AN ABSTRACT OF THE DISSERTATION OF

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Title: Oregon Coordinated Care Organizations: Impacts on Health and Health Care Utilization of Infants Enrolled in Medicaid

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In August 2012, Oregon began enrolling Medicaid beneficiaries in coordinated care organizations (CCOs), a unique mandatory-enrollment accountable care organization (ACO) model with payment methods strongly tied to preventive care; care coordination; and integration of physical, mental and dental health care through patient-centered medical homes. This dissertation, consisting of two studies, examined the impact of the new delivery model on healthcare utilization and mortality among infants enrolled in Medicaid. Also, it investigated if the CCO model had heterogeneous impacts for preterm and full-term infants and if the effect of CCOs changed over the implementation timeline.

Study 1 examined the extent to which CCOs had effects on healthcare utilization of infants during their two years of birth. Using Oregon birth certificates, Medicaid enrollment data, Medicaid claims, and hospital discharge data, a sample of

77,101 pre-CCO infants and 90,775 post-CCO infants was created whose healthcare utilization was followed for two years after birth. Service utilization outcomes included pediatric preventive care services, i.e., well-child visits and developmental screenings, emergency department (ED) visits, and hospital admissions. This study found that infants enrolled in CCOs received more preventive services compared to their pre-CCO counterparts. Impacts of CCOs on preventive care services also grew over the CCO implementation timeline. ED visits slightly increased and hospital admissions reduced after CCO implementation but not statistically significant. No statistically significant difference was found in the effects of CCOs on service utilization between preterm infants and full-term infants.

Study 2 investigated the impact of CCO implementation on neonatal and infant mortality. The sample consisted of the pre-CCO birth cohort of 136,519 infants and the post-CCO birth cohort of 149,523 infants. Using difference-in-differences approach, the CCO model was found to be significantly associated with a reduction in both neonatal mortality (68% compared to the pre-CCO level) and infant mortality (37% compared to the pre-CCO level), and also with a greater reduction in infant mortality among preterm infants compared to full-term infants. The impact on infant mortality also grew in magnitude over the post implementation timeline.

CCOs should continue their strategies to improve preventive care and health outcomes for infants. Given the plan to incorporate more specific policies to address children’s health in the next phase of CCO implementation in 2020-2024, future research should further investigate the effects of CCOs on utilization of ED and inpatient services and cost of care for children, as well as how CCOs would have an impact on different high-risk children populations.

Oregon Coordinated Care Organizations: Impacts on Health and Health Care Utilization of Infants Enrolled in Medicaid

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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

Linh N Bui, Author

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CONTRIBUTION OF AUTHORS

Dr. Jangho Yoon assisted with the research design, analysis plan, interpretation of analysis results and writing throughout the dissertation. Dr.Marie Harvey and Dr.Jeff Luck were coauthors of the two manuscripts (Chapter 3 and Chapter 4). Dr. Marie Harvey also provided numerous suggestions and edits for Chapter 1 and Chapter 2. Dr. Adam Branscum provided advices and suggestions on methods.

CHAPTER ONE

General Introduction

1.1 Rationale

In the U.S, children under 18 years old comprise a third of all people living in poverty (Jiang, Granja, & Koball, 2017). Infants and toddlers under 3 years old are especially vulnerable because they are most likely to live in households with income less than 100% of the federal poverty level (FPL) (Jiang et al., 2017). Nearly one-quarter (23%) of children under three years of age live in a poor family compared to 21% in children between 3 and 18 years old, 14% in adults less than 65 years old, and 9% in adults 65 years and older (Jiang et al., 2017). Low-income parents have been shown to be negatively associated with poor infant outcomes. For example, poorer children are more likely to be born preterm (Olson, Diekema, Elliott, & Renier, 2010), have low birth weight, and acquire chronic conditions that they may have to manage throughout their lives (Currie & Lin, 2007; Kehrer & Wolin, 1979; Margolis et al., 1992). Additionally, infants in low-income families also experience an increased infant mortality rate (Olson et al., 2010; Singh & Kogan, 2007).

Low-income children face barriers to accessing care. Affordability and availability of healthcare services have been reported by parents or care givers as the most significant barriers to accessing care for children (Angier et al., 2014). Low socioeconomic status families with young children report a lack of a usual source of care and unmet health needs including medical care, dental care, or prescription drugs

(Boudreau et al., 2014; Dubay & Kenney, 2001). To address these barriers, providing insurance coverage is an important first step in increasing access to care for this population.

Oregon Medicaid, known as the Oregon Health Plan (OHP), is the largest health insurer for children in Oregon. OHP currently covers about 50% of all births and over 400,000 children (0-18 years old) from low-income families (income lower than 200% FPL) who account for about 43% of the state's Medicaid population (Child Welfare League of America, 2017; National Center for Children in Poverty, 2017; Oregon Health Authority, 2016). Medicaid programs covering low-income children play an important role in enabling them to enter the healthcare system. However, simply having insurance coverage does not guarantee access to needed care. Although Medicaid provides a comprehensive benefits package with services under the Early and Periodic Screening, Diagnosis, and Treatment (EPSDT) program for children with no or little cost sharing, children enrolled in Medicaid continue to face difficulties in obtaining needed care or reporting satisfaction with the care they receive (Mayer, Skinner, & Slifkin, 2004). For instance, social-emotional screening for young children on Medicaid is not covered in eight states. In four states, Medicaid does not pay for child mental health services in pediatric or family medicine settings. Also, eligibility requirements for mental healthcare or covered mental health services vary by states (Smith, Granja, Ekono, Robbins, & Magarur, 2017). Over one-fifth (22%) of children with special healthcare needs, defined as "who have or are at an increased risk for a chronic physical, developmental, behavioral, or emotional condition and who also require health and related services of a type or amount beyond that required by children generally" (McPherson et al., 1998), are living in households with income below the FPL and are mainly covered by Medicaid. Nevertheless, challenges remain for state Medicaid programs to address problems with access to care for this group, especially to effectively coordinate care between different providers and between Medicaid and other programs (Silow-Carroll et al., 2016).

One strategy to address access and care coordination problems was the development of fully-capitated Medicaid Managed Care Organizations (MCOs) (Centers for Medicare & Medicaid Services). As of 2011, nearly all Medicaid beneficiaries in Oregon are mandatorily enrolled in fully-capitated MCOs. Although MCOs covered physical health care, behavioral health and dental care were frequently not covered (McConnell et al., 2014). Also, healthcare was still delivered from a fragmented care delivery system where different MCOs managed physical health, behavioral health, and dental care separately. This fragmentation often leads to increased costs and poorer health outcomes (Howard, Bernell, Yoon, Luck, & Ranit, 2015).

The passage of the Patient Protection and Affordable Care Act (ACA) in 2010 prompted significant changes in health insurance and managed care. Two important provisions included Medicaid expansion and the creation of Accountable Care Organizations (ACOs) ("Patient Protection and Affordable Care Act," 2010). An ACO is a healthcare organization that is accountable or responsible for the quality, efficiency, and cost of the care they provide for its enrolled population. The ultimate goal of ACOs is to provide care coordination to improve patients' outcomes, especially for those with chronic conditions (Centers for Medicare & Medicaid Services). Although ACOs were originally applied to Medicare beneficiaries under fee-for-service program, states have begun to apply the model to Medicaid programs. This model arguably contributes to cost containment because of better care coordination. For this reason states are motivated to adopt the model to address budgetary pressures for Medicaid programs (Kocot, Dang-Vu, White, & McClellan, 2013). However, the growth of pediatric ACOs has been modest compared to that of ACOs serving older populations.

With a history of Medicaid expansion and reform, Oregon transformed its healthcare delivery model for low-income people with the implementation of Coordinated Care Organizations (CCOs) which was launched in 2012. Fifteen regional CCOs providing integrated care for physical, behavioral, and dental health are currently serving more than 90% of Oregon’s Medicaid population, both adults and children (Oregon Health Authority, 2016). The CCO arrangements are considered as a highly comprehensive managed care model and distinguished from most MCOs and ACOs in many ways (Howard et al., 2015; McConnell et al., 2014). For example, CCOs receive a global budget to improve care for its beneficiaries. Each CCO has its governance from not only healthcare providers but also members of a community advisory council that ensure community’s health needs are met (Kushner et al., 2017). They share similarities with ACOs in that they are held accountable for both cost and quality of care, and through the use of payment incentives that reward improved health outcomes and saved cost.

Patient-Centered Primary Care Homes (PCPCHs), which were established in Oregon in 2009, have been strongly promoted in OHP in order to coordinate care. Each CCO aims to provide care to the majority of its beneficiaries through PCPCHs. In

PCPCHs, physicians, and non-physician providers work together to manage patients' healthcare needs. With a focus on increasing preventive and primary care and improving the management of chronic conditions or high-risk patients, the CCO model could have significant impacts on both children's and women's health, especially during pregnancy. Recent evidence found that the implementation of CCOs in Oregon was associated with a significant increase in timely receipt of prenatal care among women on Medicaid (Muoto, Luck, Yoon, Bernell, & Snowden, 2016; Oakley, Harvey, Yoon, & Luck, 2017). In addition, adverse neonatal and infant outcomes (e.g., low birth weight and abnormal conditions) were shown to decrease following CCO implementation (Harvey, Oakley, Yoon, & Luck, 2017).

Also, given CCOs' focus on high-risk patients, we may expect an improvement in healthcare and health outcomes for preterm infants (babies are born before 37 weeks of pregnancy. Preterm babies are commonly admitted to a hospital's neonatal intensive care unit (NICU) at birth and require ongoing chronic care management because of higher risks for chronic respiratory diseases and neurodevelopmental disabilities after NICU discharge (Jarjour, 2015; McCormick, Litt, Smith, & Zupancic, 2011). Preterm infants continue to have significant health service utilization compared to babies who were not admitted to the NICU, such as more frequent outpatient visits, increased primary and specialty care utilization, a greater number of prescription drugs (Mccourt & Griffin., 2000; Wade et al., 2008), and excess hospital readmission, especially in the first 2 years after NICU discharge (Johnston et al., 2014; Underwood, Danielsen, & Gilbert, 2007). A healthcare delivery system for preterm infants after NICU discharge has been proposed based on a population health approach utilizing the chronic care management framework

(Kuo, Lyle, Casey, & Stille, 2017). Within such a framework, care delivery system transformation, like CCOs, could play an important role in improving care quality and health outcomes for NICU graduates in Oregon.

Limited studies have investigated the impact of Medicaid ACO models on children's health. Mixed results were found on the impacts of pediatric Medicaid ACO models on healthcare utilization. Kelleher et al. (2015) found that a Medicaid ACO model was able to provide quality of care for their members and demonstrated some improvements in NICU days per 1,000 members and well-child visits (Kelleher et al., 2015). Christensen and Payne (2016) also found that receiving primary care at an ACO clinic was associated with a significant decrease in inpatient days and an increase in office visits, ER visits, and pharmaceutical usage of pediatric Medicaid population. However, McConnell and colleagues (McConnell et al., 2017) found that access to primary care declined and did not find statistical significant reduction in ED visits and inpatient days in the two-year period after CCO implementation among children under 18 years of age. Although infant mortality had been widely used as a measure of the quality of health care, only two studies examined the impact of Medicaid ACOs on this outcome and suggested no reduction in mortality (Harvey et al., 2017; Henke et al., 2019).

1.2 Aims

To my knowledge, no study has examined the impact of CCOs on healthcare utilization and mortality among infants enrolled in Medicaid. Also, no evidence is available to understand whether and how the CCO model impacts healthcare utilization and mortality among preterm infants. The implementation of CCOs in Oregon in 2012 provides a unique natural experiment to study the role of healthcare delivery transformation on the health of low-income infants. The primary purpose of this dissertation was to examine the impacts of Oregon CCOs on health service utilization and mortality of infants enrolled in Medicaid during the first two years after birth. This dissertation also investigated whether the effects of CCOs on health service utilization and mortality differ between preterm infants and full-term infants enrolled in Medicaid.

Manuscript 1:

The first manuscript examined the extent to which the CCO implementation had an effect on health service utilization of infants enrolled in Medicaid during the first two years after birth. Because the CCO model aims to improve comprehensive care management for Medicaid beneficiaries through the primary care setting, I hypothesized that infants enrolled in CCOs would have increased usage of preventive services. Improved case management by primary physicians through the CCO model would then reduce hospital admission and emergency department (ED) visits. Because CCOs target high-risk patients, I investigated if the effect of the CCO implementation on health service utilization differed between preterm infants and full-term infants. I also tested if the impact of CCOs on health service utilization changed over the CCO implementation timeline.

Manuscript 2

The goal of the second manuscript was to examine the extent to which the CCO implementation had an effect on mortality during the first year of birth among infants enrolled in Medicaid. A previous study did not find a reduction in infant mortality after one year of CCO implementation (Harvey et al., 2017). It is possible that the impact of health delivery transformation on mortality may require a longer period of time to find an association. With the ability to follow CCO implementation in four years, I investigated the effect of CCO implementation on both neonatal and infant mortality. I tested my hypotheses that the CCO model resulted in a greater reduction in mortality among preterm infants compared to full-term infants and impacts of CCO implementation on mortality increased over the four years of implementation.

1.3. Policy significance

The application of the Medicaid ACO model is modest in the pediatric population and, thus, evidence on the effects of ACOs on health and healthcare utilization of children is still limited. Early evidence showed that the CCO model, a unique type of Medicaid ACOs, reduced some adverse health outcomes but not mortality in infants (Harvey et al., 2017). Furthermore, effects of the CCO model on healthcare utilization for infants are unknown. This dissertation will have two major policy implications. First, infancy and early childhood are vulnerable periods and abnormal or adverse development in the early years of infants could shape their wellbeing over their lifespan. Therefore, if CCOs are shown to improve quality of care and health outcome, they could serve as a care delivery model for infants and young children in other Medicaid programs or private health plans. Second, no evidence has been found on the impacts of CCOs on high-risk groups, like preterm infants. If the CCO model is found to have a greater impact on preterm infants compared to full-term infants, it could be a potential care model to address healthcare needs for other high-risk pediatric populations.

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CHAPTER 2

Literature Review

2.1 History of Managed Care Organizations (MCOs) and Accountable Care Organizations (ACOs)

Starting in the mid-1960s, both health service utilization and the price of services in the U.S have increased as a result of a third-party payment system, developments in the field of medical science, and an increased demand for health care. National health expenditure accelerated during the 1970s and 1980s and led to the development and growth of managed care organizations (MCOs). Two examples of early MCOs included Health Maintenance Organizations (HMOs) and Preferred Provider Organizations (PPOs). HMOs rapidly grew and gradually replaced traditional health insurance plans due to lower premiums, cost sharing, and more comprehensive benefits, including coverage of preventive services and prescription drugs. PPOs give beneficiaries lower cost sharing if they see “in network” providers, who have accepted discounted fees by the health insurance plan. Compared to HMOs, PPOs do not require primary care physicians’ authorization for access to specialists and other providers. Different HMO-like plans were also developed, such as Point-of-service (POS) plans in which members accessed care through primary care physicians (PCPs) and had little cost sharing if they saw “in-network” providers. The difference between POS and HMOs is that members are still covered if they see an out-of-network provider but with higher cost sharing (P. D. Fox & Kongstvedt, 2013).

From the mid-1980s to late 1990s, Medicaid managed care witnessed a sharp increase from 2.3 million to 18.8 million Medicaid beneficiaries (Kaiser Family

Foundation, 2001) and Medicare enrollment in capitated plans like HMOs reached 6.9 million by 2000 (Centers for Medicare & Medicaid Services, 2002). Utilization management was widely used in MCOs to manage healthcare cost. It helped control cost by acting as a “gate keeper” and requiring authorization for PCPs to access specialists, by shifting care from inpatient to outpatient settings, and by reducing the length of stay in a hospital through paying a fixed amount per admission for each diagnosis group. Some HMOs became extremely aggressive in reducing utilization to control cost. The rapid growth of MCOs created a burden on the delivery system through mistakes in paperwork or delays in claims processing. Moreover, resentment grew with some consumers who were upset with the requirement for authorization to seek specialty care and denials of coverage. Altogether, by the early 2000s these complaints were referred to as the “managed care back-lash” and forced HMOs to loosen restrictions on utilization management, causing healthcare costs to rapidly rise from 2000 to 2010, resulting in an increased number of uninsured people and higher cost sharing in health plans (P. D. Fox & Kongstvedt, 2013).

The expansion of Medicaid coverage and the creation of Accountable Care Organizations (ACO) are two significant changes in health insurance and managed care that resulted from the Patient Protection and Affordable Care Act (ACA) passed in 2010. An ACO is defined as a healthcare organization that is accountable for the quality, efficiency, and cost of the care they provide for its enrolled population. Under the ACA, ACOs were originally applied only to Medicare beneficiaries under a fee-for-service program. Medicare beneficiaries were assigned to ACOs in which participating providers were responsible for the cost of Medicare Part A and Part B benefits and may share any savings associated with improved quality of care in the Medicare Shared Savings Program. ACOs aim to provide care coordination to improve patients' outcomes, especially for those with chronic conditions (Centers for Medicare & Medicaid Services). Because better care coordination could contribute to cost control, the model has more recently been applied to Medicaid programs as well. By mid-2013, nine states had implemented ACO models for their Medicaid programs (Kocot, Dang-Vu, White, & McClellan, 2013). While structures of Medicaid ACOs are heterogeneous, they all focus on care coordination, patient-centered care, usage of quality metrics, and the design of incentives to reward improved care quality. Medicaid ACOs are similar to Medicaid MCOs in that they both receive capitated payment and provide comprehensive health benefits. With some MCOs, benefits like behavioral or dental health could be excluded. However, some ACOs attempt to integrate physical, behavioral, and dental health care. In terms of payment methods, all ACOs have some form of risk-adjusted and outcomes-adjusted reimbursement. Data collection for quality and cost measures are critical for ACOs to determine incentive payments for improved quality and/or lower cost. Furthermore, primary care and data sharing among providers are other emphases of ACOs in their attempt to improve care coordination.

Given ACO characteristics (patient-centered care, care coordination, and primary care focus) ACO models potentially serve as a good care model for children, especially low-income children. Children with chronic conditions require more complex care management to prevent long-term consequences and, thus, care coordination is critical to this population. Yet, the growth of pediatric ACOs has been modest compared to that of ACOs who serve older population (Perrin et al., 2017). A lack of general support for pediatric ACOs exists. For example, the Pediatric ACO Demonstration Project, which was outlined in the ACA ("Patient Protection and Affordable Care Act," 2010), has never received funding and pediatric ACO models have not been directly supported by the Centers for Medicare and Medicaid Services (Perrin et al., 2017). Additionally, cost saving and improved outcomes are more difficult to achieve for children in the short-term making arguments for pediatric ACO funding more difficult (Horowitz & Stein, 1990; Perrin et al., 2017).

2.2 Health reforms in Oregon and Oregon Coordinated Care Organizations (CCOs)

Oregon has a history of Medicaid expansion and reforms. In 1994, its Medicaid program, known as Oregon Health Plan (OHP), was expanded to cover people with incomes up to 100% of the FPL. Under the ACA, the state chose to further expand the OHP to people whose incomes were up to 133% of the FPL. OHP currently covers over 400,000 low-income children (aged 0-18 years old) who account for over 40% of the state's Medicaid population and nearly half of the state's children population (Child Welfare League of America, 2017; National Center for Children in Poverty, 2017; Oregon Health Authority - Office of Health Analytics, 2018). Among children covered, nearly 34% are less than five years old. Children younger than one year are eligibility for Medicaid if they are living in households with a modified adjusted gross income (MAGI) under 185% of the FPL. For children aged 1-18, the income threshold for eligibility is under 133% of the FPL (Centers for Medicare & Medicaid Services).

To control cost and improve care quality, Oregon transformed its healthcare delivery model for low-income people with the implementation of Coordinated Care Organizations (CCOs) launched in August 2012. Fifteen regional CCOs are providing integrated care for physical, behavioral, and dental health for Oregon's Medicaid adults and children (Kushner et al., 2017). To assist the implementation of CCOs, the Centers for Medicare & Medicaid Services (CMS) provided the state with $1.9 billion over five years with the agreement that heath care costs will reduce by 2% by 2015, (i.e. spending growth targets at or below 3.4%), while maintaining care quality is ensured. Like ACOs, CCOs are accountable for cost and quality of care but distinguished from ACOs and MCOs by also being accountable for the population health of the region they serve. Each CCO is governed by not only healthcare providers but also community members, and other stakeholders in local health systems, to ensure community's health needs are met. CCOs are required to conduct Community Health Assessments to design care delivery systems that help improve population health (Kushner et al., 2017). CCOs receive capitated global budgets that allow more flexibility in spending for CCOs to improve care, such as spending on services that are not "medically necessary" or on public health interventions. Also, CCOs could receive incentive payments that reward improved health outcomes and saved costs, based on a list of CCO Incentive Measures (Kushner et al., 2017). Unlike MCOs, where behavioral health and dental health are not commonly included with physical health in a plan (McConnell et al., 2014), CCOs provide integrated care of the three components. Therefore, they help move away from a fragmented health delivery system where different MCOs manage physical, behavioral, and dental healthcare separately. To help coordinate care, Patient-Centered Primary Care Homes (PCPCHs) have been strongly promoted in OHP. All CCOs aim to provide care to a majority of its beneficiaries through PCPCH where physicians and non-physician providers work together to accommodate patients' healthcare needs and coordinate care for their patients. However, organization structure varies from one CCO to another. For instance, some CCOs operate more like MCOs who contract with providers to provide integrated care for OHP members, while others are groups of different MCOs and health providers, such as behavioral health groups, dental health organizations, and county health departments (Howard, Bernell, Yoon, Luck, & Ranit, 2015).

2.3 Care delivery design for preterm children

Medicaid covers a higher proportion of preterm births (babies are born before 37 weeks of pregnancy) than private insurance (Markus, Krohe, Garro, Gerstein, & Pellegrini, 2017). About eight percent of babies are born premature in Oregon each year (Oregon Health Authority) which is lower than the national average of nearly 10% (Martin, Hamilton, Osterman, Driscoll, & Drake, 2018). Preterm babies are often admitted to the hospital neonatal intensive care unit (NICU) as they have a higher risk of complications compared to full-term babies. They also often require ongoing chronic care management because they have a higher risk for chronic respiratory diseases and neurodevelopmental disabilities (Jarjour, 2015; McCormick, Litt, Smith, & Zupancic, 2011). Besides the excessive cost of care in NICU, research has shown that preterm children continue to have significant health service utilization and cost. Preterm infants require more frequent outpatient visits, both primary care and specialty care, and prescription drugs (Mccourt & Griffin., 2000; Wade et al., 2008). They also have excess hospital readmission, especially in the first two years after NICU discharge (Johnston et al., 2014; Underwood, Danielsen, & Gilbert, 2007). Given the special characteristics and needs of preterm children, care delivery for this population requires close follow-up care in outpatient settings, especially primary care, care coordination, and integration for the management of both acute and chronic conditions as well as ongoing developmental screening and intervention.

In 2017, Kuo et al., (2017) proposed a conceptual model of care delivery for preterm infants in primary care settings based on the Chronic Care Model. The main focus of the model includes (1) building a registry system that allows primary care physicians to track preterm infants after NICU discharge; (2) improving care coordination among providers in the care team of preterm infants in which the primary care physician is usually the designated physician for continuity of care; (3) providing family-centered care in which families are partners of the provider team; (4) applying standardized clinical care protocols among providers; and (5) utilizing data to inform care and improve care quality. Within this framework, care delivery system transformation, like CCOs, could play an important role in improving care quality and health outcomes for preterm children in Oregon. Because CCOs target high-risk and high cost patients, preterm children should be considered one of their priority populations. CCOs could provide better care management for these children through care integration and care coordination provided by their PCPCHs. CCOs' accountability for population health and more flexibility with global budgets would allow for interventions that address social determinants of health for children and improve outreach services for families with preterm babies. Given excessive hospitalization readmission and emergency department visits of these children, reduction of costs is also potentially high. Potential cost savings could be used to provide financial incentives for providers based on improved care quality. Examples of suggested quality measures include preventive care, acute and chronic care, developmental screening, nutrition, psychosocial evaluations, and provider communication (Wang et al., 2006).

2.4 Impacts of Medicaid MCOs, ACOs, and CCOs on children's health outcomes

Mixed results have been found on the impacts of managed care on children's healthcare utilization. In terms of access to care, a study showed that children covered by MCOs were more likely to have a usual source of care (Freeman & Kirkman-Liff, 1985), however, others have found decreased access to primary care and office visits for Medicaid children under managed care plans (Hurley, Freund, & Gage, 1991; Research Triangle Institute, 1992). Similarly, managed care yields disparate impacts on healthcare utilization of Medicaid children (Szilagyi, 1998). The review by Szilagyi et al., (1998) concluded that although most studies have found no difference in hospital admission by plan type (managed care versus fee-for-service), some have observed small decreases in hospitalization for MCO plans. MCOs using fee-for-service reimbursement mechanisms have increased primary care and office visits but those using capitation methods to pay providers were more likely to have no effect on office visits or decrease primary care ambulatory services for children (Szilagyi, 1998). One positive impact of managed care consistently found in literature is the reduction in ED visits, especially low-severity ED visits (Szilagyi, 1998). Also, strong evidence has been found to suggest that managed care reduces specialty care services among Medicaid children (Davidson et al., 1992; Leibowitz, Buchanan, & Mann, 1992). Yet, decrease in ED and specialty care utilizations also brought some concerns that under managed care ED visits for high-risk children could potentially be denied, or coverage for high-cost specialty care could have reduced for children with chronic conditions (H. B. Fox, Wicks, & Newacheck, 1993; Horowitz &

Stein, 1990). Regarding care coordination, Gilchrist-Scott et al., (2017) compared access to and receipt of care coordination of Medicaid children in two Medicaid managed care structures, primary care case management (PCCM) and HMO. The authors found that the enrollment in PCCM was associated with increased access to care coordination and receipt of care. This finding suggests that manage care structures that emphasize primary care could yield better care coordination, a metric could lead to improved health outcome.

Medicaid managed care with specific interventions on care delivery for women and children have been shown to decrease NICU admission rate. Stankaitis and colleagues (2005) examined how a quality improvement intervention in an MCO serving a Medicaid population in New York could reduce NICU admissions. The intervention comprised of identification and stratification of high-risk women, improved outreach through nursing care coordination, offering home visits, transportation, support services, social work services, connection with community organizations, and strengthening informatics structure. It resulted in a reduction of NICU admission from 107.6 per 1,000 births to 56.7 per 1,000 births after five years of implementation. The authors witnessed similar a decrease in trends of preterm births and births with extremely low birth weight (<1,900 gram).

Researchers have also investigated the impacts of Medicaid managed care on children with special health needs. Many studies have suggested that children with special health needs who are covered by Medicaid managed care have similar levels of health service utilization compared to those covered by fee-for-service plans. Nonetheless, some have found a reduction in ED visits among infants on Medicaid managed care (Huffman, Brat, Chamberlain, & Wise, 2010). Limited studies have provided information on the impacts of Medicaid managed care on cost and health status of preterm children. More specifically, Hutchinson and Foster (2003) conducted a review on research examining the effects of Medicaid managed care on children with mental health problems or those using mental health services. Their review concluded that Medicaid managed care reduced the use of inpatient care and shifted care to outpatient settings. Total expenditure for mental health services has been found to also decrease under managed care models. Although Medicaid managed care models encourage the measurement of health outcomes and quality of care, research that directly measures the effect of Medicaid managed care on mental health outcomes is lacking (Hutchinson & Foster, 2003) .

Recent studies show that pediatric ACOs can change healthcare utilization patterns, reduce costs, and maintain care quality. Kelleher et al., (2015) assessed changes in cost and quality of care for a pediatric ACO, a physician/hospital organization, covering more than 300,000 low-income children in central and southeastern Ohio. The ACO is paid per-member, per-month (PMPM) for care and is responsible for both care management and provider reimbursement. The study showed that the ACO was able to contain cost growth with a much lower rate compared to Medicaid managed care and FFS over the period from 2008 to 2013. Meanwhile, quality of care for its members was stable with some improvement in NICU days per 1,000 members and well-child visits. The authors suggest that care coordination was the key to the success of this ACO, specifically using digital communications and health record portals to manage care, providing a single set of guidelines for providers, and collaborating with specialty practice groups to coordinate care. Christensen and Payne (2016) also found that the length of consistent primary care (length of attribution) as part of an ACO changed healthcare utilization and cost in Medicaid children. Continuous attribution to the ACO for more than two years was associated with an increase in office visits, ER visits, and pharmaceutical use. In contrast, receiving more than one primary care visit at an ACO clinic during a two-year period was associated with a 40.6% decrease in inpatient hospitalization days of pediatric Medicaid children. Such change in healthcare utilization reduced cost by 15.7%. Although ACOs have some form of outcome-based reimbursement to incentivize providers for improved care quality, only one study investigated Pay-for-Performance (P4P) as an alternative payment mechanism in a pediatric ACO (Gleeson, Kelleher, & Gardner, 2016). The study compared pediatric performance on 14 quality measures among 3 groups of primary care physicians: incentivized community physicians, non-incentivized community physicians, and non-incentivized physicians employed at hospitals. The P4P model resulted in modest improvements in performance of incentivized community physicians compared to the non-incentivized community physicians but no improvements when comparing with the non-incentivized hospital physicians.

As aforementioned, one study has examined the effect of Oregon CCO implementation on neonatal and infant outcomes (Harvey, Oakley, Yoon, & Luck, 2017). The authors compared changes in outcomes from pre- and post-CCO periods and between Medicaid and non-Medicaid births born in Oregon. CCO implementation was associated with the reduction of low birth weight and abnormal conditions, but did not find an association for low 5-minute Apgar score, congenital anomalies, or infant mortality after one year launching this new care model. In this study, the likelihood of low birth weight and abnormal conditions were reduced by 0.95%, 1.08%, respectively. It was suggested by the authors that the positive impacts of CCOs on neonatal and infant health might be a result of not only improved prenatal care but also other pathways, such as enhanced access to integrated care for women before and during pregnancy in primary care homes (Harvey et al., 2017). Also, it would require longer follow-up time for any health delivery transformation to have impacts on health outcome like mortality. Another recent study examined the impact of Medicaid ACOs on maternal and neonatal outcomes in Colorado, New Jersey and Oregon (Henke et al., 2019). The authors used hospital discharge data to compare each of the three states before and after Medicaid ACO implementation with an adjacent state where Medicaid ACO was not implemented and found no impact of Medicaid ACO on infant neonatal mortality. Some possible reasons the authors did not find impact of Medicaid ACO on neonatal outcomes includes that ACOs may focus on some other areas of care, e.g., mental health and substance use disorders, or the health system was not able to address social determinants of health (Henke et al., 2019).

Another recent study investigated the effect of CCO implementation on healthcare utilization (McConnell et al., 2017). The authors used physical health claims data to examine access to care, appropriateness of care, utilization, and cost of five service areas, including evaluation and management, imaging, procedures, tests, and inpatient care in both adults and children. They also compared pre- and post-CCO periods between Oregon, a state with CCO transformation, and Washington, a state without CCO implementation. The study found that ED visits and inpatient admissions were reduced in the two-year period after CCO implementation. Additionally, inpatient days decreased significantly but primary care also declined following CCO implementation. Especially concerning is the finding that access to a primary care physician among children who are 1-6 years old decreased by 1.1% and access to preventive ambulatory care in adults reduced by 3.0%. Overall, standardized expenditures PMPM reduced by seven percentage points across service areas. However, a reduction in cost was not significant in children (McConnell et al., 2017).

To conclude, mixed results have been reported about the effects of Medicaid managed care on healthcare utilization and costs for children. Some research has suggested positive impacts of pediatric ACOs on children's healthcare utilization and health outcomes but none found an impact of pediatric ACOs on infant mortality or examined impacts of ACOs on high-risk infant populations. Because of Oregon's healthcare delivery system transformation, further evidence is need to document whether CCO implementation improves health outcomes for infants and young children, especially those born preterm who may be at greater need.

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CHAPTER 3

Manuscript 1: Coordinated Care Organizations and healthcare utilization among low-income infants in Oregon

3.1 Abstract

Objective: The main goal of the study was to examine the impact of coordinated care organizations (CCOs), a unique mandatory-enrollment accountable care organization (ACO) model for Oregon Medicaid beneficiaries, on healthcare utilization of infants during their two years of birth.

Data sources: Oregon birth certificates, Medicaid claims, Medicaid enrollment data, and hospital discharge data from 2008 to 2016.

Study design: Using Oregon 2008-14 birth certificates, we created the pre- and post-CCO cohorts of infants. The birth certificates were then linked to Medicaid enrollment data, Medicaid claims, and hospital discharge data to compare health service utilization of infants before and after the implementation of the CCO model. Service utilization outcomes included pediatric preventive care services, i.e., well-child visits and developmental screenings, emergency department (ED) visits and hospital admissions. We estimated multivariate count data models and binary outcome models, adjusting for time trends in the outcomes over the study period as well as comprehensive maternal and infant characteristics.

Principal findings: Infants enrolled in CCOs received more preventive services compared to their pre-CCO counterparts, e.g., 0.6 and 0.7 more well-baby visits per infant by the first and the second birthdays ($p<0.001$), respectively; and 26.0 percentage points increase in the probability of having annual development screening ($p<0.001$). ED visits slightly increased and hospital admissions reduced after CCO implementation but not statistically significant. We found no statistically significant difference in the effects of CCOs on service utilization between preterm infants and full-term infants. Impacts of CCOs on preventive care services grew over the CCO implementation timeline.

Conclusions: The CCO model was associated with improved preventive care but had no statistically significant effects on reducing ED and inpatient services in infants enrolled in Medicaid during two years after birth.

3.2 Introduction

The creation of Accountable Care Organizations (ACO) was a significant change in managed care that resulted from the Patient Protection and Affordable Care Act (ACA) passed in 2010 ("Patient Protection and Affordable Care Act," 2010). An ACO is defined as a healthcare organization that is accountable for the quality, efficiency, and cost of the care they provide for its enrolled population. ACOs have been applied to Medicare and private insurance and mostly in adult population (Wyman., 2014). However, the application of this model is really modest in children (Perrin et al., 2017). The model has recently been applied to Medicaid programs due to its potential in cost control and care quality improvement through care coordination (Kocot, Dang-Vu, White, & McClellan, 2013). While structures of Medicaid ACOs are heterogeneous, they all focus on care coordination, patient-centered care, primary care focus, usage of quality metrics, and the design of incentives to reward improved care quality. Children account for more than 40% of Medicaid enrollees (Center for Medicaid and CHIP Services) and low-income children, especially infants and young children, are more likely to have poor health outcomes (Currie & Lin, 2007; Kehrer & Wolin, 1979; Margolis et al., 1992; Olson, Diekema, Elliott, & Renier, 2010; Singh & Kogan, 2007). Given Medicaid ACO characteristics, the care models potentially serve as a good care model for children.

Oregon's Medicaid program, known as the Oregon Health Plan (OHP), is the largest health insurer for children in Oregon. OHP currently covers approximately 50% of all births and over 400,000 children (0-18 years old) from low-income families (Child Welfare League of America, 2017; National Center for Children in Poverty, 2017; Oregon Health Authority, 2016). OHP provides a comprehensive benefit package with services under the Early and Periodic Screening, Diagnosis, and Treatment (EPSDT) program for children with no or little cost sharing. As of 2011, nearly all Medicaid beneficiaries in Oregon are mandatorily enrolled in fully-capitated Medicaid Managed Care Organizations (MCOs). Although MCOs covered physical health care services, behavioral health and dental care services were frequently not covered (McConnell et al., 2014). In addition, the health care delivery system was much fragmented as evident as elsewhere in the U.S. that different MCOs provided physical, behavioral, and dental health services separately without any coordination. This fragmentation often leads to greater costs and poorer health outcomes (Howard, Bernell, Yoon, Luck, & Ranit, 2015).

With a history of Medicaid reform, Oregon transformed its health care delivery model for low-income people with the implementation of Coordinated Care Organizations (CCOs) which was launched in 2012. Fifteen regional CCOs providing integrated care for physical, behavioral, and dental health are currently serving more than 90% of Oregon's Medicaid population, both adults and children (Oregon Health

Authority, 2016). The CCO arrangements are considered as a unique Medicaid Accountable Care Organizations (ACOs) model. They share similarities with ACOs in that they are held accountable for both cost and quality of care, and through the use of payment incentives that reward improved health outcomes and saved cost. However, CCOs receive a global budget to improve care for its beneficiaries. Each CCO has its governance from not only health care providers but also members of a community advisory council that ensure community's health needs are met (Kushner et al., 2017)..

Only few studies investigating the impact of pediatric Medicaid ACO models have suggested positive impacts on health care utilization of pediatric Medicaid population, e.g., improvement in well-child visits and reduction in inpatient days (Christensen & Payne, 2016; Kelleher et al., 2015). Early evidence also showed that the CCO model changed service utilization among their beneficiaries. McConnell and colleagues (McConnell, Renfro, Lindrooth, et al., 2017) found that ED visits and inpatient days were reduced in the two-year period after CCO implementation but not statistical significant in children under 18 years of age. Besides, access to primary care also declined following CCO implementation among Oregon Medicaid children. Further evidence is needed to document how the CCO implementation changes health care utilization among infants and young children.

The main objective of this study is to examine the extent to which the CCO implementation had an effect on health service utilization of infants enrolled in Medicaid during the first two years of birth. Preterm infants are considered as a "high-risk" population because they have higher risk for chronic conditions and greater needs for follow-up care and care coordination compared to full-term babies (Jarjour, 2015; Mccourt & Griffin., 2000; Wade et al., 2008). As CCOs target high-risk and high-cost patients, we also investigated whether the effects of CCOs on health care utilization differ between preterm infants and full-term infants. We also tested if the impact of CCOs on health care utilization of infants grew over the implementation timeline.

3.3 Methods

3.3.1 Data sources

Data came from multiple sources, including Oregon birth certificates, Medicaid eligibility and CCO enrollment data, Medicaid claims, and hospital discharge files for years 2008 through 2016. Every infant had a unique person identification number that allowed individual linkage across the datasets. Also, each infant had a unique mother-to-child identification number that enabled linkage between infant's information and maternal characteristics.

3.3.2 Sample

Using Oregon 2008-14 birth certificates, we created the pre- and post-CCO cohorts of infants, following their health care utilization for two years of birth. Pre-CCO cohort included infant born between August 2008 and July 2010. Cohort of infants born between August 2012 and December 2014 were considered as post-CCO. The birth certificates were then linked to Medicaid enrollment files to identify Medicaid infants and non-Medicaid infants. A Medicaid infant was defined as being enrolled in Medicaid for at least 80% (657 days) of the two years after birth. This threshold was used to ensure that Medicaid enrollment period during two years after birth was long enough to detect services received by infants but not overly restrictive by excluding infants who were without coverage for only a short interval.

Starting from August 2012, almost all Medicaid beneficiaries were enrolled in 16 CCOs, except for a small number of people could be exempted from CCO enrollment (e.g., American Indians, Alaska Natives, members eligible for both Medicaid and Medicare, or members with special health needs) (Oregon Health Authority, 2016, 2017, 2018). We excluded 1,379 infants (2.8% of post-CCO Medicaid infants) who were not enrolled in CCOs during post-CCO period. Non-Medicaid infants were defined as those who were not enrolled in Medicaid anytime during their two years after birth. The sample included 77,101 pre-CCO infants (36,546 Medicaid infants and 40,555 non-Medicaid infants) and 90,775 post-CCO infants (47,973 Medicaid infants and 42,802 non-Medicaid infants).

We analyzed two different analytic samples. To examine the impacts of CCOs on pediatric preventive care and ED utilization, we restricted analysis to the sample of Medicaid infants because claims for these services were not available for non-Medicaid infants. Medicaid claims were linked to identify preventive care services or ED visits. To investigate the extent to which the CCO implementation had an effect on hospitalization, we analyzed the full sample that included both Medicaid and non-Medicaid infants. Information on hospitalizations was retrieved from hospital discharge data.

3.3.3 Outcome variables

Pediatric preventive care: Pediatric preventive care services included well-child visits and developmental screenings. A list of diagnosis and procedure codes for pediatric preventive services suggested by the American Academy of Pediatrics was used to identify utilization of these services from Medicaid claims (American Academy of Pediatrics., 2012, 2019). Following the guideline recommended by the American Academy of Pediatrics that a baby should receive six well-child visits by the first birthday and nine well-child visits by the second birthday (American Academy of Pediatrics., 2018; Bright Futures Periodicity Schedule Work Group., 2017), we examined two outcomes of well-child visits: the total number of well-child visits and an indicator of receiving recommended numbers of well-child visits. It is also recommended that infants receive one developmental screening each year during the first two years after birth. Therefore, we constructed a binary outcome measure of receiving a developmental screening each year.

ED services and hospital admissions: ED utilization was measured by the annual number of ED visits. A baby had an ED visit if having Medicaid claims with place of services was the ED. We also examined the annual number of hospital admissions and hospital admissions were identified if an infant had admission records from the hospital discharge data.

3.3.4 Main independent variables

The indicator of post-CCO infant took value of 1 if a baby was born during the post-CCO period. Another binary indicator, CCO infant (i.e., Medicaid infant), took value of 1 if an infant enrolled in Medicaid for at least 80% of their two years after birth. We also used an indicator of preterm infant as defined by babies born before the 37th week of pregnancy using information on gestation weeks from birth certificates.

To estimate how the impact of CCOs grew over the implementation timeline, we used a monthly time indicator for the length of CCO implementation. This variable equaled 0 if an infant was born before the implementation of CCO (pre-CCO infants). It took value of 1 if an infant was born during the month when a CCO started its implementation and increased by 1 for another month of the implementation timeline.

3.3.5 Covariates

We examined the effects of CCO on health care utilization while controlling for a set of maternal characteristics, including age, race/ethnicity, education, marital status, rurality, body mass index (BMI) at delivery, smoking during pregnancy, number of previous births and whether a mother received adequate prenatal care. Adequacy of prenatal care was measured using the Kotelchuck Index (Kotelchuck, 1994). Adequacy of prenatal care was defined as prenatal care initiation within the first 4 months of pregnancy and completing at least 80% of the American Congress of Obstetricians and Gynecologists (ACOG) recommended number of visits for the gestational age of the infant (American College of Obstetricians and Gynecologists., 1985). The impacts of CCO implementation were also adjusted for important birth characteristics, i.e. birth weight, presence of birth risk factors, presence of abnormal conditions or congenital anomalies of newborns, and birth plurality. We used a binary indicator for the presence of abnormal conditions if an infant was admitted to the neonatal intensive care unit, needed immediate assisted ventilation following delivery, received assisted ventilation for more than six hours, received either surfactant replacement therapy or antibiotics for suspected neonatal sepsis, had a seizure or serious neurologic dysfunction or significant birth injury. Similarly, a binary indicator for presence of congenital anomalies was used. Congenital anomalies included anencephaly, meningomyelocele or spina bifida, cyanotic congenital heart disease, congenital diaphragmatic hernia, omphalocele, gastroschisis, limb reduction defect (excluding congenital amputation and dwarfing syndromes), cleft lip, cleft palate, Down syndrome, and hypospadias. Information on maternal and birth characteristics were retrieved from birth certificates. We also adjusted the effects of CCO implementation for time trends in the utilization outcomes over the study period.

3.3.6 Statistical analyses

Well-child and ED visit count outcomes

We estimated a hurdle model to examine CCOs' impacts on the number of well-child visits and ED visits. The model involved two-part analysis. The first part estimated a change in predicted probabilities of receiving each type of service following the CCO implementation and the second part restricted the analysis to infants who had at least one service claim to predict a change in the count of services between pre-CCO infants and post-CCO infants. The post-CCO infant indicator was the main independent variable. The hurdle model was controlled for maternal and birth characteristics mentioned above.

We estimated logistic regression for the first part of the hurdle model and zero-truncated negative binomial (ZTNB) for the second part. Person cluster-robust standard errors were computed in all models. In each part, an average marginal effect was computed for each outcome that captures an average change in predicted probabilities or predicted counts of outcomes between pre-CCO and post-CCO periods. Let g denote the link function for estimations in each part, ***post*** denote the indicator variable for post-CCO period, and x denote the vector of covariates, average marginal effects (AME) was estimated as followed:

$$\widehat{AME} = \frac{1}{n}\sum[g(1,x) - g(0,x)]$$

where $g(1,x) = E[Y|post = 1, x]$ and $g(0,x) = E[Y|post = 0, x]$ with Y is the outcome variable. Combining estimates from both parts by multiplying the average change in predicted probabilities of receiving any service from the first part by the average difference in predicted counts of services in the second part, we obtained full marginal effects, i.e., average change in predicted numbers of service utilization after CCO implementation. Bootstrapped standard errors of marginal effects were all obtained based on 1,000 repetitions.

Hospitalization count outcome

Regarding hospitalizations for which we had claims for both Medicaid and non-Medicaid infants, we estimated a difference-in-differences (DID) hurdle model. We included the interaction term of the post-CCO infant and CCO infant indicators. The coefficient of this interaction term represented a difference in hospital admission outcomes between CCO infants and non-CCO infants, attributable to the CCO implementation. AME of the interaction term in each part of the DID hurdle model was estimated as followed:

$$\widehat{AME} = \frac{1}{n}\sum[\left(\hat{y}_{cco=1,post=1} - \hat{y}_{cco=1,post=0}\right) - \left(\hat{y}_{cco=0,post=11} - \hat{y}_{cco=0,post=0}\right)]$$

where ***cco*** is the indicator variable for infants enrolled in Medicaid, ***post*** is the indicator for post-CCO infant, x is the vector of covariates, $\hat{y}$ is predicted outcomes, and

$$\hat{y}_{cco=1,post=1} = E[Y|cco = 1, post = 1, x]$$

$$\hat{y}_{cco=1,post=0} = E[Y|cco = 1, post = 0, x]$$

$$\hat{y}_{cco=0,post=1} = E[Y|cco = 0, post = 1, x]$$

$$\hat{y}_{cco=0,post=0} = E[Y|cco = 0, post = 0, x]$$

Binary utilization outcomes

To investigate if CCO implementation had an effect on the probabilities of receiving recommended number of well-child visits or developmental screenings, we used both logistic regression models and linear probability models. As in the count data model, we obtained average marginal effects from logistic regression models to estimate an average change in the probabilities of each outcome as well as bootstrapped standard errors from 1,000 repetitions.

Heterogeneous effects of CCOs separately for preterm and full-term infants

We also used a variant of DID approach to examine heterogeneous effects of CCOs on health care utilization. In particularly, we expanded all models for preventive care and ED utilization by including an interaction term between the post-CCO infant and preterm birth indicators. To investigate if the impacts of CCO implementation on hospitalizations differed between pre-term and full-term infants, we added a three-way interaction term between the post-CCO infant, CCO infant and preterm infant indicators to the models of hospitalization. The coefficients of these interaction terms represented the difference in the outcomes between preterm infants and full-term infants that was attributable to the CCO implementation.

Impacts of CCOs over the implementation timeline

We compared pre-CCO average to post-CCO value by month to investigate the extent to which the impact of CCOs grew over the implementation timeline. In all models for preventive care and ED utilization, the main independent variable was the monthly time indicator for the length of CCO implementation. In models for hospital admission, we included a three-way interaction term between the post-CCO infant, CCO infant indicators and the monthly time indicator for the length of CCO implementation. Average marginal effects were computed to estimate the monthly change in outcomes after CCO implementation.

3.3.7 Sensitivity analysis

We estimated the impacts of CCO implementation using different threshold for the definition of CCO infants (enrolled in Medicaid for at least 80%, 90% and 100% of the two year duration after birth). Also, we compared models with and without controlling for the indicator of adequacy of prenatal care. Because CCOs were shown to increase prenatal care that resulted in improved infant health outcomes (Harvey, Oakley, Yoon, & Luck, 2017; Oakley, Harvey, Yoon, & Luck, 2017) and thus might affect healthcare utilization of infants after birth, such comparison allowed us to investigate if CCOs had an effect on infant's service utilization through other pathways other than improving prenatal care for the mothers during pregnancy.

Analyses used Stata software, version 15.1. This study was approved by the Institutional Review Boards at Oregon State University and the Oregon Health Authority.

3.4 Results

3.4.1 Characteristics of the sample

Table 1 presents characteristics of our sample of infants. Mothers of Medicaid infants were younger, more likely to be Hispanic, less likely be White or to be married and had lower education levels compared to mothers of non-Medicaid babies. The proportion of babies living in rural areas was also higher in Medicaid infants. Mothers of Medicaid babies were also more likely to smoke during pregnancy and less likely to receive adequate prenatal care during pregnancy. The proportions of preterm births or presence of abnormal conditions or congenital anomalies in Medicaid babies were slightly higher than that in non-Medicaid babies.

Comparing the post-CCO birth cohorts to the pre-CCO birth cohorts, mothers of post-CCO babies were older, less likely to be Hispanic, had higher education level and more likely to be married. There was an increase in the proportion of mothers receiving adequate prenatal care after CCO implementation among Medicaid infants. The percentage of preterm births was also lower during post-CCO period among Medicaid babies.

3.4.2 Utilization of preventive services and ED services among Medicaid babies

Table 2 presents information on utilization of preventive services and ED services among Medicaid babies. During pre-CCO period, the average number of well-child visits a Medicaid baby received in the first year after birth was 3.98 (SD = 1.69) visits. By the second birthday, the average number of visits a baby received was 5.61 (SD = 2.28). The proportion of infants had recommended six visits by the first birthday was 16.78%. Only 8.32% of babies received nine visits as recommended by the end of two years after birth. After CCO implementation, the average number of well-child visits increased (4.29 visits by the 1st birthday and 6.0 visits by the 2nd birthday). There was a sharp increase in the proportion of babies having at least one developmental screening annually during the post-CCO period (25.68% in post-CCO infants compared to 8.19% in pre-CCO infants). In both pre- and post-CCO periods, preterm infants had slightly lower number of well-child visits but higher probability of receiving development screenings compared to full-term infants.

In terms of ED service utilization, average number of ED visits was the same between pre-CCO and post-CCO cohorts, i.e., 0.26 visits per baby per year. Preterm births had more ED visits compared to full-term births both before and after CCO implementation.

3.4.3 Hospital admissions

Table 3 shows annual counts of hospital admissions of infants in our sample. CCO infants, i.e., Medicaid infants, had more hospital admissions during their two years after birth compared to their non-CCO counterparts. After the implementation of CCOs, both CCO infants and non-CCO infants experienced a reduction in the number of admissions, i.e., a reduction from 0.075 to 0.056 admissions among CCO infants compared to a reduction from 0.002 to 0.001 admissions among non-CCO infants. Preterm infants had higher number of hospital admissions than full-term infants.

3.4.4 Impacts of CCO implementation on healthcare service utilization

Table 4 shows marginal effects from our models estimating the effects of CCO implementation on service utilization. CCO implementation increased pediatric preventive care among Medicaid infants. The combined marginal effects from both parts of hurdle models indicated that after CCO implementation, on average, the number of well-baby visits for each infant increased by 0.6 visit ($p < 0.001$) during the first year after birth. By the second birthday, the count of well-baby visits per infant also significantly increased by 0.7 visit ($p < 0.001$). The probability of receiving recommended numbers of well-baby visits also significantly improved after CCO implementation, i.e., 14.4% points (95%CI: 11.5; 17.4) by the first birthday and 6.7% point (95%CI: 4.3; 9.0) by the second birthday.

CCOs had a significant positive impact on providing developmental screenings for infants enrolled in Medicaid during their first two years of life. Annual probability of having developmental screening increased by 26.0% points ($p < 0.001$) from pre-CCO period to post-CCO period.

In terms of ED visits, infants born after CCO implementation had more ED visits compared to their counterparts in the pre-CCO period, i.e., 0.001 visits per year, but the difference was not statistically significant. In contrast, hospital admissions decreased in the post-CCO period by 0.004 admission per infant but not statistically significant.

3.4.5 Heterogeneous effects of CCO implementation between preterm infants and full-term infants

Table 5 presents results from our models investigating if there were heterogeneous effects of CCO implementation on service utilization between preterm infants and full-term infants. CCOs improved preventive care services among preterm infants, however, we did not find statistically significant difference in the impact of CCOs on preventive care between preterm infants and full-term infants, except for the probability of receiving adequacy of well-child visits during the first year of birth. For instance, by the first birthday, average number of well-child visits per infant increased by 0.6 visits ($p < 0.001$) among preterm infants. The increase was less by 0.01 visits than that among full-term infants but not statistically different. The probability of receiving adequacy of well-child visits improved by 11.9% points ($p < 0.001$) in preterm infants but lower by 2.3% points ($p < 0.05$) compared to full-term infants. We found a greater reduction in ED visits among preterm infants compared to full-term infants, i.e., 0.006 visits per infant, but the difference was not statistically significant. CCO implementation was not associated with a statistically significant reduction in annual hospital admission in preterm infants, i.e., −0.003 visits per infant (95% CI: −0.016; 0.010). Also, we did not find heterogeneous effects of CCOs on hospital admission between preterm and full-term infants.

3.4.6 Impacts of CCOs over the implementation timeline

As also shown in Table 4, the impacts of CCO implementation on preventive service use grew overtime. On average, number of well-baby visits received increased by 0.007 ($p<0.001$) by the first birthday for every month increase over the CCO implementation timeline. Impacts of CCO implementation on the probability of receiving six well-baby visits in the first year after birth increased by 0.17% points ($p < 0.001$) by a month increase in the implementation timeline. The probability of annual developmental screening also improved by 0.46% points ($p < 0.001$) every month starting from the launch of CCOs. Consistent with the findings on the overall impacts of CCOs on ED visits and hospitalization, average number of ED visits and hospital admissions reduced over the implementation period but not statistically significant.

3.4.7 Sensitivity analysis

Our results were robust with different thresholds of Medicaid enrollment. Comparing models with and without controlling for the indicator of adequacy of prenatal care, coefficients and marginal effects were very similar, which indicated that CCOs affected healthcare utilization of infants through different pathways other than improving prenatal care for the mothers during pregnancy period.

3.5 Discussion

After the implementation of Oregon's CCO model, pediatric preventive care during two years after birth was improved for infants enrolled in Medicaid. We also found that the impacts of CCOs on preventive care among infants continuously increased over the implementation timeline. The increase could be explained by the model's unique characteristic that using payment methods strongly tied to preventive care and care coordination through patient-centered primary care homes (PCPCHs). All CCOs emphasized preventive care for a majority of its beneficiaries through PCPCH where physicians and non-physician providers work together to accommodate patients' healthcare needs and coordinate care for their patients. Previous studies on the impacts of CCO implementation suggested that primary care visits decreased in Medicaid enrollees and such decreases could reflect the lack of primary care capacity after the 2014 Medicaid expansion (McConnell, Renfro, Chan, et al., 2017). Our study suggested that adult and older children might have experience the shortage in primary care, but not infants and young children.

We found that infants born after the delivery system transformation had a slightly higher number of ED visits but not statistically significant. Similarly, CCO implementation was not statistically significant with a reduction in hospital admission. Our finding is consistent with a previous study on CCOs showing that ED visits and hospital admission among Medicaid enrollees decreased after the implementation of CCO but only significant among adult population (McConnell, Renfro, Chan, et al., 2017). The reduction could be attributed to the application of non-traditional support services, e.g., social workers and community health workers involvement in care delivery and care coordination, that mostly targeted in adults and patients with multiple chronic conditions rather than in children (McConnell, Renfro, Chan, et al., 2017). Another study on pediatric ACO showed that increase in consistent primary care was associated with an increase in ED visits among children and suggested that pediatric Medicaid ACOs maybe most effective in reducing expensive inpatient services by the substitution of less expensive outpatient care (Christensen & Payne, 2016). To guide the next five years of OHP (2020-2014), the Oregon Health Policy Board proposed the CCO 2.0 policy recommendations in which incorporating children's health needs into CCO's policy (Oregon Health Authority Health Policy & Analytics Division, 2018). Future research should continue investigating how CCOs change healthcare for children, especially infants and young children, in the next phase of CCO implementation.

To our knowledge, our study is the first to investigate the impact of CCOs on health service utilization of preterm infants. We did not find a greater impact of CCOs on preterm infants compared to full-term infants. It is possibly that CCOs focus more on high-cost adult population and those with mental health problems rather than children and infants. Further research should examine the extent to which CCO implementation has an effect on service utilization for other high-risk children populations.

Our study has some important limitations. First, we were not able to use non-Medicaid infants as the control group for the analyses of preventive care and ED utilization because claims for non-Medicaid infants were not available. Second, we did not examine the effects of CCOs on immunization that is another important pediatric preventive care service among young children because vaccination events are usually under-reported by claims. Third, given the availability of data, we could follow-up infants for only two years after birth. Further study should examine change in healthcare utilization of infants in a longer follow-up period.

3.6 Conclusion

The CCO model was associated with improved preventive care but had no statistically significant effects on reducing ED and inpatient services in infants enrolled in Medicaid during two years after birth. The impacts of CCOs on healthcare utilization were not different between preterm infants and full-term infants. Further research should examine the effects of CCOs on service utilization in a longer follow-up period or among different high-risk children population.

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Table 3.1. Characteristics of infants

	Medicaid[1]		Non-Medicaid[2]	
	Pre-CCO[3] (N = 36,546)	**Post-CCO[3]** (N = 47,973)	**Pre-CCO** (N = 40,555)	**Post-CCO** (N= 42,802)
	(n/%)	(n/%)	(n/%)	(n/%)
Maternal characteristics				
Age (mean (SD))	25.6 (5.8)	26.9 (5.8)	30.6 (5.0)	31.4 (4.7)
Race/ethnicity				
White	18,671 (51.1)	27,711 (57.8)	31,937 (78.8)	33,825 (79.0)
Black	1,409 (3.9)	1,743 (3.6)	452 (1.1)	529 (1.2)
AIAN	1,148 (3.1)	1,548 (3.2)	563 (1.4)	517 (1.2)
Asian	866 (2.4)	1,570 (3.3)	3,280 (8.1)	3,757 (8.8)
NHPI	386 (1.1)	525 (1.1)	194 (0.5)	219 (0.5)
Other	310 (0.9)	410 (0.9)	334 (0.8)	408 (1.0)
Hispanic	12,359 (33.8)	13,045 (27.2)	2,908 (7.2)	2,781 (6.5)
Missing	1,379 (3.7)	1,421 (2.9)	887 (2.1)	766 (1.8)
Education				
< High school	13,060 (35.7)	11,442 (23.9)	1,286 (3.2)	759 (1.8)
High school or ED	11,543 (31.6)	14,608 (30.5)	5,043 (12.4)	4,016 (9.4)
College or higher	10,430 (28.5)	20,359 (42.4)	33,243 (82.0)	37,163 (86.8)
Missing	1,513 (4.2)	1,564 (3.2)	983 (2.4)	864 (2.0)
Married	14,728 (40.3)	21,218 (44.2)	35,642 (87.9)	38,180 (89.2)
Rurality				
Urban	30,166 (82.5)	39,713 (82.8)	36,548 (90.1)	38,609 (90.2)
Large rural	3,702 (10.1)	4,999 (10.4)	2,235 (5.5)	2,549 (6.0)
Small/isolated rural	1,201 (3.3)	1,738 (3.6)	879 (2.2)	811 (1.9)
Missing	1,643 (4.5)	1,523 (3.2)	893 (2.2)	833 (1.9)
BMI at delivery (mean (SD))	32.3 (6.7)	32.5 (6.7)	30.8 (5.8)	30.8 (5.7)
Smoking during pregnancy	7,288 (19.9)	8,780 (18.3)	1,823 (4.5)	1,308 (3.1)
Number previous births				
0	13,032 (35.7)	16,919 (35.3)	17,359 (42.8)	18,651 (43.6)
1	10,001 (27.4)	13,876 (28.9)	14,103 (34.8)	15,134 (35.4)
2	6,556 (17.9)	8,616 (18.0)	5,399 (13.3)	5,477(12.8)
>=3	5,558 (15.2)	7,221 (15.1)	2,852 (7.0)	2,891 (6.8)
Missing	1,399 (3.8)	1,341 (2.7)	842 (2.1)	649 (1.4)
Adequate prenatal care	24,193 (66.2)	33,669 (70.2)	32,473 (80.1)	34,408 (80.4)
Birth characteristics				
Preterm	2,902 (7.9)	3,619 (7.5)	2,944 (7.3)	3,053 (7.1)
Girls	17,875 (48.9)	23,322 (48.6)	19,676 (48.5)	20,862 (48.7)
Birth weight in gram (mean (SD))	3,333.4 (571.6)	3,343.6 (564.5)	3,402.6 (565.4)	3,401.9 (572.7)
Presence of birth risk factors	9,818 (26.9)	15,143 (31.6)	11,304 (27.9)	13,868 (32.4)
Presence of abnormal conditions	3,772 (10.3)	4,844 (10.1)	3,365 (8.3)	3,915 (9.2)

Presence of congenital anomalies	208 (0.6)	313 (0.7)	200 (0.5)	209 (0.5)
Birth plurality	892 (2.4)	1,303 (2.7)	1,694 (4.2)	1,915 (4.5)

[1]Medicaid status defined as enrolled in Medicaid for 80% of 2 years after birth. [2]Non-Medicaid status defined as not enrolled in Medicaid for any day during 2 years after birth. [3]Pre-CCO: August 2008 to July 2010, Post-CCO: August 2012 to December 2014

Table 3.2. Utilizations of preventive care and ED services among Medicaid infants

	Pre-CCO			Post-CCO		
Variables	**All Medicaid** (N = 36,546)	**Full-term** (N = 33,644)	**Preterm** (N = 2,902)	**All Medicaid** (N = 47,973)	**Full-term** (N = 44,354)	**Preterm** (N= 3,619)
Count of well-baby visits (mean (SD))						
By 1st birthday	3.98 (1.69)	4.01 (1.68)	3.71 (1.69)	4.29 (1.83)	4.32 (1.83)	3.99 (1.79)
By 2nd birthday	5.61 (2.28)	5.63 (2.28)	5.34 (2.25)	6.00 (2.45)	6.03 (2.46)	5.71 (2.41)
Received recommended number of well-baby visits (n (%))						
By 1st birthday	6,134 (16.78)	5,771 (17.15)	363 (12.51)	12,226 (25.49)	11,562 (26.07)	664 (18.35)
By 2nd birthday	3,040 (8.32)	2,869 (8.53)	171 (5.89)	6,398 (13.34)	6,044 (13.63)	354 (9.78)
Annual developmental screening (%)	8.19	8.09	9.37	25.68	25.64	26.08
Annual ED visits (mean (SD))	0.258 (0.634)	0.252 (0.613)	0.325 (0.721)	0.262 (0.628)	0.257 (0.620)	0.330 (0.714)

Table 3.3. Annual hospital admissions per infant during two years after birth

	Pre-CCO mean (SD)			Post-CCO mean (SD)		
Medicaid	All (N = 36,546)	Full-term (N = 33,644)	Preterm (N = 2,902)	All (N = 47,973)	Full-term (N = 44,354)	Preterm (N = 3,619)
	0.075 (0.352)	**0.065** (0.320)	**0.187** (0.599)	**0.056** (0.310)	**0.049** (0.285)	**0.141** (0.520)
Non-Medicaid	All (N = 40,555)	Full-term (N = 37,611)	Preterm (N = 2,944)	All (N = 42,802)	Full-term (N = 39,749)	Preterm (N = 3,053)
	0.037 (0.249)	**0.034** (0.237)	**0.082** (0.366)	**0.030** (0.218)	**0.027** (0.205)	**0.067** (0.340)

Table 3.4. Impacts of CCO implementation on service utilization

	Overall impacts of CCO implementation Marginal effects (95%CI)			Monthly change in impacts of CCO implementation Marginal effects (95%CI)		
	Probability of utilization[1] (%)	Count of services[2]	Combined[3]	Probability of utilization[1] (%)	Count of services[2]	Combined[3]
Number of well-baby visits						
By 1st birthday	−0.50	0.61***	0.56***	0.06	0.005***	0.007**
	(−1.38; 0.38)	(0.49; 0.73)	(0.444; 0.679)	(-0.07; 0.18)	(0.002; 0.008)	(0.002; 0.013)
By 2nd birthday	−0.05	0.67***	0.65***	−0.02	−0.001	−0.002
	(−0.78; 0.68)	(0.51; 0.83)	(0.496; 0.802)	(-0.05; 0.01)	(-0.005; 0.002)	(-0.010; 0.006)
Adequacy of well-baby visits						
By 1st birthday	14.43***	N/A	N/A	0.17***	N/A	N/A
	(11.45; 17.41)			(0.09, 0.25)		
By 2nd birthday	6.66***	N/A	N/A	0.09**	N/A	N/A
	(4.31; 9.01)			(0.03; 0.15)		
Annual developmental screening	26.02***	N/A	N/A	0.46***	N/A	N/A
	(23.88; 28.17)			(0.41; 0.51)		
Annual ED visits	4.73***	−0.055	0.001	0.62***	−0.007	−0.00003
	(2.60; 6.86)	(−0.119; 0.009)	(−0.012; 0.014)	(0.44; 0.79)	(−0.016; 0.001)	(−0.004; 0.003)
Annual hospital admissions	−0.24*	−0.05	−0.004	−0.01	−0.002	−0.0002
	(−0.58; 0.11)	(−0.19; 0.09)	(−0.015; 0.006)	(−0.029; 0.004)	(−0.007; 0.003)	(−0.0004; 0.0001)

Note: Marginal effects with bootstrapped SEs from 1,000 repetitions. Hurdle Part 1 models the probability of receiving any services using logistic regression. Hurdle Part 2 models the count of services among those used at least one service using zero-truncated negative binomial regression. Models for the probability of receiving recommended number of well-child visits using logistic regression. Model for the annual probability of receiving DSBA using linear probability model. All models controlled for time trends of outcome variables. Cluster SEs are in parentheses. *p < .05;** p < .01; *** p < .001.

Table 3.5. Heterogeneous effects of CCO implementation on service utilization between preterm infants and full-term infants

		Effects of CCOs Marginal effects (95%CI)		
		Probability of utilization[1] (% points)	Count of services[2]	Combined[3]
Number of well-baby visits				
By 1st birthday	Preterm infants	0.23 (−1.29; 1.75)	0.56*** (0.42; 0.71)	0.55***(0.40; 0.70)
	Difference between preterm and full-term infants (preterm − full-term)	0.78 (−0.37; 1.94)	−0.043 (−0.137; 0.051)	−0.01 (−0.12; 0.09)
By 2nd birthday	Preterm infants	0.46 (−0.80; 1.71)	0.65*** (0.46; 0.83)	0.65*** (0.46; 0.84)
	Difference between preterm and full-term infants (preterm − full-term)	0.56 (−0.40; 1.51)	−0.02 (−0.14; 0.09)	0.006 (−0.126; 0.137)
Adequacy of well-baby visits				
By 1st birthday	Preterm infants	11.88*** (8.99; 14.76)	N/A	N/A
	Difference between preterm and full-term infants (preterm − full-term)	−2.27* (−4.34; -0.19)	N/A	N/A
By 2nd birthday	Preterm infants	6.06*** (3.74; 8.37)	N/A	N/A
	Difference between preterm and full-term infants (preterm − full-term)	−0.36 (−2.07; 1.35)	N/A	N/A
Developmental screening	Preterm infants	25.92*** (24.03; 27.81)	N/A	N/A
	Difference between preterm and full-term infants (preterm − full-term)	−0.12 (−1.62; 1.39)	N/A	N/A
Annual ED visits	Preterm infants	5.40*** (2.90; 7.89)	−0.085* (−0.165; −0.005)	−0.005 (−0.023; 0.014)
	Difference between preterm and full-term infants (preterm − full-term)	0.79 (−0.60; 2.18)	−0.037 (−0.082; 0.009)	−0.006 (−0.017; 0.004)
Annual hospital admissions	Preterm infants	−0.08 (−0.79; 0.64)	−0.03 (−0.15; 0.09)	−0.003 (−0.016; 0.010)
	Difference between preterm and full-term infants (preterm − full-term)	0.19 (−0.42; 0.79)	0.03 (−0.06; 0.12)	0.002 (−0.005; 0.008)

Note: Marginal effects with bootstrapped SEs from 1,000 repetitions. Hurdle Part 1 models the probability of receiving any services using logistic regression. Hurdle Part 2 models the count of services among those used at least one service using zero-truncated negative binomial regression. Models for the probability of receiving recommended number of well-child visits using logistic regression. Model for the annual probability of receiving DSBA using linear probability model. All models controlled for time trends of outcome variables. Cluster SEs are in parentheses. *p < .05;** p < .01; *** p < .001.

Appendix Table 3.1. Coefficients of models for overall impacts of CCOs on preventive services & ED services

	Well-baby visits						Developmental screening	ED	
	By 1st birthday			By 2nd birthday					
	Hurdle model for number of services		Adequacy of services	Hurdle model for number of services		Adequacy of services		Hurdle model for number of services	
	Part 1	Part 2		Part 1	Part 2			Part 1	Part 2
Post CCO	-0.145 (0.130)	0.143*** (0.015)	0.877*** (0.093)	-0.024 (0.163)	0.113*** (0.014)	0.686*** (0.124)	0.260*** (0.011)	0.318*** (0.073)	-0.223 (0.131)
Maternal characteristics									
Age	-0.025*** (0.004)	0.004*** (0.000)	0.017*** (0.002)	-0.023*** (0.005)	0.006*** (0.0003)	0.031*** (0.002)	0.002*** (0.0002)	-0.037*** (0.002)	-0.025*** (0.003)
Race/ethnicity									
Black	0.326** (0.112)	0.0001 (0.008)	0.040 (0.051)	0.378** (0.140)	0.002 (0.007)	-0.070 (0.070)	-0.030*** (0.005)	0.445*** (0.035)	0.255*** (0.050)
AIAN	-0.059 (0.105)	-0.019* (0.009)	-0.052 (0.053)	0.158 (0.143)	-0.034*** (0.008)	-0.047 (0.072)	-0.013* (0.006)	0.141*** (0.039)	0.056 (0.071)
Asian	0.198 (0.105)	0.041*** (0.009)	0.225*** (0.052)	0.195 (0.128)	0.063*** (0.008)	0.264***(0.065)	-0.025*** (0.006)	-0.024 (0.048)	0.082 (0.100)
NHPI	0.335 (0.196)	-0.002 (0.014)	-0.161 (0.099)	0.186 (0.221)	-0.010 (0.014)	-0.355* (0.145)	-0.023* (0.010)	0.390*** (0.065)	0.426*** (0.106)
Other	0.186 (0.193)	-0.009 (0.017)	0.055 (0.098)	0.265 (0.241)	-0.020 (0.016)	0.083 (0.128)	-0.010 (0.011)	-0.016 (0.084)	-0.264 (0.145)
Hispanic	0.685*** (0.060)	0.097*** (0.003)	0.435*** (0.022)	0.703*** (0.074)	0.105*** (0.003)	0.433*** (0.028)	0.001 (0.003)	0.107*** (0.018)	-0.011 (0.032)
Education									
High school or ED	-0.352*** (0.063)	-0.008* (0.004)	-0.037 (0.023)	-0.452*** (0.079)	-0.008* (0.003)	-0.048 (0.030)	0.007* (0.003)	-0.171*** (0.018)	-0.119*** (0.031)
College or higher	-0.582*** (0.061)	-0.032*** (0.004)	-0.128*** (0.025)	-0.657*** (0.078)	-0.028*** (0.004)	-0.142*** (0.032)	0.009(((0.003)	-0.353*** (0.020)	-0.234*** (0.035)
Married	-0.424*** (0.042)	-0.003 (0.003)	-0.015 (0.020)	-0.451*** (0.053)	0.002 (0.003)	0.074** (0.025)	0.001 (0.002)	-0.247*** (0.016)	-0.099** (0.030)
Rurality									
Large rural	0.327*** (0.074)	0.059*** (0.004)	0.505*** (0.027)	0.273** (0.089)	0.045*** (0.004)	0.472*** (0.034)	0.032*** (0.004)	-0.703*** (0.028)	-0.033 (0.052)
Small/isolated rural	-0.119 (0.100)	0.0001 (0.008)	0.111* (0.048)	-0.016 (0.129)	-0.033*** (0.008)	-0.048 (0.067)	-0.022*** (0.006)	-0.730*** (0.048)	-0.122 (0.099)
BMI at delivery	0.014*** (0.003)	0.001*** (0.000)	0.004** (0.001)	0.017*** (0.004)	0.001*** (0.000)	0.004* (0.002)	0.0002 (0.000)	0.017*** (0.001)	0.012***(0.002)
Smoking during pregnancy	0.408*** (0.059)	-0.013*** (0.004)	-0.080*** (0.025)	0.501*** (0.075)	-0.018*** (0.004)	-0.102** (0.033)	-0.005 (0.003)	0.213*** (0.019)	0.086** (0.032)
Number previous births									
1	-0.104* (0.053)	-0.068*** (0.004)	-0.279*** (0.023)	-0.200** (0.066)	-0.093*** (0.003)	-0.474*** (0.030)	-0.030*** (0.003)	-0.010 (0.019)	0.014 (0.034)
2	-0.149* (0.062)	-0.089*** (0.005)	-0.369*** (0.028)	-0.299*** (0.077)	-0.123*** (0.004)	-0.582*** (0.036)	-0.036*** (0.003)	0.091*** (0.023)	0.047 (0.042)
>=3	-0.404*** (0.067)	-0.129*** (0.005)	-0.528*** (0.033)	-0.689*** (0.082)	-0.180*** (0.005)	-0.860*** (0.044)	-0.053*** (0.004)	0.140*** (0.027)	0.058 (0.049)
Adequacy of PNC	0.322*** (0.042)	0.051*** (0.003)	0.176*** (0.021)	0.392*** (0.052)	0.061*** (0.003)	0.177*** (0.028)	0.026*** (0.002)	0.090*** (0.017)	-0.011 (0.030)
Birth characteristics									
Preterm	-0.210* (0.084)	-0.047*** (0.007)	-0.266*** (0.047)	-0.109 (0.103)	-0.040*** (0.007)	-0.224*** (0.063)	-0.010 (0.005)	0.203*** (0.032)	0.118* (0.055)
Birth weight in gram	-0.0001 (0.000)	0.00001** (0.000)	0.0003 (0.000)	-0.0001 (0.000)	0.00001* (0.000)	0.0003 (0.000)	-0.0001 (0.000)	-0.0001*** (0.000)	-0.0001** (0.000)
Girls	0.026 (0.040)	0.007* (0.003)	0.041* (0.018)	0.057 (0.049)	0.005 (0.003)	0.047* (0.023)	0.002 (0.002)	-0.148*** (0.015)	-0.160*** (0.026)
Presence of birth risk factors	0.110* (0.045)	0.008* (0.003)	0.036 (0.021)	0.130* (0.055)	0.010** (0.003)	0.044 (0.028)	0.0001 (0.002)	0.090*** (0.017)	0.061* (0.030)
Presence of abnormal conditions	-0.134* (0.066)	-0.035*** (0.005)	-0.193*** (0.036)	-0.201* (0.079)	-0.016*** (0.005)	-0.152*** (0.047)	0.012** (0.004)	0.002 (0.026)	0.074 (0.047)

Presence of congenital anomalies	-0.307 (0.208)	-0.069*** (0.021)	-0.275* (0.126)	-0.054 (0.286)	-0.056** (0.019)	-0.092 (0.158)	-0.004 (0.013)	0.466*** (0.082)	0.375** (0.122)
Birth plurality	-0.234* (0.111)	0.014 (0.010)	-0.041 (0.064)	-0.274* (0.135)	0.033*** (0.009)	-0.101 (0.087)	0.012 (0.007)	-0.343*** (0.049)	-0.188* (0.085)
Constant	4.113*** (0.207)	1.213*** (0.018)	-2.411*** (0.112)	4.652*** (0.260)	1.529*** (0.016)	-3.450*** (0.150)	0.058*** (0.011)	-0.625*** (0.087)	-0.682*** (0.173)

Note: Hurdle Part 1 models the probability of receiving any services using logistic regression. Hurdle Part 2 models the count of services among those used at least one service using zero-truncated negative binomial regression. Models for the probability of receiving recommended number of well-child visits using logistic regression. Model for the annual probability of receiving DSBA using linear probability model. All models controlled for time trends of outcome variables. Cluster SEs are in parentheses. *p < .05;** p < .01; *** p < .001.

Appendix Table 3.2. Coefficients of models for heterogeneous impacts of CCOs on preventive services & ED services between preterm and full-term infants

	Well-baby visits						Developmental screening	ED	
	By 1st birthday			By 2nd birthday					
	Hurdle model for number of services		Adequacy of services	Hurdle model for number of services		Adequacy of services		Hurdle model for number of services	
	Part 1	Part 2		Part 1	Part 2			Part 1	Part 2
Post CCO	-0.166 (0.131)	0.143*** (0.015)	0.879*** (0.093)	-0.044 (0.164)	0.113*** (0.014)	0.680*** (0.124)	0.260*** (0.011)	0.316*** (0.073)	-0.208 (0.132)
Post CCO * Preterm	0.223 (0.138)	-0.004 (0.012)	-0.021 (0.077)	0.223 (0.174)	0.0004 (0.011)	0.089 (0.105)	-0.001 (0.008)	0.015 (0.051)	-0.116 (0.083)
Maternal characteristics									
Age	-0.025*** (0.004)	0.004*** (0.000)	0.017*** (0.002)	-0.023*** (0.005)	0.006*** (0.0003)	0.031*** (0.002)	0.002*** (0.0002)	-0.037*** (0.002)	-0.025*** (0.003)
Race/ethnicity									
Black	0.326** (0.112)	0.0001 (0.008)	0.040 (0.051)	0.378** (0.140)	0.002 (0.007)	-0.070 (0.070)	-0.030*** (0.005)	0.445*** (0.035)	0.254*** (0.050)
AIAN	-0.060 (0.105)	-0.019* (0.009)	-0.052 (0.053)	0.158 (0.143)	-0.034*** (0.008)	-0.047 (0.072)	-0.013* (0.006)	0.141*** (0.039)	0.057 (0.071)
Asian	0.199 (0.105)	0.041*** (0.009)	0.225*** (0.052)	0.196 (0.128)	0.063*** (0.008)	0.264***(0.065)	-0.025*** (0.006)	-0.024 (0.048)	0.081 (0.100)
NHPI	0.336 (0.196)	-0.002 (0.014)	-0.161 (0.099)	0.186 (0.221)	-0.010 (0.014)	-0.355* (0.145)	-0.023* (0.010)	0.390*** (0.065)	0.424*** (0.106)
Other	0.185 (0.193)	-0.009 (0.017)	0.055 (0.098)	0.264 (0.241)	-0.020 (0.016)	0.082 (0.128)	-0.010 (0.011)	-0.017 (0.084)	-0.264 (0.145)
Hispanic	0.685*** (0.060)	0.097*** (0.003)	0.435*** (0.022)	0.703*** (0.074)	0.105*** (0.003)	0.433*** (0.028)	0.001 (0.003)	0.107*** (0.018)	-0.011 (0.032)
Education									
High school or ED	-0.351*** (0.063)	-0.008* (0.004)	-0.037 (0.023)	-0.451*** (0.079)	-0.008* (0.003)	-0.048 (0.030)	0.007* (0.003)	-0.171*** (0.018)	-0.120*** (0.031)
College or higher	-0.581*** (0.061)	-0.032*** (0.004)	-0.129*** (0.025)	-0.656*** (0.078)	-0.028*** (0.004)	-0.142*** (0.032)	0.009 (0.003)	-0.353*** (0.020)	-0.234*** (0.035)
Married	-0.423*** (0.042)	-0.003 (0.003)	-0.015 (0.020)	-0.451*** (0.053)	0.002 (0.003)	0.074** (0.025)	0.001 (0.002)	-0.247*** (0.016)	-0.100** (0.030)
Rurality									
Large rural	0.327*** (0.074)	0.059*** (0.004)	0.505*** (0.027)	0.272** (0.089)	0.045*** (0.004)	0.472*** (0.034)	0.032*** (0.004)	-0.703*** (0.028)	-0.033 (0.052)
Small/isolated rural	-0.119 (0.100)	0.0001 (0.008)	0.111* (0.048)	-0.016 (0.129)	-0.033*** (0.008)	-0.048 (0.067)	-0.022*** (0.006)	-0.730*** (0.048)	-0.123 (0.099)
BMI at delivery	0.014*** (0.003)	0.001*** (0.000)	0.004** (0.001)	0.017*** (0.004)	0.001*** (0.000)	0.004* (0.002)	0.0002 (0.000)	0.017*** (0.001)	0.012***(0.002)
Smoking during pregnancy	0.407*** (0.059)	-0.013*** (0.004)	-0.080*** (0.025)	0.499*** (0.075)	-0.018*** (0.004)	-0.102** (0.033)	-0.005 (0.003)	0.213*** (0.019)	0.087** (0.032)
Number previous births									
1	-0.105* (0.053)	-0.068*** (0.004)	-0.279*** (0.023)	-0.200** (0.067)	-0.093*** (0.003)	-0.474*** (0.030)	-0.030*** (0.003)	-0.010 (0.019)	0.014 (0.034)
2	-0.149* (0.062)	-0.089*** (0.005)	-0.369*** (0.028)	-0.299*** (0.077)	-0.123*** (0.004)	-0.581*** (0.036)	-0.036*** (0.003)	0.091*** (0.023)	0.046 (0.042)
>=3	-0.404*** (0.067)	-0.129*** (0.005)	-0.528*** (0.033)	-0.689*** (0.082)	-0.180*** (0.005)	-0.860*** (0.044)	-0.053*** (0.004)	0.140*** (0.027)	0.057 (0.049)
Adequacy of PNC	0.323*** (0.042)	0.051*** (0.003)	0.176*** (0.021)	0.392*** (0.051)	0.061*** (0.003)	0.178*** (0.028)	0.026*** (0.002)	0.090*** (0.017)	-0.012 (0.030)
Birth characteristics									
Preterm	-0.344** (0.115)	-0.045*** (0.010)	-0.253*** (0.068)	-0.246 (0.143)	-0.040*** (0.009)	-0.283*** (0.093)	-0.009 (0.005)	0.195*** (0.044)	0.182* (0.072)
Birth weight in gram	-0.0001 (0.000)	0.00001** (0.000)	0.0003 (0.000)	-0.0001 (0.000)	0.00001* (0.000)	0.0003 (0.000)	-0.0001 (0.000)	-0.0001*** (0.000)	-0.0001** (0.000)
Girls	0.026 (0.040)	0.007* (0.003)	0.041* (0.018)	0.057 (0.049)	0.005 (0.003)	0.047* (0.023)	0.002 (0.002)	-0.148*** (0.015)	-0.159*** (0.026)

Presence of birth risk factors	0.110* (0.045)	0.008* (0.003)	0.036 (0.021)	0.130* (0.055)	0.010** (0.003)	0.044 (0.027)	0.0001 (0.002)	0.090*** (0.017)	0.061* (0.030)
Presence of abnormal conditions	-0.133* (0.067)	-0.035*** (0.005)	-0.193*** (0.036)	-0.200* (0.080)	-0.016*** (0.005)	-0.152*** (0.047)	0.012** (0.004)	0.002 (0.026)	0.073 (0.047)
Presence of congenital anomalies	-0.309 (0.208)	-0.069*** (0.021)	-0.275* (0.126)	-0.057 (0.286)	-0.056** (0.019)	-0.092 (0.156)	-0.004 (0.013)	0.466*** (0.082)	0.375** (0.122)
Birth plurality	-0.236* (0.111)	0.014 (0.010)	-0.041 (0.063)	-0.275* (0.135)	0.033*** (0.009)	-0.101 (0.087)	0.012 (0.007)	-0.344*** (0.049)	-0.184* (0.085)
Constant	4.127*** (0.207)	1.213*** (0.018)	-2.411*** (0.113)	4.666*** (0.260)	1.529*** (0.016)	-3.447*** (0.150)	0.057*** (0.011)	-0.624*** (0.087)	-0.691*** (0.173)

Note: Hurdle Part 1 models the probability of receiving any services using logistic regression. Hurdle Part 2 models the count of services among those used at least one service using zero-truncated negative binomial regression. Models for the probability of receiving recommended number of well-child visits using logistic regression. Model for the annual probability of receiving DSBA using linear probability model. All models controlled for time trends of outcome variables. Cluster SEs are in parentheses. *p < .05;** p < .01; *** p < .001.

CHAPTER 4

Manuscript 2: Coordinated Care Organizations and mortality among low-income infants in Oregon

4.1 Abstract

Objective: To examine the impact of Oregon's Coordinated Care Organizations (CCOs), an accountable care model for Oregon Medicaid enrollees implemented in 2012, on neonatal and infant mortality.

Data sources: Oregon birth certificates linked with death certificates, and Medicaid/CCO enrollment files for years 2008 to 2016.

Study Design: The sample consisted of the pre-CCO birth cohort of 136,519 infants and the post-CCO birth cohort of 149,523 infants. We used a difference-in-differences probit model to estimate the difference in mortality between Medicaid infants and non-Medicaid infants attributable to CCO implementation. We also examined heterogeneous effects of CCOs for preterm and full-term infants and the impact of CCOs over the implementation timeline. All models were adjusted for maternal and infant characteristics and secular time trends.

Principal findings: The CCO model was significantly associated with a reduction in both neonatal mortality (68% compared to the pre-CCO level) and infant mortality (37% compared to the pre-CCO level), and also with a greater reduction in infant mortality among preterm infants compared to full-term infants. The impact on infant mortality grew in magnitude over the post implementation timeline.

Conclusions: The CCO model contributed to a statistically significant reduction in mortality within the first year of birth among infants enrolled in Medicaid.

4.2 Introduction

In the U.S., infants and toddlers under three years of age are most likely to live in poverty (Jiang, Granja, & Koball, 2017). Research has linked having low-income parents to poor health outcomes among infants and young children, such as preterm birth, low birth weight, acquired chronic conditions (J. Currie & Lin, 2007; Kehrer & Wolin, 1979; Margolis et al., 1992; Olson, Diekema, Elliott, & Renier, 2010; Singh & Kogan, 2007) and especially increased risk of infant death (Olson et al., 2010; Singh & Kogan, 2007). Providing insurance coverage may contribute to improving access to care and subsequently reducing infant mortality (Bhatt & Beck-Sagué, 2018; Janet Currie & Gruber, 1996; Moss & Carver, 1998). However, it requires more than simply having insurance coverage to further improve infant survival. A health care delivery system that ensures timely and quality care for women and their infants is also crucial to improving infant's health outcomes.

Oregon's Medicaid program, known as the Oregon Health Plan (OHP), is the largest health insurer for children in Oregon. OHP currently covers approximately 50% of all births and over 400,000 children (0-18 years old) from low-income families (income lower than 200% Federal Poverty Level) (Child Welfare League of America, 2017; National Center for Children in Poverty, 2017; Oregon Health Authority, 2016). OHP provides a comprehensive benefit package with services under the Early and Periodic Screening, Diagnosis, and Treatment (EPSDT) program for children with no or little cost sharing. As of 2011, nearly all Medicaid beneficiaries in Oregon were mandatorily enrolled in fully-capitated Medicaid Managed Care Organizations (MCOs). Although MCOs covered physical health care services, behavioral health and dental care services were frequently not covered (McConnell et al., 2014). In addition, as elsewhere in the U.S., different MCOs provided physical, behavioral, and dental health services separately without any coordination. This fragmentation often led to greater costs and poorer health outcomes (Howard, Bernell, Yoon, Luck, & Ranit, 2015).

Since August 2012, Oregon has transformed its health care delivery model for Medicaid enrollees with the implementation of Coordinated Care Organizations (CCOs). Fifteen regional CCOs are currently serving more than 90% of Oregon's Medicaid population, both adults and children, providing integrated care for physical, behavioral, and dental health (Oregon Health Authority, 2016). The CCO arrangements are considered a unique Medicaid Accountable Care Organization (ACO) model. CCOs share similarities with ACOs in that they are held accountable for both cost and quality of care, and through the use of payment incentives that reward improved health outcomes and saved cost. However, this is a mandatory enrollment model with required integration of physical, behavioral and dental health care in which enrollees are served by a geographically-defined network of providers. CCOs receive a global budget and focus on primary care through patient-centered medical homes to improve care for its beneficiaries. Each CCO has its governance from not only health care providers but also members of a community advisory council that ensure community's health needs are met (Chang, Cohen, McCarty, Rieckmann, & McConnell, 2015; Howard, Bernell, Jangho, &

Luck, 2014; Howard et al., 2015; Kushner et al., 2017; McConnell, Renfro, Lindrooth, et al., 2017).

Medicaid ACOs have been shown to improve access to care and care quality in some areas, e.g., increasing in preventive care, decreasing in emergency department visits or inpatient days, and containing cost growth (Colorado Health Institute, 2017; McConnell, Renfro, Chan, et al., 2017; McConnell, Renfro, Lindrooth, et al., 2017; Oakley, Harvey, Yoon, & Luck, 2017; Oregon Health Authority, 2018a). Few studies have, however, investigated the impact of pediatric Medicaid ACO models on health care utilization, cost, and care quality (Christensen & Payne, 2016; Kelleher et al., 2015) partly because of modest growth of pediatric ACOs (Perrin et al., 2017). Only one study to our knowledge examined the effect of Medicaid ACOs on childbirth outcomes and found no impact on infant inpatient mortality (Henke et al., 2019). Specific for Oregon, a recent study investigated the impact of CCO implementation on neonatal and infant outcomes, including infant mortality (Harvey, Oakley, Yoon, & Luck, 2017). Findings from this study indicated that CCO implementation was not associated with a reduction of infant mortality after one year of implementation. Another study, however, found that following Oregon’s CCO implementation women on Medicaid experienced a significant increase in receiving timely prenatal care (Oakley et al., 2017). The CCO model is designed to enhance access to integrated care for women before and during pregnancy as well as infants after birth, via primary care homes. Further evidence is needed to document whether CCO implementation has an impact on infant mortality over a longer timeframe.

In this study, we followed CCO implementation for four years to examine the extent to which CCO implementation had an effect on mortality of infants enrolled in Medicaid during the first year of birth. Preterm infants are considered a high-risk population because they have higher risk for chronic conditions, mortality, and greater needs for follow-up care and care coordination compared to full-term babies (Jarjour, 2015; Mccourt & Griffin., 2000; Wade et al., 2008). Because CCOs target high-risk and high-cost patients, we investigated whether the effects of CCOs on mortality differ between preterm infants and full-term infants. We also tested if the impact of CCOs on infant mortality increased over the first four years of implementation.

4.3 Methods

4.3.1 Data sources

Data came from multiple sources, including Oregon birth certificates, death certificates, Medicaid and CCO enrollment data for years 2008 through 2016. Every infant had a unique person identification number that allowed the same infants across the different data sources to be linked deterministically. Also, each infant had a unique mother-to-child identification number that enabled linkage between infant's information and maternal characteristics.

4.3.2 Sample

Using Oregon 2008-15 birth certificates, we created the pre- and post-CCO cohorts of births. The pre-CCO birth cohort included births from August 2008 to July 2011. The cohort of babies born between August 2012 and December 2015 was defined as the post-CCO births. The birth certificates were then linked to death certificates to identify infants who died within a year after birth. For Medicaid financed births, Medicaid provides coverage for infants from birth to one year of age. Therefore, we then linked with Medicaid enrollment files to identify Medicaid infants. A Medicaid infant was defined as having Medicaid enrollment record on date of birth or within two weeks of birth to account for possible delay in Medicaid enrollment for newborns. Non-Medicaid infants were defined as those who were not enrolled in Medicaid anytime during their first year after birth.

Beginning in August 2012, almost all Medicaid beneficiaries were enrolled in 16 CCOs, except for a small number of people exempt from CCO enrollment (e.g., American Indians, Alaska Natives, members eligible for both Medicaid and Medicare, or members with special health needs) (Oregon Health Authority, 2016, 2017, 2018b). We excluded 2,592 infants (2.8% of post-CCO Medicaid infants) who were not enrolled in CCOs during post-CCO period. Therefore, all Medicaid infants in our post-CCO cohort were enrolled in CCOs. The sample included 136,519 pre-CCO infants (58,174 Medicaid infants and 78,345 non-Medicaid infants) and 149,523 post-CCO infants (60,246 Medicaid infants and 89,277 non-Medicaid infants).

4.3.3 Outcome variables

We examined two mortality outcomes: neonatal mortality and infant mortality. Neonatal mortality was defined as deaths within 28 days after birth, and infant mortality was deaths within a year of birth.

4.3.4 Main independent variables

The indicator of the post-CCO period took a value of 1 if an infant was born during the post-CCO period. We included an indicator for CCO infant (i.e., Medicaid infant) that took a value of 1 if an infant had a Medicaid enrollment record on the date of birth or within two weeks of birth. We also used an indicator of preterm infant as defined by babies born before the 37^{th} week of pregnancy using information on gestation weeks from birth certificates.

To estimate how the impact of CCOs grew over the implementation timeline, we used a monthly time indicator for the length of CCO implementation. This variable equaled 0 if an infant was born before the implementation of CCOs (pre-CCO infants). It took a value of 1 if an infant was born during the month when a CCO started its implementation and increased by one each month post CCO.

4.3.5 Covariates

We examined the effects of CCOs on mortality while controlling for a set of maternal characteristics, including age, race/ethnicity, education, marital status, rurality, body mass index (BMI) at delivery, smoking during pregnancy, number of previous births and whether a mother received adequacy of prenatal care. We applied the Rural Urban Commuting Area (RUCA) criteria to the ZIP code of residence to create a rurality variable with three categories, including urban, large rural and small rural areas (University of Washington). Adequacy of prenatal care was measured using the Kotelchuck Index (Kotelchuck, 1994). Adequacy of prenatal care was defined as prenatal care initiation within the first 4 months of pregnancy and completing at least 80% of the American Congress of Obstetricians and Gynecologists (ACOG) recommended number of visits for the gestational age of the infant (American College of Obstetricians and Gynecologists., 1985).

The impacts of CCO implementation were also adjusted for important birth characteristics, i.e. birth weight, presence of birth risk factors, presence of abnormal conditions or congenital anomalies of newborns, and birth plurality. We used a binary indicator for the presence of *abnormal conditions* if an infant was admitted to the neonatal intensive care unit, needed immediate assisted ventilation following delivery, received assisted ventilation for more than six hours, received either surfactant replacement therapy or antibiotics for suspected neonatal sepsis, had a seizure or serious neurologic dysfunction or significant birth injury. Similarly, a binary indicator for presence of *congenital anomalies* was used. Congenital anomalies included anencephaly, meningomyelocele or spina bifida, cyanotic congenital heart disease, congenital diaphragmatic hernia, omphalocele, gastroschisis, limb reduction defect (excluding congenital amputation and dwarfing syndromes), cleft lip, cleft palate, Down syndrome, and hypospadias. Information on maternal and birth characteristics were retrieved from birth certificates. We also adjusted the effects of CCO implementation for time trends in the outcomes over the study period.

4.3.6 Statistical analyses

We employed a difference-in-differences (DD) approach to estimate the effect of the CCO implementation on mortality. Our main DD model compared the average change in probability of mortality between the pre-CCO and post-CCO periods among Medicaid infants, who were affected by the CCO implementation, to the average change in mortality between the two periods among non-Medicaid infants, who were not influences by CCOs. To justify the DD approach, we tested for a common trend of mortality between Medicaid and non-Medicaid infants in the pre-CCO period. The tests were not statistically significant ($p > .05$), which indicated that mortality trends in the pre-CCO period were similar between Medicaid and non-Medicaid infants.

We estimated probit models and included an interaction term of the post-CCO period and CCO infant indicators. This interaction effect represented a difference in mortality outcomes between Medicaid infants and non-Medicaid infants, attributable to the CCO implementation. Because coefficients of interaction terms in probit models are misleading for the interpretation of interaction effects(Ai & Norton, 2003), average marginal effects of the interaction term with bootstrapped standard errors from 1,000 repetitions were then computed to estimate the average change in predicted probabilities of mortality in Medicaid infants after the implementation of CCO. Let ***cco*** denote the indicator variable for infants enrolled in Medicaid, ***post*** denote the indicator for post-CCO period, and $\hat{p}$ denote probability of mortality estimated from probit regression, the average marginal effect (AME) is estimated as follow:

$$\widehat{AME} = \frac{1}{n}\sum[\,(\hat{p}_{cco=1,post=1} - \hat{p}_{cco=1,post=0}) - (\hat{p}_{cco=0,post=11} - \hat{p}_{cco=0,post=0})]$$

where

$$\hat{p}_{cco=1,post=1} = P(Y = 1|cco = 1, post = 1, x)$$

$$\hat{p}_{cco=1,post=0} = P(Y = 1|cco = 1, post = 0, x)$$

$$\hat{p}_{cco=0,post=1} = P(Y = 1|cco = 0, post = 1, x)$$

$$\hat{p}_{cco=0,post=0} = P(Y = 1|cco = 0, post = 0, x)$$

with Y is mortality outcome, and x denotes the vector of covariates.

Heterogeneous effects of CCOs on mortality separately for preterm and full-term infants

To examine heterogeneous effects of CCOs on mortality between preterm and full-term infants, we expanded our models by adding a three-way interaction term between the post-CCO infant, CCO infant and preterm infant indicators (henceforth the triple interaction model). The coefficients of this interaction term represented the difference in mortality outcomes between Medicaid preterm infants and full-term infants, attributable to the CCO implementation. Average marginal effects of the interaction term were also computed to estimate the difference between the change in predicted mortality in preterm infants and such change in full-term infants after the implementation of CCO.

Impacts of CCOs on mortality over the implementation timeline

We compared pre-CCO averages to post-CCO averages by month to investigate the extent to which the impact of CCOs on mortality changed over the implementation timeline. We included a three-way interaction term between the post-CCO infant, CCO infant indicators and the monthly time indicator for the length of CCO implementation. The coefficients of this interaction term represented the impacts of the CCO implementation on the monthly change in mortality among Medicaid infants. We estimated linear probability models in order to gauge the magnitude of the monthly change in mortality. Coefficients from linear probability models of the interaction term were the average monthly change in predicted probabilities of death among Medicaid infants after the implementation of CCOs.

Analyses used Stata software, version 15.1. The study was approved by institutional review boards at the Oregon Health Authority and at [blinded for review].

4.4 Results

4.4.1 Characteristics of the sample

Table 1 presents characteristics of our sample of infants. Mothers of Medicaid infants were younger, more likely to be Hispanic, less likely be White or to be married and had lower education levels compared to mothers of non-Medicaid babies. The proportion of infants living in rural residence was also higher in Medicaid infants. Mothers of Medicaid infants were more likely to smoke during pregnancy and less likely to receive adequate prenatal care during pregnancy. The proportions of preterm births or presence of abnormal conditions or congenital anomalies were higher in Medicaid infants than non-Medicaid infants.

Comparing post-CCO infants to pre-CCO infants, mothers of post-CCO infants were older, less likely to be Hispanic, had higher education level, and more likely to be married. During the post-CCO period, the proportion of mothers receiving adequate prenatal care increased for both Medicaid and non-Medicaid infants, yet, mothers of Medicaid infants experienced a larger increase, i.e., from 67.1% to 70.6%, than mothers of non-Medicaid infants, i.e., from 80.9% to 81.9%. The percentage of preterm births was also lower by 0.4% during post-CCO period among Medicaid infants. However, post-CCO infants, both Medicaid and non-Medicaid, had higher proportions of presence of birth risk factors and abnormal conditions.

4.4.2 Mortality

Table 2 presents the probability of mortality for our sample. Both neonatal and infant mortality were lower among Medicaid infants. For instance, during the pre-CCO period, infant mortality among Medicaid infants was slightly lower than that among non-

Medicaid infants, i.e., 0.40% compared to 0.48%. After CCO implementation of the CCOs, the difference in infant mortality between Medicaid infants and non-Medicaid infants was larger, i.e., 0.25% in Medicaid infants compared to 0.43% in non-Medicaid infants. Mortality decreased during the post-CCO period but Medicaid infants experienced a larger decline in mortality. Among Medicaid infants, neonatal mortality decreased from 0.19% in pre-CCO period to 0.10% in post-CCO period. Meanwhile, the change in neonatal mortality was smaller in non-Medicaid infants, i.e., 0.41% in pre-CCO period to 0.37% in post-CCO period.

4.4.3 Impacts of CCO implementation on mortality

Coefficients of probit models are presented in Table 3. On average, infants enrolled in Medicaid had lower mortality than those who were not enrolled in Medicaid. Mortality during the post-CCO period was higher but only statistical significant for infant mortality ($p < .05$). Our main interest is the marginal effects of the interaction term between CCO infant and post-CCO period indicators presented in Table 4 that represent the magnitude of CCOs' impacts on mortality. On average, neonatal mortality was reduced by 0.13 percentage-point (95%CI: −0.25; −0.01) among Medicaid infants after the implementation of CCOs. This reduction represented a 68% decrease in neonatal mortality compared to the pre-CCO level. Infant mortality among infants enrolled in Medicaid also decreased by 0.15 percentage-points (95%CI: −0.26; −0.03) during the post-CCO period, equivalent to a 37.5% reduction in infant mortality from the pre-CCO level.

4.4.4 Heterogeneous effects of CCO implementation between preterm infants and full-term infants:

Table 4 also presents marginal effects from our models investigating if there were heterogeneous effects of CCO implementation on mortality between preterm infants and full-term infants. On average, infant mortality and neonatal mortality in Medicaid preterm infants decreased after the CCO implementation; however, the decrease in mortality was statistically significant for only infant mortality (i.e., −0.25 percentage-point, 95%CI: −0.38; −0.12). Reduction in infant mortality was found to be greater among preterm infants compared to that of full-term infants, i.e, −0.07 percentage-points (95%CI: −0.147; −0.002).

4.4.5 Impacts of CCOs over the implementation timeline

Marginal effects of models examining whether the impacts of CCOs increased over the implementation timeline are shown in the last row of Table 4. On average, infant mortality of Medicaid infants decreased by 0.004 percentage-points (95%CI: −0.006; −0.0001) for every month further from the start month of CCO implementation. Neonatal mortality also marginally decreased each month over the implementation timeline, but this change was not statistically significant.

4.4.6 Sensitivity analysis

Although impacts of CCO implementation on mortality were adjusted for a comprehensive set of maternal and birth characteristics as well as time trends of the outcomes over the study period, our estimates might be biased if there were omitted variables that affected both the main exposure and mortality outcomes such as the quality of care received by Medicaid and non-Medicaid mothers and infants. To mitigate this concern, we adjusted our estimates using inverse probability weights (IPW) to make the Medicaid and non-Medicaid groups more similar based on observable characteristics. To estimate the propensity scores, we fitted a logistic regression for the indicator of CCO infant (i.e., Medicaid infant) as a function of smoking status during pre-pregnancy and pregnancy periods and mother's county as well as the covariates included in the main models. The estimated effects of CCOs were in the same direction and remain significant but the magnitude of the effects were greater (Table 5).

Because CCOs have been shown to increase prenatal care that resulted in improved infant health outcomes (Harvey et al., 2017; Oakley et al., 2017), we compared models with and without controlling for the indicator of adequacy of prenatal care to investigate if CCOs had an impact on mortality through other pathways other than improving prenatal care for pregnant women. The marginal effects of the interaction term between CCO infant and post-CCO period indicators were very similar to that in the models when controlling for adequacy of prenatal care (Table 5), which implied that improving prenatal care was not the only pathway through which CCOs influenced mortality among Medicaid infants.

4.5 Discussion

Finding from our study indicated that neonatal mortality and infant mortality declined among infants enrolled in Medicaid after four years of the implementation of the Oregon CCO model. Previous studies on the impacts of CCOs or Medicaid ACOs found favorable effects on infant mortality but these findings were not statistically significant (Harvey et al., 2017; Henke et al., 2019). Several reasons may account for the differences between our findings and prior studies. First, it takes time for changes in a health care delivery system to affect health outcomes like mortality. Our study examined the effects on outcomes after four years of implementation of the CCO model. Second, in order to change mortality outcomes, Medicaid ACO models may require not only coordinated care but also the delivery of care that addresses the social determinants of health (Henke et al., 2019). With the ability to examine the effects of CCOs in a longer time frame, our findings suggest that the Oregon CCO model was effective in improving survival of infants enrolled in Medicaid.

We also found that the impacts of CCOs on infant mortality continuously increased over the implementation timeline. Compared to the monthly change in infant mortality before the implementation of CCO model, the monthly change in mortality during the post-CCO period was lower by 0.004 percentage-points. Similar to any care delivery system reform, each CCO requires time to develop and adapt its strategies and structures to improve health care and health outcomes for Medicaid enrollees.

Our finding indicated that CCOs are moving in the right direction to address infant health outcomes. CCOs have been shown to improve access to prenatal care for pregnant women (Oakley et al., 2017) and to reduce some adverse infant's health outcomes, such as low birth weight and abnormal conditions at birth (Harvey et al., 2017) that could contribute to a reduction in infant mortality. Also, the CCO model uses quality incentive payments tied to preventive care and care coordination through patient-centered primary care homes (PCPCHs), which may improve health care for women during pre-pregnancy period and follow-up care for infants after birth. Furthermore, CCOs have flexibility to provide care addressing social determinants of health and health equity that could positively impact children's health. For example, CCOs could use their global budget to pay for non-traditional health care expenses like housing or transportation (Smith & Rissi, 2015).

Our study is the first, to our knowledge, to examine the impact of the Medicaid ACO models on mortality among preterm infants. We found that the CCO model had a greater impact on infant mortality in Medicaid preterm infants than that in full-term infants. After CCO implementation, the reduction in infant mortality in Medicaid preterm infants was lower by 0.07 percentage points compared to the decrease in mortality among full-term infants. One possible explanation for this result is that most CCOs initially focused on care coordination for high-risk and high-cost population (Smith & Rissi, 2015) and addressing social determinants of health. Thus, preterm infants could have benefited from improved follow-up and coordinated care after birth.

Our study has some important limitations. Although our models controlled for a comprehensive set of maternal and birth characteristics that are associated with mortality in infants, we were not able to control for other time variant variables, e.g., health care utilization before and during pregnancy of mothers or health care utilization after birth of infants. Also, reporting errors may be present for maternal and birth characteristics in birth certificates. However, such errors are considered as random and should not influence our findings. Finally, our study examined the overall effects of the CCO implementation on mortality. Because CCO model has different features that could contribute to the reduction of mortality among infants, future research should investigate how each specific characteristic of this care delivery model has an effect on mortality among infants enrolled in Medicaid.

4.6 Conclusion

The implementation of CCOs in Oregon was associated with a reduction in neonatal and infant mortality among infants enrolled in Medicaid. This health care delivery reform also had a greater impact on improving survival among preterm infants compared to full-term infants. CCOs should continue their strategies to further improve infants' health outcomes, especially for other high-risk infant groups.

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Table 4.1. Characteristics of infants

Variable	Medicaid[1]		Non-Medicaid[2]	
	Pre-CCO[3] (N = 78,345)	Post-CCO[3] (N = 89,277)	Pre-CCO (N =58,174)	Post-CCO (N= 60,246)
	(n/%)	(n/%)	(n/%)	(n/%)
Maternal characteristics				
Age (mean (SD))	25.9 (5.8)	27.0 (5.8)	30.8 (5.0)	31.4 (4.7)
Race/ethnicity				
White	42,772 (54.6)	52,858 (59.2)	45,896 (78.9)	47,586 (79.0)
Black	2,787 (3.6)	3,382 (3.8)	656 (1.1)	797 (1.3)
AIAN	2,545 (3.3)	2,869 (3.2)	781 (1.3)	591 (1.3)
Asian	2,160 (2.8)	3,072 (3.4)	4,791 (8.2)	5,422 (9.0)
NHPI	927 (1.2)	1,070 (1.2)	285 (0.5)	295 (0.5)
Other	661 (0.8)	742 (0.8)	495 (0.9)	540 (0.9)
Hispanic	23,511 (30.0)	23,373 (26.2)	4,004 (6.9)	4,041 (6.7)
Missing	2,982 (3.7)	1,911 (2.2)	1,266 (2.2)	806 (1.3)
Education				
< High school	23,674 (30.2)	20,197 (22.6)	1,643 (2.8)	1,015 (2.7)
High school or ED	24,267 (31.0)	26,712 (29.9)	6,833 (11.8)	5,493 (9.1)
College or higher	27,191 (34.7)	40,216 (45.1)	48,339 (83.1)	52,800 (87.6)
Missing	2,740 (4.1)	2,152 (2.4)	1,359 (2.3)	938 (1.6)
Married	34,240 (43.7)	40,616 (45.5)	51,402 (88.4)	54,170 (89.9)
Rurality				
Urban	61,604 (82.5)	73,691 (82.5)	52,551 (90.3)	54,060 (89.7)
Large rural	7,943 (10.1)	9,910 (11.1)	3,143 (5.4)	3,810 (6.3)
Small/isolated rural	2,295 (3.4)	3,283 (3.7)	1,234 (2.1)	1,145 (1.9)
Missing	3,106 (4.0)	2,393 (2.7)	1,246 (2.2)	1,231 (2.1)
BMI at delivery (mean (SD))	32.2 (6.6)	32.4 (6.7)	30.9 (5.9)	30.8 (5.7)
Smoking during pregnancy	14,529 (18.5)	16,235 (18.2)	2,416 (4.2)	1,830 (3.0)
Number previous births				
0	28,999 (37.0)	32,196 (36.1)	24,827 (42.7)	26,394 (43.8)
1	21,915 (28.0)	26,172 (29.3)	20,462 (35.2)	21,314 (35.4)
2	13,394 (17.1)	15,852 (17.8)	7,698 (13.2)	7,768 (12.9)
>=3	11,065 (14.1)	13,280 (14.9)	4,030 (6.9)	4,123 (6.8)
Missing	2,544 (3.8)	1,777 (1.9)	1,157 (2.0)	647 (1.1)
Adequacy of prenatal care	52,543 (67.1)	63,019 (70.6)	47,055 (80.9)	49,364 (81.9)
Birth characteristics				
Preterm	6,253 (8.0)	6,816 (7.6)	4,116 (7.1)	4,201 (7.0)
Girls	38,198 (48.8)	43,706 (49.0)	28,276 (48.6)	29,210 (48.5)
Birth weight in gram (mean (SD))	3,334.1 (579.6)	3,341.2 (567.8)	3,404.1 (563.5)	3,402.9 (567.3)

Presence of birth risk factors	21,293 (27.2)	27,617 (30.9)	16,689 (28.7)	19,228 (31.9)
Presence of abnormal conditions	8,001 (10.2)	9,239 (10.4)	4,736 (8.1)	5,465 (9.1)
Presence of congenital anomalies	495 (0.6)	594 (0.7)	271 (0.5)	279 (0.5)
Birth plurality	1,937 (2.5)	2,417 (2.7)	2,439 (4.2)	2,676 (4.4)

[1]Medicaid births defined as enrolled in Medicaid on date of birth or within two weeks of birth
[2]Non-Medicaid status defined as not enrolled in Medicaid during the first year of birth
[3]Pre-CCO infants were those born between August 2008 and July 2011, Post-CCO infants were those born between August 2012 and December 2015

Table 4.2. Mortality among infants

Population	Mortality		Pre-CCO[3]			Post-CCO[3]		
Medicaid[1]			**All (N=78,345)**	**Full-term (N=72,092)**	**Preterm (N=6,253)**	**All (N=89,277)**	**Full-term (N=82,461)**	**Preterm (N=6,816)**
	Neonatal mortality	n	152	45	107	92	22	70
		%	0.19	0.06	1.71	0.1	0.03	1.03
	Infant mortality	n	317	160	157	226	121	105
		%	0.4	0.22	2.51	0.25	0.15	1.54
Non-Medicaid[2]			**All (N=58,174)**	**Full-term (N=54,058)**	**Preterm (N=4,116)**	**All (N=60,246)**	**Full-term (N=56,045)**	**Preterm (N=4,201)**
	Neonatal mortality	n	241	51	190	222	52	170
		%	0.41	0.09	4.62	0.37	0.09	4.05
	Infant mortality	n	279	72	207	262	71	191
		%	0.48	0.13	5.03	0.43	0.13	4.55

[1]Medicaid births defined as enrolled in Medicaid on date of birth or within two weeks of birth
[2]Non-Medicaid status defined as not enrolled in Medicaid during the first year of birth
[3]Pre-CCO infants were those born between August 2008 and July 2011, Post-CCO infants were those born between August 2012 and December 2015

Table 4.3. Impacts of CCO implementation on neonatal mortality and infant mortality: Coefficients from difference-in-differences probit models

	Impacts of CCOs on mortality Coefficients (SE)	
Variables	***Neonatal mortality***	***Infant mortality***
CCO (Medicaid)	−0.417*** (0.068)	−0.176*** (0.048)
Post-CCO period	0.156 (0.110)	0.190* (0.080)
CCO x Post-CCO period	−0.164* (0.079)	−0.110* (0.056)
Maternal characteristics		
Age	−0.008 (0.004)	−0.015*** (0.003)
Race/ethnicity (Reference = *White*)		
Black	0.086 (0.097)	−0.004 (0.074)
AIAN	0.113 (0.115)	0.221** (0.068)
Asian	−0.265** (0.092)	−0.105 (0.067)
NHPI	0.124 (0.168)	−0.101 (0.147)
Other	−0.554 (0.360)	−0.397 (0.252)
Hispanic	−0.042 (0.056)	−0.109** (0.042)
Education (Reference = < *High school*)		
High school or ED	0.009 (0.064)	0.012 (0.044)
College or higher	−0.020 (0.068)	−0.019 (0.047)
Married	−0.061 (0.052)	−0.079* (0.036)
Rurality (Reference = *Urban*)		
Large rural	0.027 (0.065)	0.005 (0.046)
Small/isolated rural	−0.214 (0.159)	0.023 (0.078)
BMI at delivery	0.010*** (0.003)	0.011*** (0.002)
Smoking during pregnancy	0.108 (0.060)	0.168*** (0.040)
Number previous births (Reference = 0)		
1	0.086 (0.049)	0.134*** (0.036)
2	0.112 (0.063)	0.190*** (0.046)
>=3	0.150* (0.071)	0.270*** (0.051)
Adequacy of prenatal care	−0.129* (0.052)	−0.086* (0.035)
Birth characteristics		
Preterm	0.056 (0.069)	0.019 (0.047)
Birth weight in gram	−0.001*** (0.000)	−0.001*** (0.000)
Girls	−0.067 (0.039)	−0.086** (0.028)
Presence of birth risk factors	−0.088* (0.045)	−0.074* (0.033)
Presence of abnormal conditions	−0.075 (0.080)	0.053 (0.054)
Presence of congenital anomalies	1.322*** (0.075)	1.283*** (0.056)
Birth plurality	−0.233*** (0.053)	−0.193*** (0.044)
Constant	0.093 (0.203)	−0.167 (0.149)

Notes: Standard errors are in parentheses. All models controlled for time trend of mortality.
$*p < .05$. $**p < .01$. $***p < .001$.

Table 4.4. Impacts of CCO implementation on neonatal mortality and infant mortality among Medicaid infants: Marginal effects

	Impacts of CCOs on mortality among Medicaid infants Marginal effects in percentage points (95% CI)	
Type of analysis	***Neonatal mortality***	***Infant mortality***
Main difference-in-differences model	−0.130* (−0.252; −0.009)	−0.146* (−0.263; −0.029)
Triple interaction model:		
Preterm infants	−0.079 (−0.220; 0.062)	−0.249*** (−0.384; −0.114)
Difference between preterm and full-term infants (preterm − full-term)	−0.012 (−0.058; 0.034)	−0.073* (−0.147; −0.002)
Monthly change in mortality	−0.0005 (−0.002; 0.002)	−0.004* (−0.006; −0.0001)

Notes: All average marginal effects were computed with bootstrapped 95%CI from 1,000 repetitions, except for models on monthly impacts of CCOs where marginal effects were from linear probability models. All models controlled for maternal and birth characteristics and time trend of mortality.

*p < .05. ***p < .001.

Table 4.5. Sensitivity analysis: Marginal effects

	Impacts of CCOs on mortality among Medicaid infants	
	Marginal effects in percentage points (95% CI)	
Type of analysis	***Neonatal mortality***	***Infant mortality***
Without controlling for adequacy of prenatal care		
Main difference-in-differences model	−0.125* (−0.249; −0.001)	−0.164** (−0.285; −0.044)
Triple interaction model		
Pre-term infants	−0.107 (−0.230; 0.015)	−0.281*** (−0.423; −0.138)
Difference between preterm and full-term infants (preterm − full-term)	−0.016 (−0.063; 0.032)	−0.081* (−0.154; −0.008)
Monthly change in mortality	−0.0008 (−0.003; 0.001)	−0.004** (−0.007; −0.001)
Models with IPW		
Main difference-in-differences model	−0.176 (−0.379; 0.028)	−0.222** (−0.387; −0.057)
Triple interaction model:		
Pre-term infants	−0.162 (−0.390; −0.066)	−0.325*** (−0.491; −0.158)
Difference between preterm and full-term infants (preterm − full-term)	−0.042 (−0.140; 0.057)	−0.109* (−0.205; −0.014)
Monthly change in mortality	−0.0003 (−0.003; 0.002)	−0.004* (−0.008; −0.0008)

Notes: All average marginal effects were computed with bootstrapped 95%CI, except for models on monthly impacts of CCOs where marginal effects were from linear probability models. All models controlled for maternal and birth characteristics and time trend of mortality.
*$p < .05$. **$p < .01$. ***$p < .001$.

CHAPTER 5

Overall conclusions

The implementation of CCOs in 2012 provided a natural experiment to examine a unique healthcare delivery transformation for Medicaid beneficiaries in Oregon. Given the limitations of current literature on impacts of Medicaid ACOs on infants, this dissertation investigated how the CCO model affected healthcare utilization and mortality of infants enrolled in Medicaid. I found a positive impact of CCOs on preventive care for infants during two years after birth. Average number of well-child visits and the probability of receiving adequacy of well-child visits both increased after CCO implementation. Especially, there was a sharp improvement in annual probability of developmental screening in the post-CCO period. CCOs receive payment based on their performance on incentive metrics. Developmental screening in the first 36 months of life and patient-centered primary care home enrollment are two of the CCO incentive metrics. This could be the reason for such improvement in preventive care for infants. It suggests that using specific incentive measures could be highly effective to improve care for a population of interests.

After CCO implementation, ED visits and hospital admissions did not reduce among infants. Also, I did not find a difference in utilization of these services between preterm infants and full-term infants during the post-CCO period. In any care model aiming to control cost, reducing ED and inpatient costs is usually the priority. Also, high-cost and high-risk populations are often considered as target groups. During the study period, all CCOs had their transformation plans focusing on high-cost adult populations, such as patients with multiple chronic illnesses or mental health issues, rather than children. It could be a possible explanation for my findings. For the next phase of CCO implementation (2020-2014), the Oregon Health Policy Board has designed multiple specific policies to improve child and family outcomes. For instance, each CCO will be required to implement new value-based payments in maternity care and children's health care with contracted providers. Various policies addressing barriers for care coordination and integration for children have also been identified. Future research should investigate the extent to which CCOs will have an impact on children's utilization of these services when CCOs implements more policies targeting children's health.

In terms of health outcomes, the CCO model was found to be associated with a reduction in both neonatal mortality and infant mortality. I also found a greater reduction in infant mortality among preterm infants compared to full-term infants. Infant mortality has been widely used as a crude indicator of population health status as well as availability and quality of health services. Improvement of care integration and prenatal care for women via primary care homes could have contributed to better infant health outcomes. Furthermore, CCOs have flexibility to provide care to address social determinants of health, rather than just medical care, that could help reduce mortality risk after birth. In the next phase of CCO implementation, research should continue investigating the impacts of CCOs on other children's health outcomes and outcomes in different high-risk children populations.

In the scope of this dissertation, I examined the overall impacts of CCOs rather than impacts of each specific characteristics of the care model. Besides, CCOs also vary in terms of organizational structure and care delivery transformation plans. Research looking at how these features have an impact on health outcomes for children further could contribute to literature. Besides, without the availability of complete cost data for pre-CCO period, I was not able to examine the effect of CCOs on cost of care for infants. The question on how the CCO model influences cost of care for children deserves an answer.

APPENDICES

Appendix 1: Conceptual framework

This dissertation modifies Andersen's behavioral model of health services use (Andersen & Newman, 2005) and the conceptual model of care delivery for preterm infants after NICU discharge suggested by Kuo et al (2017). According to Andersen's model, healthcare utilization is affected by individual determinants that are either directly influenced by social determinants or indirectly affected through the healthcare system.

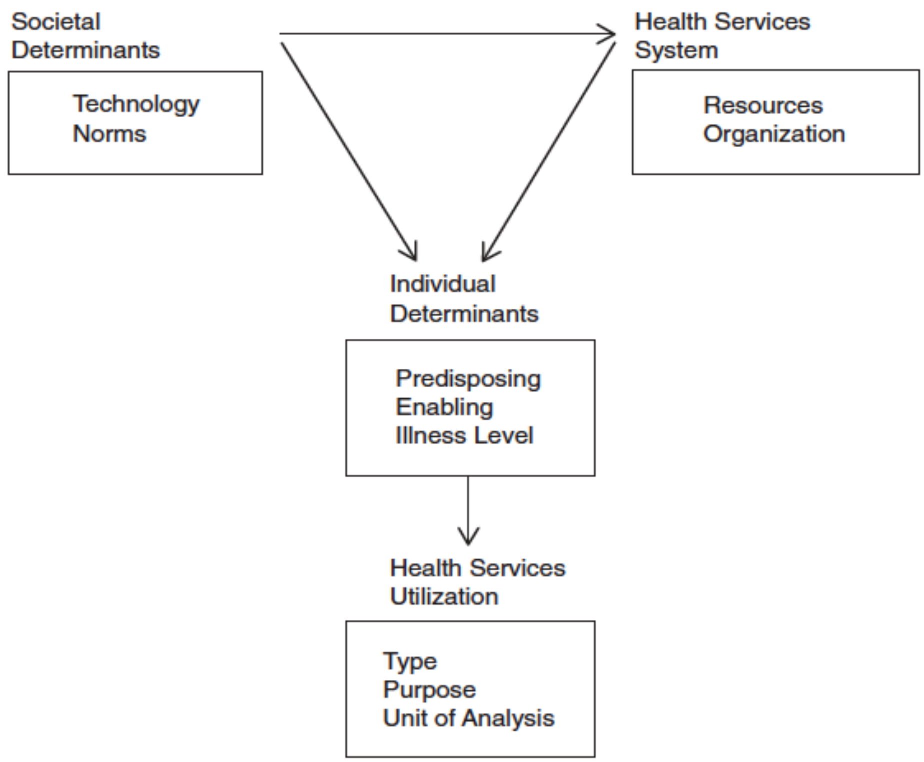

Figure 1. Andersen's behavioral model of health services use (Andersen & Newman, 2005)

The conceptual model of Kuo et al., emphasizes that care delivery systems need to include the medical home within the culture of quality improvement to improve health outcome for preterm infants.

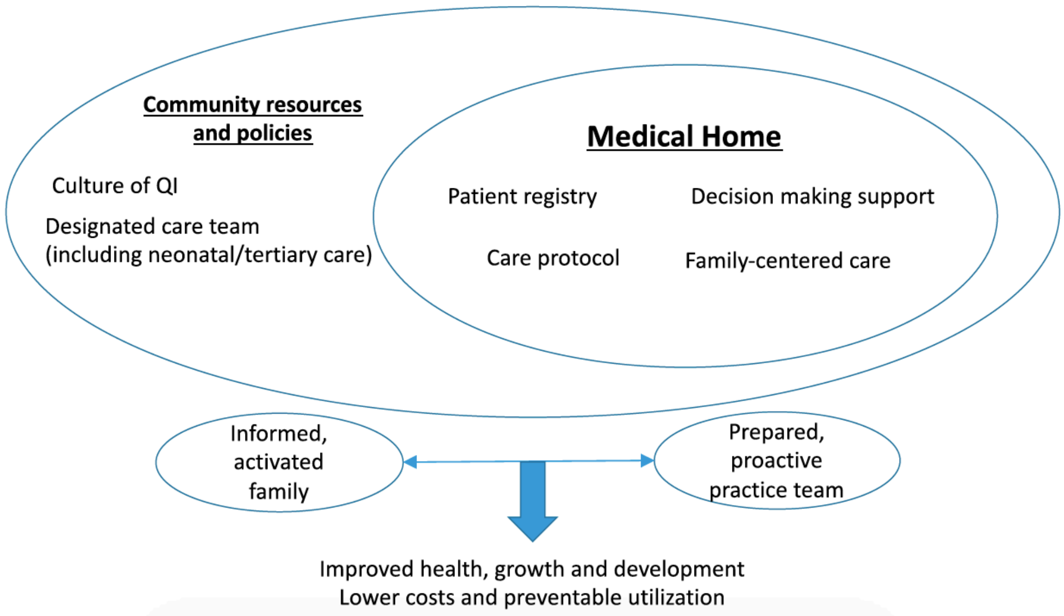

Figure 2. Conceptual framework of effective care delivery for preterm infants in the primary care setting (Kuo et al., 2017)

Figure 3 shows the conceptual framework tailored to this dissertation to examine the effects of CCO implementation on healthcare utilization and mortality of infants enrolled in Medicaid. In our conceptual framework, the healthcare system directly determines demand for healthcare services among infants. It also indirectly influences infants' health outcomes through individual determinants, and, thus, induces demand for healthcare services. For example, CCO implementation was shown to improve prenatal care that contributed to improved health outcomes in infants (Harvey, Oakley, Yoon, & Luck, 2017) and change in health outcomes could influence healthcare utilization patterns in infants. Healthcare utilization then determines healthcare cost and eventually impacts health outcomes of infants.

Healthcare system factors

In Andersen’s behavioral model of health services use, the healthcare system determines how healthcare is provided or represents the “supply” of healthcare services. A healthcare system is comprised of two components, resources and organization. The resources component includes healthcare personnel, equipment, and materials used to provide care, while organization component refers to how resources are coordinated and facilitated to provide health care. The organization component can be further broken down into two sub-components, access and structure. Access includes the requirements or factors that affect an individual’s entry into the healthcare system, such as eligibility criteria, out-of-pocket costs, or waiting time to receive treatment. Structure includes information about the care procedures/processes once patients enter the system. Given such definition, CCOs belong to structure of a healthcare organization.

The key features of CCOs define how infants enrolled in Medicaid receive healthcare services and also address important domains of care delivery for preterm infants proposed by Kuo et al. For instance, CCOs aim to provide care for their members through the PCPCH model by helping ensure that primary care providers (PCPs) are recognized by the state as PCPCHs and assigning members to certified PCPCH clinics. This model enhances care coordination, disease management, and physical/ behavioral/ dental integration for the Medicaid population. PCPCHs could provide family-centered care and improve continuity of care for Medicaid preterm infants. In addition, receiving a global budget could improve efficiency in healthcare delivery as the CCOs are encouraged to provide services that are effective but not costly and accountable for quality of the care they provide within the budget received. It fosters the use of evidence-based, cost-effective treatment and preventive services while reducing the provision of unnecessary services. A global budget also provides more flexibility for CCOs to apply interventions addressing social determinants of health without restriction to only medical services. This feature could improve outreach services for families with preterm babies. Furthermore, alternative payment mechanisms that reward quality would help shape the culture of quality practice among providers that contributes to improved health outcomes in infants enrolled in Medicaid.

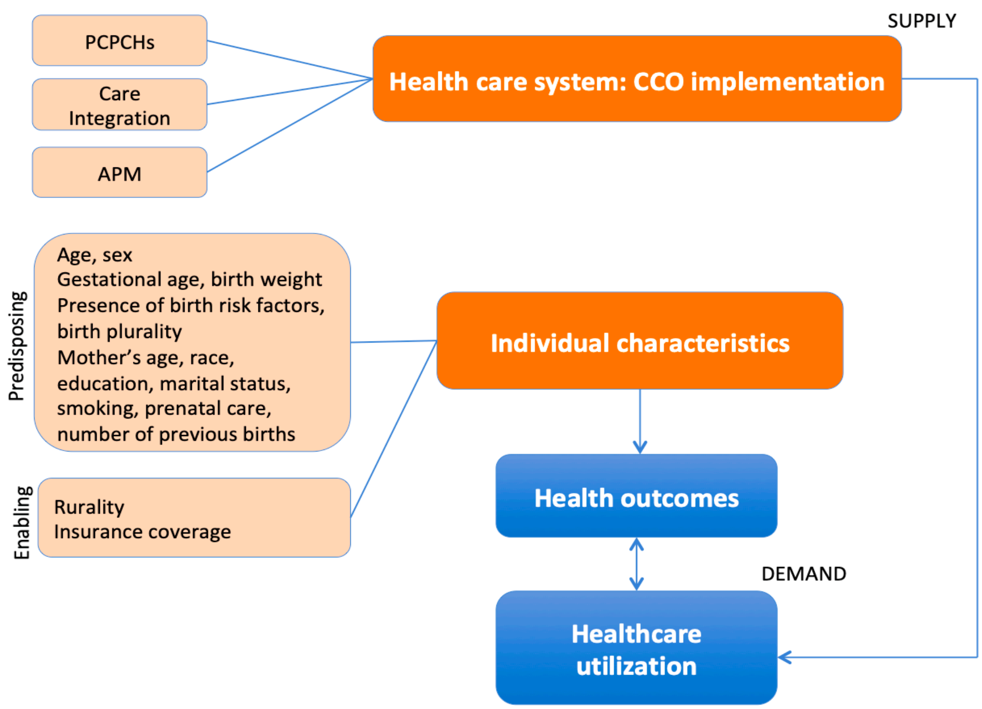

Figure 3. Conceptual framework of healthcare utilization and health outcomes of infants enrolled in Medicaid

Individual determinants

Certain individual factors determine the health status/outcomes of infants, and, thus, influence their healthcare utilizations. Types of services, as well as frequency of services, used by a baby depend on predisposing factors and enabling factors of the baby and their mother.

Predisposing factors are individual characteristics that determine how likely an individual is to use healthcare services, without being directly responsible for service usage. They include demographic factors of the infant (e.g. age and sex), demographic and utilization factors of the mother (e.g., education, marital status, age, race, number of previous births, prenatal care utilization).

Enabling factors include conditions that permit a family to use care services for their babies. Such conditions include insurance coverage and community characteristics such as living environment (e.g., rural or urban).

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Appendix 2. Econometric models

A. Hurdle models of number of well-child visits and ED visits

All models for number of well-child visits and ED visits were applied for the subsample of Medicaid infants only. Because ED visits are rare events with excess zeros (i.e., many infants did not visit the ED during two years after birth), hurdle models for count data will be used to account for the two-part nature of the outcome. Although well-child visits are more common in infants than ED visits, hurdle models are also capable of modeling count of events that are not rare. In the hurdle models, the first part will model the probability of visiting ED, or having well-child visit at all among all Medicaid infants and the second part will model the number of services used only among the restricted sample of infants who visited ED, or received well-child visits.

Hurdle models for overall impacts of CCOs on well-child visits or ED visits:

Part 1 will use models for the binary outcome variables indicating if an infant had ever used services (e.g. visited ED, or had well-child visit) by the first and the second birthday (Model 1).

$$[\boldsymbol{Pr}(\boldsymbol{Y_{ik}} = \mathbf{1})|\boldsymbol{post}, \boldsymbol{x'}] = \boldsymbol{g}(\boldsymbol{\beta_0} + \boldsymbol{\beta_1} \boldsymbol{post_k} + \boldsymbol{x'_i} \boldsymbol{\beta}) \qquad \textbf{(1)}$$

where $\boldsymbol{Y}$ indicates if any service was used by individual $\boldsymbol{i}$ in CCO $\boldsymbol{k}$, "g" is the link function.

Logit CDF, or linear index function were used for estimations. The variable ***post*** represents CCO infants, and the coefficient $\boldsymbol{\beta_1}$ captures the average difference in the probabilities of service use between CCO infants and non-CCO infants. The vector $\boldsymbol{x'}$ includes all covariates. Because the coefficients of logit models are log odds, average marginal effects were computed to estimate the average difference in predicted probabilities of each outcome between CCO infants and non-CCO infants.

Part 2 used zero-truncated negative binomial (ZTNB) models to restrict the analysis to infants who had at least one ED visit, or any well-child visit (Model 2).

$$\boldsymbol{ln}[\boldsymbol{E}(\boldsymbol{Y}_{ik}|\boldsymbol{Y}_{ik} > \mathbf{0})] = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 \boldsymbol{post}_k + \boldsymbol{x}'_i\boldsymbol{\beta} \qquad \textbf{(2)}$$

where $\boldsymbol{Y}$ is the count of each type of service for individual $\boldsymbol{i}$ in CCO $\boldsymbol{k}$. The coefficient $\boldsymbol{\beta}_1$ in model 2 indicates the difference in the average numbers of service utilizations between CCO infants and non-CCO infants who had used at least one service. Similar to Model 1, average marginal effects were computed for Model 2 to predict the difference in the average counts of utilizations between CCO infants and non-CCO infants who had ever used services.

Full marginal effects were estimated by combining two parts of the hurdle models. Full marginal effects, i.e. average difference in predicted numbers of service utilizations between CCO infants and non-CCO infants, were computed by multiplying the average difference in predicted probabilities of utilizing any service from the first part by average difference in predicted counts of services in the second part. Bootstrapped standard errors of all marginal effects were obtained based on 1,000 repetitions.

Investigate if the effects of CCO implementation on the utilization of well-child visits and ED services differ between preterm and full-term babies

A difference-in-differences (DID) approach was applied to examine if the effect of CCO implementation on the utilization of each service type (e.g., well-child visits, and ED visits) differs between preterm and full-term babies. The average difference in the usage of each service between pre-CCO and post-CCO periods in preterm infants will be compared with the average difference between two periods in full-term infants.

I expanded hurdle models (Models 1 and 2) by including an interaction term between the indicator of CCO infants and a binary variable representing preterm births (Models 3 and 4):

Part 1:

$$[\boldsymbol{Pr}(\boldsymbol{Y_{ik}} = \mathbf{1})|\boldsymbol{post}, \boldsymbol{preterm}, \boldsymbol{x'}] = \boldsymbol{g}(\boldsymbol{\beta_0} + \boldsymbol{\beta_1 post_k} + \boldsymbol{\beta_2 preterm_i} + \boldsymbol{\beta_3}(\boldsymbol{post} \times \boldsymbol{preterm})_{\boldsymbol{ik}} + \boldsymbol{x'_i \beta}) \qquad \textbf{(3)}$$

where $\boldsymbol{Y}$ indicates if any service was used by individual $\boldsymbol{i}$ in CCO $\boldsymbol{k}$, and g is logit CDF, or linear index function.

Part 2:

$$\boldsymbol{ln}[\boldsymbol{E}(\boldsymbol{Y_{ik}}|\boldsymbol{Y_{ik}} > \mathbf{0})] = \boldsymbol{\beta_0} + \boldsymbol{\beta_1 post_k} + \boldsymbol{\beta_2 preterm_i} + \boldsymbol{\beta_3}(\boldsymbol{post} \times \boldsymbol{preterm})_{\boldsymbol{ik}} + \boldsymbol{x'_i \beta} \qquad \textbf{(4)}$$

where $\boldsymbol{Y}$ is the count of each type of services for individual $\boldsymbol{i}$ in CCO $\boldsymbol{k}$.

In models 3 and 4, the variable ***post*** represents CCO infants, and $\boldsymbol{\beta_1}$ captures the average difference in outcome Y between CCO infants and non-CCO infants. The variable ***preterm*** indicates if the infant was born preterm, and its coefficient $\boldsymbol{\beta_2}$ estimates the average difference in the outcome Y between preterm births and full-term births. I was most interested in the coefficient $\boldsymbol{\beta_3}$ of the interaction term between ***post*** and ***preterm*** as it represents the difference in the outcome among preterm infants versus full-term infants that was attributable to CCO implementation. The vector $\boldsymbol{x'}$ includes all covariates, except the variable indicating preterm births.

In Model 3, because the coefficients of logit models are often difficult to interpret for interaction terms (Ai & Norton, 2003), marginal effects were computed to estimate the average difference of predicted probabilities of each outcome between preterm babies and full-term babies that is attributable to CCO implementation. Similarly, marginal interaction effects were computed for Model 4 to predict the average difference in the counts of services between preterm infants and full-term infants after CCO implementation. Marginal interaction effect of ***(post x preterm)*** for each outcome will be computed as a DID in $\hat{\boldsymbol{y}}$ (i.e., predicted probabilities of using at least one service from logit model, or predicted counts of services among those who used any service in ZINB model) as the value of ***post*** and ***preterm*** changed from 0 to 1 (Equation 5):

$$\frac{\sum(\Delta\hat{\boldsymbol{y}}_{\boldsymbol{preterm=1}} - \Delta\hat{\boldsymbol{y}}_{\boldsymbol{preterm=0}})}{N}$$

$$= \frac{\sum[(\hat{\boldsymbol{y}}_{\boldsymbol{preterm=1,post=1}} - \hat{\boldsymbol{y}}_{\boldsymbol{preterm=1,post=0}}) - (\hat{\boldsymbol{y}}_{\boldsymbol{preterm=0,post=1}} - \hat{\boldsymbol{y}}_{\boldsymbol{preterm=0,post=0}})]}{N} \quad (\mathbf{5})$$

Full marginal interaction effect was the production of average difference in predicted probabilities of utilizing any service and average difference in predicted counts of services between preterm and full-term babies. Bootstrapped standard errors of all marginal interaction effects were obtained based on 1,000 repetitions.

<u>*Investigate if the effects of CCO implementation on the utilization of well-child visits and ED services change over the implementation timeline*</u>

Model 6 and Model 7 are 2 parts of the hurdle model examining if the impact of CCOs on utilization of well-child visits and ED visits change over the CCO implementation timeline:

$$[\boldsymbol{Pr}(\boldsymbol{Y_{ik}} = \mathbf{1})|\boldsymbol{cco\_matur}, \boldsymbol{x}'] = \boldsymbol{g}(\boldsymbol{\beta_0} + \boldsymbol{\beta_1 cco\_matur_k} + \boldsymbol{x'_i\beta}) \quad \textbf{(6)}$$

where $\boldsymbol{Y}$ indicates if any service was used by individual $\boldsymbol{i}$ in CCO $\boldsymbol{k}$, "g" is the link function. Logit CDF, or linear index function were used for estimations

$$\boldsymbol{ln}[\boldsymbol{E}(\boldsymbol{Y}_{ik}|\boldsymbol{Y}_{ik} > \boldsymbol{0})] = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 \boldsymbol{cco\_matur}_k + \boldsymbol{x'}_i\boldsymbol{\beta} \qquad \textbf{(7)}$$

where $\boldsymbol{Y}$ is the count of each type of service for individual $\boldsymbol{i}$ in CCO $\boldsymbol{k}$.

The variable ***cco_matur*** is a monthly time indicator for the length of CCO implementation, and the coefficient β_1 captures the average change in the outcome when ***cco_matur*** increased by 1 unit. The vector $\boldsymbol{x'}$ includes all covariates. Full marginal effects were also estimated by combining two parts of the hurdle models to estimate average change in predicted numbers of service utilizations for every month further in the CCO implementation timeline. Bootstrapped standard errors of all marginal effects were obtained based on 1,000 repetitions.

B. Hurdle models of hospitalization

As information on number of hospital admissions was available for both Medicaid infants and non-Medicaid infants, I used the DID approach to compare the average differences in hospitalization between pre-CCO and post-CCO periods between Medicaid infants and non-Medicaid infants.

Hurdle models (Models 8 and 9) of hospitalization are presented as followed.

Part 1:

$$[\boldsymbol{Pr}(\boldsymbol{Y}_{ik} = \boldsymbol{1})|\boldsymbol{post}, \boldsymbol{cco}, \boldsymbol{x'}] = \boldsymbol{g}(\boldsymbol{\beta}_0 + \boldsymbol{\beta}_1\boldsymbol{post}_k + \boldsymbol{\beta}_2\boldsymbol{cco}_i + \boldsymbol{\beta}_3(\boldsymbol{post} \times \boldsymbol{cco})_{ik} + \boldsymbol{x'}_i\boldsymbol{\beta}) \qquad \textbf{(8)}$$

where $\boldsymbol{Y}$ indicates if any inpatient service was used by individual $\boldsymbol{i}$ in CCO $\boldsymbol{k}$, and g is logit CDF.

Part 2:

$$\boldsymbol{ln[E(Y_{ik}|Y_{ik} > 0)] = \beta_0 + \beta_1 post_k + \beta_2 cco_i + \beta_3 (post \times cco)_{ik} + x'_i\beta} \quad \textbf{(9)}$$

where ***Y*** is the counts of admissions/hospital days for individual ***i*** in CCO ***k***.

In models 8 and 9, the coefficient $\boldsymbol{\beta_1}$ captures the average difference in outcome Y between post-CCO infants and pre-CCO infants. The variable ***cco*** indicates if the infant was enrolled in Medicaid, and its coefficient $\boldsymbol{\beta_2}$ estimates the average difference in the outcome Y between Medicaid and non-Medicaid infants. The coefficient $\boldsymbol{\beta_3}$ of the interaction term between ***post*** and ***cco*** represents the difference in the outcome among Medicaid infants versus non-Medicaid infants that is attributable to CCO implementation. The vector $\boldsymbol{x'}$ will include all covariates.

Marginal interaction effect of ***(post x cco)*** was computed as a DID in predicted outcome $\boldsymbol{\hat{y}}$ as the value of ***post*** and ***cco*** changed from 0 to 1 (Equation 10):

$$\frac{\sum(\Delta\boldsymbol{\hat{y}}_{\boldsymbol{cco=1}} - \Delta\boldsymbol{\hat{y}}_{\boldsymbol{cco=0}})}{N}$$

$$= \frac{\sum[(\boldsymbol{\hat{y}}_{\boldsymbol{cco=1,post=1}} - \boldsymbol{\hat{y}}_{\boldsymbol{cco=1,post=0}}) - (\boldsymbol{\hat{y}}_{\boldsymbol{cco=0,post=1}} - \boldsymbol{\hat{y}}_{\boldsymbol{cco=0,post=0}})]}{N} \quad (\mathbf{10})$$

Full marginal interaction effect was the production of the average difference in predicted probabilities of hospitalization and the average difference in predicted counts of services between Medicaid and non-Medicaid babies. Bootstrapped standard errors of all marginal interaction effects were obtained based on 1,000 repetitions.

Investigate if the effects of CCO implementation on hospitalization differ between preterm and full-term babies

Next, models 8 and 9 were expanded to investigate if the effect of CCO implementation on admissions is different between preterm and full-term babies. A three-way interaction term was included in both parts of the hurdle model (Model 11 and Model 12):

Part 1:

$$[\boldsymbol{Pr}(\boldsymbol{Y_{ik}}=\mathbf{1})|\boldsymbol{post},\boldsymbol{cco},\boldsymbol{x'}] = \boldsymbol{g}(\boldsymbol{\beta_0}+\boldsymbol{\beta_1 post_k}+\boldsymbol{\beta_2 cco_i} + \boldsymbol{\beta_3}(\boldsymbol{post}\times\boldsymbol{cco})_{\boldsymbol{ik}} + \boldsymbol{\beta_4}(\boldsymbol{post}\times\boldsymbol{cco}\times\boldsymbol{preterm})_{\boldsymbol{ik}} + \boldsymbol{x'}_{\boldsymbol{i}}\boldsymbol{\beta}) \quad \mathbf{(11)}$$

where ***Y*** indicates if any inpatient service was used by individual ***i*** in CCO ***k***, and g is logit CDF.

Part 2:

$$\boldsymbol{ln}[\boldsymbol{E}(\boldsymbol{Y_{ik}}|\boldsymbol{Y_{ik}}>\mathbf{0})] = \boldsymbol{\beta_0}+\boldsymbol{\beta_1 post_k}+\boldsymbol{\beta_2 cco_i}+\boldsymbol{\beta_3}(\boldsymbol{post}\times\boldsymbol{cco})_{\boldsymbol{ik}} + \boldsymbol{\beta_4}\,(\boldsymbol{post}\times\boldsymbol{cco}\times\boldsymbol{preterm})_{\boldsymbol{ik}} + \boldsymbol{x'}_{\boldsymbol{i}}\boldsymbol{\beta}) \quad \mathbf{(12)}$$

where ***Y*** is the counts of admissions for individual ***i*** in CCO ***k***.

In models 11 and 12, the coefficient $\boldsymbol{\beta_3}$ of the interaction term between ***post*** and ***cco*** represents the effect of CCO implementation on the outcome among all infants enrolled in Medicaid, both preterm and full-term babies. The coefficient $\boldsymbol{\beta_4}$ of the three-way interaction terms of ***post***, ***cco,*** and ***preterm*** estimates the difference in the impacts of CCO implementation on outcome Y between preterm and full-term infants enrolled in Medicaid. Therefore, the sum of $\boldsymbol{\beta_3}$ and $\boldsymbol{\beta_4}$ will estimate the total effect of CCO implementation on preterm infants enrolled in Medicaid.

Investigate if the effects of CCO implementation on the hospital admissions change over the implementation timeline

Model 13 and Model 14 are 2 parts of the hurdle model examining if the impact of CCOs on hospital admission change over the CCO implementation timeline:

Part 1:

$$[Pr(Y_{ik} = 1)|post, cco\_matur, cco, x'] = g(\beta_0 + \beta_1 post_k + \beta_2 cco_i + \beta_3 (post \times cco \times cco\_matur)_{ik} + x'_i \beta) \quad (13)$$

where Y indicates if any inpatient service was used by individual i in CCO k, and g is logit CDF.

Part 2:

$$ln[E(Y_{ik}|Y_{ik} > 0)] = \beta_0 + \beta_1 post_k + \beta_2 cco_i + \beta_3 (post \times cco \times cco\_matur)_{ik} + x'_i \beta) \quad (14)$$

where Y is the counts of admissions for individual i in CCO k.

The variable ***cco_matur*** is a monthly time indicator for the length of CCO implementation, and the coefficient β_3 captures the average change in the outcome when ***cco_matur*** increased by 1 unit, i.e., for every month increase in the implementation timeline. The vector x' includes all covariates. Full marginal effects were also estimated by combining two parts of the hurdle models to estimate average change in predicted number of admissions for every month further in the CCO implementation timeline. Bootstrapped standard errors of all marginal effects were obtained based on 1,000 repetitions.

References

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