenatal care") actually contribute to infant health. For example, the fact that the visits discrepancy is higher for women with pre-existing hypertension is potentially consistent with this hypothesis if these women are counting visits with specialists who treat this ongoing pre-existing condition.

- If the discrepancy between self-reported and provider-reported Visits reflects the degree of maternal knowledge of the "correct" number of visits and motivation to state this "correct" number, it might measure maternal characteristics that are also associated with behaviors that contribute to infant health. The significant positive relationship between maternal education and the Visits discrepancy is consistent with this hypothesis.

4. Conclusion

Data derived from birth-certificates provides convenient input and output measures for analyzing the impact of prenatal care on infant health. However, analysis of matched provider, hospital and birth-certificate records indicates that these convenient measures are problematic. First, low birthweight is a narrow measure of infant health that accounts for less than five percent of the variation in the marginal cost of providing hospital care during the infant's delivery-episode hospital stay. In addition, substantial discrepancies exist between the numeric classification system for identifying low birthweight infants and the medical identification of infants with health problems associated with low birthweight, and the medical system appears to produce more meaningful results. Second, the correlation between self-reported and provider-reported prenatal care is low. Finally – and most troubling - estimates of the impact of prenatal care on infant health are not robust with respect to reliance on self-reported vs. provider-reported Visits. Consistent with the results reported by Reichman, et al. (2006) , self-reported prenatal care Visits appear to exert a significant beneficial impact on infant health, while provider-reported Visits do not.

Table 1: Relation between marginal cost, low birthweight and infant diagnoses					
Independent variables:	**Dependent variable: lnMC estimated regression coefficients (t-statistics)**				
Gender (male = 1, female = 2)	-.032 (1.37)	-.034 (1.47)	-.018 (0.80)	-.020 (0.89)	
LBW	.377** (6.81)				
Weight (grams)		-.000 (4.37)**			
ICD9-765			.635**		.444 (6.89)**
Premature (0 = no, 1 = yes)				.636 (11.23)**	
Congenital abnormalities					.326 (5.19.)**
Maternal causes of perinatal morbidity and mortality					.269 (3.57)**
Other conditions originating in the perinatal period, excluding growth or gestation issues					.679 (16.27)**
Slow growth or gestation issues					.295 (2.77)**
High birthweight					.067 (1.10)
constant	Not printed to maintain confidentiality				
R-squared statistic	**.02**	**.01**	**.04**	**.06**	**.18**
N = 2076					
**significant at 1%					

Table 2: Identifying low birthweight infants:
Numeric (LBW) vs. medical (ICD9-765) classification

	Numbers of infants	
	LBW: Weight >= 2500 grams[1]	**LBW: Weight < 2500 grams**[2]
Not ICD9-765	1948	68
ICD9 -765	33	27

[1]Average lnMC is significantly higher for infants with ICD9-765 than for other infants in this category.

[2]Average lnMC is significantly higher for infants with ICD9-765 than for other infants in this category.

Table 3: Discrepancy (D) between self-reported and provider-reported care		
Independent variables	**Dependent variable: D=Discrepancy Estimated coefficients (t statistics)**	
	$D_{duration}$	**D_{visits}**
Maternal demographic characteristics		
age	0.010	-0.030
	(0.28)	(0.42)
Completed high school (Y/N)	0.156*	0.416**
	(1.66)	(2.31)
Insurance status		
Self-insured	-0.223*	-0.435*
	(1.83)	(1.84)
Government (primarily Medicaid)	-0.240*	-0.114
	(1.84)	(0.45)
Race/ethnicity		
black	-0.485*	-1.265**
	(1.90)	(2.53)
Hispanic	0.008	-0.816***
	(0.08)	(4.41)
Exogenous diagnoses		
Pre-existing hypertension	0.049	1.048**
	(0.19)	(2.09)
Pre-existing high-risk	-1.812***	-1.896***
	(9.31)	(4.69)
Other maternal diagnoses	0.014	-0.185
	(0.12)	(0.88)
Infant congenital abnormalities	0.004	0.438
	(0.02)	(0.90)
Infant health		
lnMC	-0.394***	-0.577
	(4.05)	(1.26)
Provider-reported prenatal care		
ln(provider-reported Visits)		-4.428***
		(3.20)
Interaction Visits and MC		0.138
		(0.59)
ln(provider-reported Duration)	-2.371***	
	(6.17)	
Interaction Duration and MC	0.285***	
	(4.43)	
Constant	6.483***	13.772***
	(11.22)	(5.04)
Observations	2046	1970
R-squared statistic	**0.19**	**0.26**

Absolute value of t statistics in parentheses;
*** significant at 10%; ** significant at 5%; *** significant at 1%**

Table 4: OLS estimation results: impact of prenatal care on infant health				
Independent variables	**Dependent variable**			
	lnMC (estimated coefficients)		**LBW (marginals)**	
	visits reported by:			
	self	**provider**	**self**	**provider**
Number of visits				
self-reported visits	-0.006**		-0.003***	
	(2.280)		(3.33)	
provider-reported visits		0.000		-0.002
		(0.060)		(1.39)
year	0.167***	0.167***	0.012**	0.012**
	(11.950)	(11.900)	(2.43)	(2.33)
Infant gender (male = 1; female = 2)	-0.019	-0.020	0.021***	0.022***
	(0.860)	(0.940)	(2.67)	(2.65)
Maternal demographic characteristics				
Completed high school (yes = 1; no = 0)	0.051**	0.048**	0.005	0.004
	(2.190)	(2.100)	(0.59)	(0.51)
married	0.007	0.009	0.004	0.004
	(0.330)	(0.390)	(0.51)	(0.44)
Tobacco use	-0.005	-0.009	-0.027***	-0.029***
	(0.190)	(0.370)	(2.93)	(3.04)
Alcohol use	-0.027	-0.022	-0.019	-0.020
	(0.710)	(0.570)	(0.86)	(0.84)
Race/ethnicity				
black	0.130**	0.141**	0.001	0.005
	(2.030)	(2.190)	(0.07)	(0.20)
Hispanic	0.015	0.022	0.001	0.003
	(0.580)	(0.890)	(0.09)	(0.34)
Exogenous diagnoses				
Pre-existing hypertension	0.310***	0.300***	0.169***	0.152***
	(4.900)	(4.760)	(3.20)	(3.03)
Pre-existing high-risk	0.110**	0.131***	-0.020**	-0.014
	(2.430)	(2.920)	(1.97)	(1.11)
Other maternal diagnoses	0.243***	0.247***	0.009	0.010
	(9.020)	(9.160)	(0.89)	(0.94)
Infant congenital abnormalities	0.346***	0.341***	0.065*	0.063
	(5.340)	(5.260)	(1.67)	(1.61)
Constant				
Observations	2059	2059	2076	2076
R-squared statistic/pseudo R-square	**0.14**	**0.13**	**.08**	**.07**

Absolute value of t statistics in parentheses;
*** significant at 10%; ** significant at 5%; *** significant at 1%**

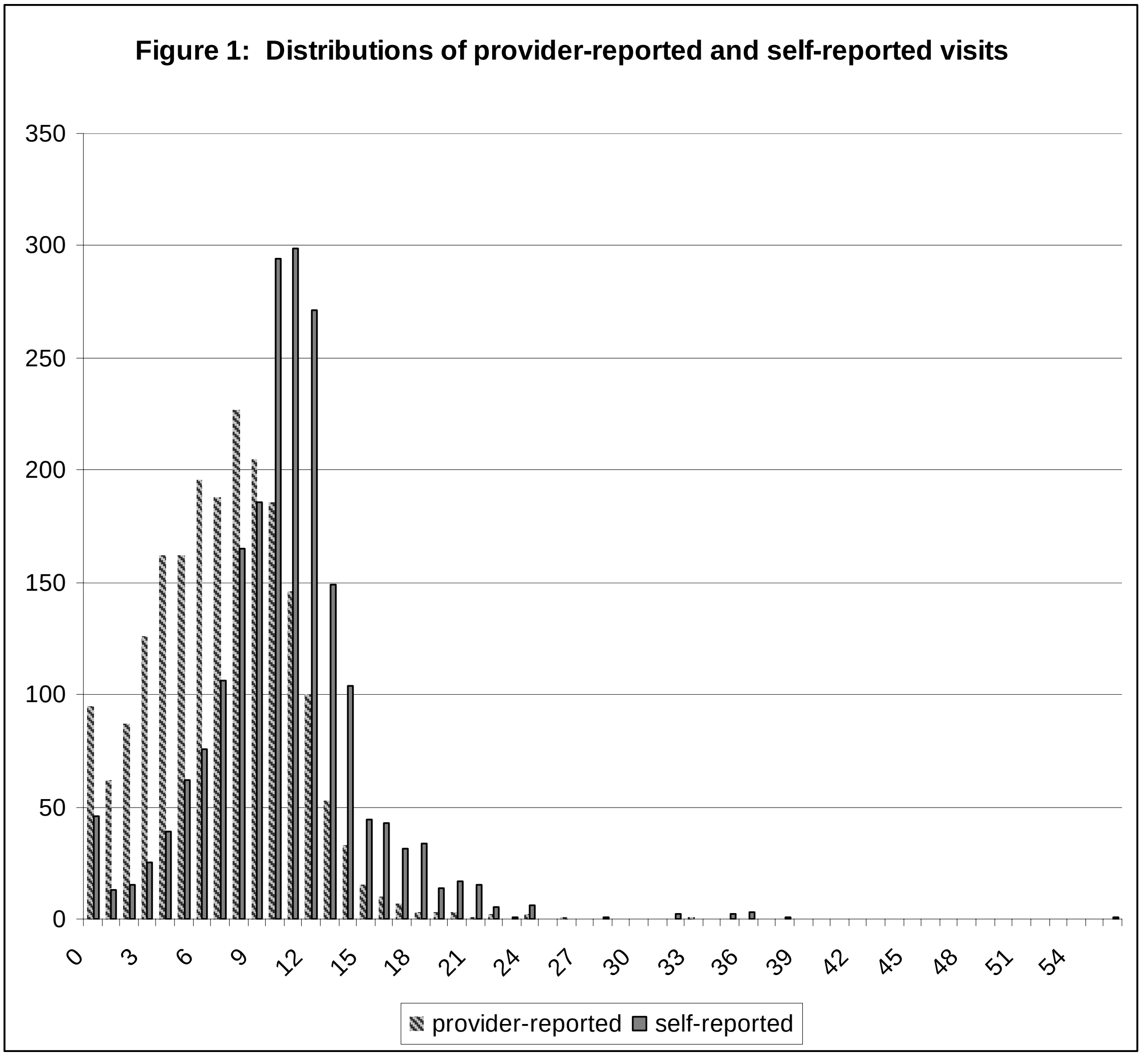
Figure 1: Distributions of provider-reported and self-reported visits
350
300
250
200
150
100
50
0
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
51
54
provider-reported
self-reported

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