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All-Star or Benchwarmer? Relative Age, Cohort Size and Career Success in the NHL

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Abstract
We analyze the performance outcomes of National Hockey League (NHL) players over 18 seasons (1990-1991 to 2007-2008) as a function of the demographic conditions into which they were born. We have three main findings. First, larger birth cohorts substantially affect careers. A player born into a large birth cohort can expect an earnings loss of roughly 18 percent over the course of an average career as compared to a small birth cohort counterpart. The loss in earnings is driven chiefly by supply-side factors in the form of excess cohort competition and not quality differences since the performance of players (as measured by point totals for non-goalies) is actually significantly greater for players born into large birth cohorts. Performance-adjusted wage losses for those born in large birth cohorts are therefore greater than the raw estimates would suggest. Second, career effects differ by relative age. Those born in early calendar months (January to April) are more likely to make it into the NHL, but display significantly lower performance across all birth cohorts than later calendar births. In short, those in the top echelon of NHL achievement are drawn from fatter cohorts and later relative age categories, consistent with the need to be of greater relative talent in order to overcome significant early barriers (biases) in achievement. We find league expansions increase entry level salaries including the salaries of those born into larger birth cohorts, but they do not affect salaries of older players. Finally we find that the 2004-05 lockout appears to have muted the differentials in pay for large birth cohort players relative to their smaller birth cohort counterparts.

Key words: Cohort size; relative age; performance; productivity; wages; career; NHL
JEL codes: J1; J24; J31; J62

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1. Introduction

The magnitude of North America's baby-boom and subsequent baby-bust has been well-documented (Foot and Stoffman, 2001). Between 1957 and 1987 birth rates plunged in Canada from 28 live births per 1000 of the population to 14 births per 1000 of the population.[1] Research on the labour market effects of those born into historically large birth cohorts suggests this group experiences significant earnings losses over their careers, relative to their luckier counterparts born before or after a baby-boom (Freeman, 1979; Welch, 1979, Berger 1986, 1989; Bloom et al., 1987; Murphy et al., 1988; Wright, 1991; Bachman, Bauer and David, 2009). A question that surprisingly still remains unanswered is whether, and how, earnings differences across birth cohorts play out amongst professional athletes. This is an interesting question since athletic careers are quite easily mapped and because the limited opportunities available for entry into the professional leagues sets up a nice quasi-experiment in which supply of labour can be allowed to vary exogenously, through lagged birth rate fluctuations, while labour demand can be held more or less constant owing to the fixed number of teams in a monopolistically run professional sport setting. This particular feature of pro sport (i.e., strong barriers to entry) turns out to be rather important since a traditional problem in the cohort size literature is that birth rate cycles (the ultimate source of labour market cohort variation) are themselves endogenously determined by economic conditions. Birth rates also change gradually, which by the time a large birth cohort enters the labour market, there may be a derived labour demand side response which serves to offset cohort supply shocks associated with increased births several decades prior (Brunello, 2010; Morin, 2013).

Research also suggests that professional athletes, in particular, face another demographic determinant of career success; namely their *relative age*. For example in hockey, an early birth month (e.g., being born between January and April) has been found to correlate quite strongly and

[1] The baby boom (and subsequent bust) was felt more in Canada than in the US where birth rates climbed to 25.3 per 1000 of the population but fell only to 17 per 1000 of the population.

positively with the probability of playing in professional sports leagues; this despite the fact that most births occur later in the year.[2] It is natural to ask whether, and how, earnings differences across birth months might interact with fluctuating birth rate cycles in a professional sport setting where this may be rather important. What kinds of players (defensive or offensive) are most susceptible to the impacts of cohort size entry conditions? Does a player with a higher relative age (i.e., born in January) who typically has a greater chance of getting into a professional league have a similar advantage in earnings and performance?

Why might professional athletes be particularly sensitive to cohort size effects? As already mentioned, unlike most labour market settings, the positive demand-side effect of a larger birth-cohort (i.e., through potential market size expansion and hence increased derived demand for labour opportunities) is muted in professional leagues which maintain monopoly privileges. This means in practice that league expansion through new team entry – even in the face of substantially larger spectator demand -- is highly restricted.[3] In other words, the league's monopsony power can be maintained while potential labour supply increases, ultimately leading to lower entry salaries for large birth cohorts.

Another mechanism is that players born during periods of relatively high birth rates presumably face tougher competition in a variety of amateur settings prior to ever entering the race to become a pro-athlete. This would make pro-athletes born into fat cohorts of greater average quality than those born in smaller cohorts. Other things constant, this should affect earnings in a positive direction.

Ultimately, the question of whether players born into fatter cohorts outperform their

[2] The actual cut-off dates do vary. This early year bias is of course not true in all sports since it depends on varying school entry date decisions. For example in Britain there is a higher percentage of September to December births in professional soccer because entry conditions into youth sports leagues are tied to the beginning of the school year.

[3] There is the special case of competing league formation as occurred in hockey under the banner of the World Hockey Association (WHA) which acted as a competitor for player talent for nearly 10 years from 1971 to 1979. If one imagines a 20 year old entry age for the average hockey player this lines up almost perfectly with the height of the baby boom in North America, from 1951 to 1959. One could speculate that a supply-side push would allow a competing league to draw near equivalent talent. Once that baby-boom talent pool dries up and wages for marginal players begin to be bid up by rival leagues, the financial viability of the less established franchises in a league is likely to fade.

skinnier counterparts – in both performance and earnings outcomes -- is an empirical one.

Why might the performance of players depend on the relative age of the athlete? First, assuming selection into amateur athletics is conducted according to calendar year conditions[4], then those born relatively early (January to April) will face a distinct advantage over those born later (October to December) given the variation in physical and mental development that occurs up to a person's late teens/early twenties (Arnett, 2000). These differences could result in a differential opportunity to play with better teams and coaches, which could lead to better athletic career trajectories for early-born athletes. Relative age effects could also counter earnings losses that come from being born into a relatively large birth cohort since being born early could translate into a differential ability to upgrade from poor initial placements into minor leagues, owing to cohort crowding effects.

On the other hand, younger relative age players that make it into the professional leagues may benefit from the positive "peer effects" of playing alongside more mature teammates throughout their amateur careers. They may also have had to have been physically capable of keeping up with relatively older counterparts almost from the start of their amateur playing careers.

Does being later-born help players weather the large birth cohort effect? This is still an open question in the literature on relative age effects.

In this paper, we analyze the career outcomes of National Hockey League (NHL) players as a function of relative cohort size at year of birth and relative age (i.e., birth month). We combine information on earnings and player performance for NHL players between the 1990-91 and 2007-08 seasons. The data set also merges birth rate information by year of birth for players born across 10 major countries/regions that are present in the league. The data set yields coverage of multiple birth rate cycles both across time (the baby boom and bust and subsequent echo in North America)

[4] Those born during a calendar year January to December are included in the same pool of those eligible to play on the same teams. Despite the potential of playing alongside someone who had almost a full year more of maturation, these systems still prevail in most amateur settings.

and space (birth rate cycles differ across countries). We examine average earnings and performance for differing cohort size groupings - large (above average) versus small (below average) cohort sizes – based on birth rates at time and country of birth. We then identify several experiential phases in a playing career (i.e., rookie, prime age prior and post free-agency and a veteran stage) and estimate impacts of being born in years with higher than average birth rates, across these experience groupings, for a range of performance outcomes over the length of a playing career.

We address four main questions. First, what is the effect on career performance of being born into a relatively large birth cohort for the average professional hockey player? Second, what is the effect of relative age on the earnings and performance of players in the NHL? Third, how does the effect of cohort size vary by relative age? Fourth, how do the answers to these questions change following the six league expansions (1991-92, 92-93, 93-94, 98-99, 99-00, and 00-01) that occurred in our sample period and after the 2004-05 lockout, which cancelled an entire season of play and imposed the first ever team cap on player salaries?

This paper proceeds as follows. We discuss relevant literature and present a simple framework to guide our analysis in section 2. In section 3 we introduce our data before describing the methodology. Section 4 presents our core results on earnings, performance, and career attainment for the average player and discusses how these results differ for players by birth cohort and also by relative age. Section 5 examines differential effects of being born into a large cohort by relative age. Section 6 examines the effect of league expansions (positive labour demand shocks) and the 2004-05 season-ending lockouts on our previous results. Section 7 concludes.

2. Birth Cohort Size, Relative Age Effects and NHL Player Performance

2.1 Cohort Size and Player Outcomes

There are several reasons why we might expect the size of a cohort to affect labour market outcomes for NHL players.

The first explanation is Easterlin's hypothesis. Easterlin (1987) in *Birth and Fortune* argues that the relative size of a cohort can affect individuals' economic and social outcomes including earnings, unemployment, college enrollment, divorce and marriage, fertility, crime and suicide. Because cohort size determines the amount of competition for job slots (slots that are assumed to be fixed in the short run and/or lagged in relation to cohort entry) this will feed through to a number of outcomes such as family formation. A recent study of marriage rates in the US over the period 1910-2011 found an increase in cohort size generated a decline in marriage rates and that a reduction in cohort size has the opposite effect, thus confirming Easterlin's hypothesis. Exploiting exogenous variation in birth rates caused by the staggered diffusion of the birth-control-pill across states, the effect of cohort size on marriage patterns is found to be causal. [5]

The second idea that cohort size matters is derived from Welch's (1979) classic paper of the effect of cohort size on earnings, which is more direct than Easterlin's and relies on an adaption of Rosen's optimal life-cycle model.[6] In keeping with this model, we believe the way cohort size affects NHL earnings follows from the notion that player careers consist of three distinct phases.

A new entrant into the NHL arrives fresh from the minor leagues and enters his profession as an "apprentice" or "rookie" who learns from his more senior players and coaches. Only rarely - if the player is a superstar or enters the NHL having played in foreign professional leagues - will he immediately become a full-fledged senior member of the team taking on tasks such as penalty killing that are normally assigned more senior players. Having entered as a rookie, the player gains skills and reaches his *prime* before his performance and learning plateau at which point (after all learning is complete) he achieves *veteran* status in the league.

Just how many career phases there are does not really matter. What does matter is that at

[5] Initially, only indirect evidence in support of the Easterlin hypothesis was advanced and other researchers that attempted to test the general idea behind it found mixed results (Pampel and Peters, 1995).

[6] Freeman (1979) published a very similar paper almost simultaneous to the one published by Welch (1979) but it did not include the model provided above.

each stage players have different skills and, in terms of overall team production, these skills are not perfect substitutes. Each activity is productive and marginal productivities are determined, as for any factor, by numbers of players engaged in these activities. In this view, the NHL is an ordered series of player types/phases/stages (*rookie*, *prime*, and *veteran*) such that at any moment in their career, a member of the NHL is in transit between two of these types and can be viewed as a (convex) combination of them.

As noted by Welch (1979) this view is essentially identical to Rosen's (1972) optimal life-cycle model in which a career consists of a continuum of occupations and a worker solves for an optimal occupational sequence by recognizing that each occupation corresponds to learning options that affect performance in subsequent occupations. Rosen allowed productivity in each occupation to depend on number of workers in that and other occupations, and it is clear that had he considered cohort size, the theory would have predicted that earnings are negatively correlated with cohort size.

To highlight effects of cohort size, we abstract from questions of optimal rates of progression or transit between career phases, and take them as exogenous. We also abstract from depreciation or skill obsolescence which could, nevertheless, be important if the skills possessed on NHL entry are more conducive to learning about the game (think of the minor leagues or first year in the professional league as learning to play in the NHL) and are depleted as the career progresses, with human capital acquisition focusing on more directly productive on-ice activities. As such, progression is toward higher realized earnings for a given player.

If players substitute perfectly for each other, regardless of experience, the structure of earnings would be independent of cohort size such that the only feasible interpretation of career-earnings-cycle profiles would be one of purely physical aging. The life-cycle investment view, however, argues that age profiles are products of learning and depreciation and therefore suggest that players at different stages of their career do different things for their teams. If so, then the value of each “thing” a player does at each stage or phase of a career would reasonably depend on the number of players potentially doing it, and so cohort size matters and should be inversely related to earnings.

A graphical illustration of this model is provided in Figure 1where the difference between the normal earnings profile for an NHL player and that for a player from an illustratively large birth cohort is always negative. In this example, new players are exclusively *rookies* who are learning the “game” (abstracting from the rare cases of superstar talents and more experienced free agents entering the league from other professional leagues) and hence $p=1$, where $p(x)$ is the fraction of time at” x” experience spent learning the game. At point of entry players not only draw all their earnings as rookie learners, but have the greatest depressing effect on fellow rookie earnings because of their lack of substitutability with prime and veteran player tasks. As experience accrues, a player transits to the prime-age phase, drawing an increasingly larger share of earnings which, for large birth cohort individuals, are being depressed by the large number of competitor players in the same large birth cohort. Earnings grow for large-cohort and average-cohort players as p falls in the early career phase. After the inflexion point the depressant effect of older age on player productivity dominates and earnings growth slows. Finally at the point indicated as $p = 0$ in figure 1, when the player has no longer any learning left and instead is fully vested in veteran status, the process is completed. Thereafter, earnings are depressed and the extent of the depression remains constant until retirement.

Several points deserve note. Effects of increased cohort size are inversely proportional to the elasticity of substitution. The substitution elasticity indexes veteran-rookie differences in the nature of roles performed on a team. It is typical for prime-age players to play on specials teams (i.e., appear during penalty killing or power play opportunities) and for veterans to be on the ice in crucial moments of the game. For this reason we feel this aspect of the model to be plausible in the context of the NHL. If, however, a team or coach designs a system of play so that players are more interchangeable, then regardless of career stage/phase, greater similarity of activities implies greater substitutability. It is likely that the substitution elasticity is also related to the transition function, *p(x).* Rapid transition from learning (rookie) to prime-age playing status implies that rookies can easily adapt to prime-age tasks. We expect that when transition occurs easily, prime-age versus rookie player tasks are more similar, that is, prime-age players and rookies are better substitutes. [7]

This model can be used to explain wage profiles but, in the context of a fixed demand for player talent, it can also be used to explain why average player quality would be expected to be higher amongst those individuals born into large cohorts. This is because those players face tougher competition in a variety of amateur settings prior to ever entering the race to become a pro-athlete. Moreover, because the best amateur talent feeds into an essentially static number of professional league openings -- owing to the monopoly privileges of the National Hockey League -- a large cohort combined with a fixed number of slots makes the lump of labour problem operative (as opposed to fallacious) This would make pro-athletes born into unusually large cohorts of greater absolute average quality than those born during smaller cohort years. Other things constant, this should affect absolute performance in a positive direction.

Another consideration is that higher ability players born into fat cohorts could also potentially recover from any early earnings setbacks through free-agency job movement, which kicks in after 7 years in the league, though perhaps more gradually for large cohorts in the face of fewer vacancies per player.[8] This is illustrated in Figure 2, where after 7 years' experience – the

[7] This leads immediately to predictions across relative age (birth month) in terms of differences in prime-age versus rookie substitution elasticities (discussed in more detail in section 2.2 below).
[8] The history of unrestricted free agency (UFA) in the NHL begins in 1995, the first year in which the UFA market came into being. From 1995 to 2004 unrestricted free agency usually began at age 31, given that a 10 year experience

typical free agency period in the NHL-- a jump in the wage profile for both large and small birth cohort occurs. The large cohort earnings profile jumps higher because presumably this would be a chance for all teams to bid on what is relatively a better quality player. This prime-aged post-free agency period may therefore lead to some catch-up in earnings for the better than average (high birth cohort) player but the question of whether lifetime earnings equalize (i.e., whether the area under *b* is greater than *a*) as a result of free-agency is dependent on length of contracts signed and also on ultimate career length in the league.

Finally, one should note that a poor early earnings start for large birth cohort players, possibly also including longer spells spent in minor-leagues or playing for lower ranked teams, could expose these players to lower quality coaching and salary opportunities, resulting in a lasting disadvantage. Ultimately, owing to the competing performance predictions and possibilities for earnings catch-up through free-agency, the question of whether players born into larger cohorts outperform their smaller cohort counterparts – in both performance and earnings outcomes -- is an empirical one.

2.2 Relative Age and Player Outcomes

The literature on relative age and NHL player success goes back to the work of Canadian psychologist Roger Barnsley who in 1985 published one of the first studies to note the effect of relative age in a professional sport setting (Barnsley et al., 1985).[9] His work showing that being

requirement was imposed with a minimum age of 31. Following the season-ending lockout of 2004-05, a new collective bargaining agreement with a salary cap was implemented, resulting in a gradual lowering of the eligibility age for UFA status from 30 to 27, and the proviso that if a player completed seven full NHL seasons, he would be free-agent eligible prior to age 27 or whichever came first. See:.http://spectorshockey.net/blog/is-the-era-of-building-through-unrestricted-free-agency-over/

[9] One year earlier a study by Grondin et al., (1984) more or less conforming to the same findings as Barnsley et al.,

born earlier in the year (January to April) resulted in a significantly increased probability of succeeding in all ranks of Canadian hockey, was popularized in the 2008 best-selling book *Outliers: The Story of Success* by Malcolm Gladwell who used these findings and those of others in the field of educational returns to show how seemingly arbitrary eligibility rules – like grouping all individual players by calendar year beginning on January 1st and ending on December 31st -- could be important in the future success of individuals.

The argument that early birth dates affect athletic success is a simple one based on the sociological idea of "accumulative advantage" or what economists might label "path dependence". Initial small advantages based, in this case, on relatively greater physical and mental maturity in formative ages for those born early in the year (January to April) as compared to those born late (September to December) build up when coaches spend additional time mentoring the better initial performers. When those initial better performers are further grouped together and are given chances to play alongside other good performers, the performance of the entire early-born group begins to rise and distances itself even further from the later born group not given these added investments and opportunities. By the time selection into a professional hockey league is possible (late teens) many talented later born players will never have had the chance to compete let alone be eligible for the NHL draft.

There is now a large body of work – located mostly in the sports science and kinesiology literature -- showing the relative age effect (RAE) in sport is real and quite widespread. In a 2001 literature review, nearly 30 studies were surveyed covering 11 sports and the consensus was pretty clear: the relative age effect exists across countries and in most professional sports (Musch and Grodin, 2001). Since then an equal if not greater number of papers have emerged showing, in various forms, the same thing (see Deaner Lowen and Cobley, 2013 and citations cited therein).

Empirically, however, any claim that cutoff dates in youth leagues is the only factor underlying the skewed birthdate distributions in professional leagues must be defended against

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(1985) was published in French and as a result is often neglected by popular English language writers in this field.

possible alternative explanations; such as a skewed distribution of births already present in the non-sport population. For hockey we know this is not the case as taking Canadian births as a representative sample, we see that a comparison of the monthly birthdate distribution for the NHL playing population diverges quite drastically from the general population (see Figure 3). The fewest births in Canada actually occur between January and February, which are the most prevalent birth months in the NHL.

Further validation of the cutoff date hypothesis has been obtained by observing the consequences of an externally imposed change in eligibility rules in Australia's youth soccer system, whereby the traditional cutoff date of January 1st was replaced by a new cutoff date of August 1st in 1988 owing to a request by FIFA. Musch and Hay (1999) found a corresponding shift in the birth distribution of Australian professional players ten years after the change, providing strong evidence that the cutoff date generates the RAE effect.

In summary, chronological age differences are certainly related to discrepancies in both physical and psychological maturity. For example, in terms of weight and height individual variability is at its maximum between 13 and 15 years of age for boys (Musch and Groding, 2001: 155). This is the age-range when players are often selected for college scholarships or junior hockey play (the two most typical feeder systems into the NHL). It therefore seems plausible that a relative age disadvantage can make it harder for an early born player to compete.

If we assume that there is a similar distribution of latent/true talent for both late and early born players, then it is likely that a greater number of below average quality players from the 'early-born' ranks make it into the league simply because their maturity is masking their true (below average) talent. In contrast, late born players who overcome the drawbacks of physical and psychological immaturity to enter the ranks of professional hockey are likely to be drawn from the higher part of the ability distribution. We should therefore expect the performance of those with later birth months, conditional on NHL entry, to be greater on average than those with early-year births since the NHL is selecting on observed performance of teenagers whose performance may be due to an 11 month gap in maturation.

This idea that the physical/psychological maturity advantage of children born in January can mask the true ability differences of an early (December) born player is illustrated in Figure 4. The figure shows that a high ability player born in December and a lower than average ability player born in January will essentially have the same "observed" performance. In other words, an underlying high-ability December born player will appear, at the time of selection into the NHL, exactly the same as an average-to-below average January born player simply because of the 11-month maturity gap. This similarity in performance is misattributed to underlying talent, although the child born in January has an 11-month age advantage over the child born in December. This later-born disadvantage is magnified even further in the teenage years where deviations from the mean physical development are largest. We therefore expect that owing to this selection pressure, any later born entrant into the NHL will be of better than average quality than early born counterparts.

Some evidence for this has already been found by Gibbs, Jarvis & Dufur (2012) who examined the distribution of birth months for 1,109 players who played on major league rosters from 2000-2009 and All-Star and Olympic hockey rosters from 2002-2010. Their findings illustrate "…how critical it is to define hockey success. When hockey success is defined as playing Major Junior Hockey, the [RAE] effect is strong, as Gladwell reported in the popular press. But the effect diminishes when ….performance and skill are considered. When hockey success is defined as the most elite levels of play, the relative age effect reverses [i.e., later born players outperform their early born counterparts].” Gibbs et al (2012) only compare means and do not control for individual confounders such as country and team effects; as such, empirically we feel the jury is still out.

3. Data and Methods

3.1 Data Sources and Sample

In order to estimate single season and career effects of cohort size at birth and relative age on the outcomes of NHL hockey players, with coverage over several league expansions and a season-ending lock-out, we draw from multiple online data sources, all of which are listed in Appendix 1.

We restrict attention to those players for whom salary data was available, to non-goalies and, in order to limit the pool of players that can be observed only once in a given season, to players who were not traded during the course of a given season. The pooled data therefore contains every player (exclusive of the restrictions mentioned above) who played in the NHL between the 1990-91 and 2007-08 seasons. This gives us an unbalanced panel (before missing variables in various specifications) of player-season observations 8,996 and 2,037 individual players.

To provide a sense of sample coverage, Appendix Tables 1 and 2 present the number of observations in the panel by categorical versions of our two key explanatory variables – relative age (birth month) and cohort size – measured against years in the league (hereafter denoted as *experience*). In both cases we have substantial sample sizes at the low and mid-levels of experience but not at the upper end. This is because the average career length in our sample is 4.5 seasons even though the upper range is 17 seasons in the league. This feature of our data leads us to truncate the experience measure and pool all those players with more than 10 seasons of play in the league into a common category called *10 plus*. Since the size of the league (as measured by teams) varies over time, we will also report how the effects on earnings of birth cohort size differ for players in seasons following a league expansion.

In table 1, we report summary statistics. The table summarizes variables for those players for whom we have earnings in our sample. Average annual earnings in our data are about $1,330,707 in constant USD 2008 dollars. The average number of seasons in the league is 4.5 and the modal season of an earnings observation is 1998-99 season. As noted above, the pooled sample yields substantial variation in country birth rates ranging from 11 to 28.1 per 1,000 of the population. The two most prevalent birth months in the NHL are January and February. By contrast, as we have seen, seasonality of fertility in the population as a whole is skewed towards the spring to early fall. This confirms that the relative age of NHL players is much higher than the population as a whole.

3.2 Regression Specifications

There are three major estimation equations that we use to answer our major questions in the paper. To estimate the main effect of birth cohort size on the earnings and performance outcomes of NHL players, we use the following specification.

$$\text{(1a)} \quad Y_{it} = B_1 X_{it} + B_2 LargeCohortSize_c + \lambda\, Team + e_{it}$$

In equation (1a), Y_{it} is the outcome (either earnings or point totals) measured for season *t*, for an individual player *i*, in birth cohort country *c* (year), and X_{it} is a set of control variables.[10] We also control for team fixed effects (λ *Team*). $LargeCohortSize_c$ is a birth cohort dummy, defined as an above average crude birth rate in the country origin at the year of birth for the player *i*. The

[10] The controls included in *Xit* are *ExperienceCat* as a direct effect, non-goalie forward positional dummy (defensemen as excluded category) a bmi indicator (weight/height) and country of origin dummies.

coefficient B_2 on $LargeCohortSize_c$ measures the impact of an above average birth cohort size (based on our sample of NHL players) on career outcomes for the average player.

To measure how this impact varies across a career, we interact birth cohort size *LargeCohortSize* with our experience measure $ExperienceCat_{it}$ in equation (1b). We measure *ExperienceCat it* as a categorical variable capturing 4 career phases upon entrance to the league -- *rookie* <3yrs, *prime pre-free-agency* 4-6yrs, *prime post-free-agency* 7-9 yrs and *veteran* 10pls yrs -- rather than actual number of games, which could be endogenously related to seasons shortened by league stoppages observed in our data. Results are robust to including a linear experience interaction and allowing these to interact with $LargeCohortSize_c$.

(1b) $Yit = B_1X_{it} + B_2LargeCohortSize_c \bullet ExperienceCat_{it} + B_3\ ExperienceCat_{it} + \lambda\ Team + e_{it}$

To estimate the effect of relative age we estimate a second version of (1a,1b) simply replacing birth cohort with birth month (*BirthMonth)* as below:

(2a) $Yit = B_1X_{it} + B_2BirthMonth_c + \lambda\ Team + e_{ict}$.

(2b) $Yit = B_1X_{it} + B_2BirthMonth_c \bullet ExperienceCat_{it} + B_3\ ExperienceCat_{it} + \lambda\ Team + e_{ict}$.

Finally we add a fourth estimated parameter to (1), B_4

(3) $Yit = B_1X_{it} + B_2LargeCohort\ Size\ C_c + B_3LargeCohort\ Size_c \bullet ExperienceCat_{it} + B_4\ Cohort\ Size \bullet BirthMonth_{it+},\lambda\ Team + e_{ict,}$,

which measures the differential impact of birth cohort size across relative age ($LargeCohortSize_c \bullet BirthMonth_{it}$).

For all specifications listed we estimate the differential impact of multiple league expansions and pre versus post-2004-05 lockout using sub-sample analysis.

5. Results

5.1 Birth Cohort Size and Player Salaries

We begin with visual evidence of the evolution of player salaries. Figure 5 presents log annual compensation in constant 2008 dollars amongst NHL players for seasons 1990-91 through to 2007-08. The raw sample is split by those players born into higher and lower than average birth cohorts (i.e., those born when birth rates were above the mean value in our data, which is 17.35 per 1000 of the population, were coded as High Birth Cohorts and those below were tagged Below Average Birth Cohort). Figure 5 also plots the difference in Log Salary between the two groups. Also highlighted in the figure is the typical window for player free agency, which happens after a player has either played 7 seasons in the league or has reached the age of 27 (whichever is first).

The pattern of data is consistent with our hypothesized career earnings path in Figure 2 for normal and high birth rate player cohorts in the presence of free-agency. We see that there is an overall penalty to being born into a large birth cohort of about 12 percent. This is amplified in the early stages ("rookie" phase) of the career as was suggested by our NHL player earnings model. Then, as anticipated, given an ability to renegotiate contracts with any team, a player from a larger birth cohort can translate their higher than average performance into a higher salary in the free agency window. However, this effect is not large enough to offset the negative impact of being born into a larger birth cohort because free-agency comes relatively late in an NHL career which, on average, only last 4.5 seasons.

We now turn to estimating the average effect of being born into an above average birth cohort for all non-goalies in our sample. Table 2 reports estimates from variants of our base specification in equation (1). The controls include a body-mass ratio, a dummy for whether the player is a forward (defenders being the excluded reference category), and country of origin. We also consider specifications where no controls other than individual points are included (our proxy for observed player ability) in order to see if the effect matches our prediction that adjusting for quality, any large birth cohort earnings losses would be expected to rise in the presence of a player quality control.

The initial parameter of interest is the Large Birth Cohort dummy. Column (1) includes no controls and estimates the panel with a random effects model in which standard errors are clustered on team. The estimated difference in log salary between a Large and Small Birth Cohort player is -0.197. The estimates and significance are largely unaltered when we add a player performance control (column 2) -- if anything the negative effect of being born into a large cohort becomes slightly larger in keeping with our hypothesis that large cohorts should produce better than average quality players – other controls are added (column 3) and when team fixed effects are added (column 4). The estimated large birth cohort effect in the full specification with all controls including player performance and team dummies is a 17.9 percent reduction in log earnings.

The primary birth cohort size variable in row 1 is estimating the effect over the average career length, which in our data is roughly 4.5 seasons. However, given the hypothetical earnings profile from our player experience model and the actual raw data seen in Figure 5, there is strong reason to suspect that the cohort effect varies by stage of career. We therefore estimate specification (1b) which disaggregates the cohort effect by years in the league. We highlight four phases: rookie (<3yrs), pre-free agency prime age (4to6yrs), free agency prime age (7to9yrs), and veteran status (10yrs plus). Each phase is included in the specification as well as the four interaction terms arising from *LargeBirthCohort*ExpereinceCat*. We include these results in row 2 where we see that after adjusting for player quality and other characteristics, there is indeed a differential negative effect that is larger upon entry into the league, narrows considerably in midcareer during the free agency window, and then widens once again in veteran status (columns 2-3). This pattern is almost unchanged with team fixed effects added (column 4). The overall cohort size dummy and the estimates by cohort size interacted with career stage suggest that large birth cohorts do put downward pressure on player wages. This is true despite the fact that hockey ability appears to be higher amongst large birth cohort players, given the larger negative effects seen in column (2) when player performance was controlled for. To see this more clearly we next turn to our player performance estimates.

5.2 Birth Cohort Size and Player Performance

A possible concern in interpreting the estimates in Table 2 is that the effects of cohort size might be biased by cohort size effects on player performance. So rather than estimating the effect of large cohort pressure on salaries we are seeing the residual effect of some systematic player performance that matches the salary data. Given that when individual performance was controlled for in Table 2 the negative values for our large birth cohort dummy actually went up, suggests that large birth cohort players are actually better. Nevertheless there is the possibility that coming of age in a large cohort may lead to a lower likelihood of getting drafted and thus playing for more years in inferior leagues, thus degrading skills.

To test if this is indeed the case, or whether the ability of large cohort players is greater because of added competition throughout a playing career, we use a similar estimating model to that employed in Table 2, only this time the dependent variable used is *season point totals* instead of salary.[11] The results can be seen in Table 3, row 1 where we see that the point estimate of a Large Birth Cohort relative to a Small Birth Cohort varies from 5.21 more (or 20 percent higher point totals relative to the mean of 25 points) in the unadjusted estimates to 1.89 (or just under 10 percent higher) when full controls and fixed team effects are added. The big drop in the coefficient occurs after games played is controlled for (see row 1 Column 1 versus Column 2

[11] Total games played is used as an explanatory variable, replacing player performance used in Table 2.

estimates). The coefficient remains stable thereafter suggesting that large birth cohort players are actually playing more games per season than small birth cohort players. When we checked to see if this is in fact the case, it turns out that the difference is non-trivial and significant. On average large birth cohort players play 52 games per season versus 46 games for small birth cohort counterparts, a difference of 6 games that is significant at the 1 percent level (p=.000). One interpretation of this finding is that games played per season is capturing yet another dimension of higher player quality (i.e., durability or 'stick-to-it-ness' required to compete in a larger talent pool) that larger birth cohorts possess relative to their smaller cohorts.

When we examine the large birth cohort effect by career stage, essentially replacing our single dummy with four large birth cohort dummies interacted with seasons in the league we find that the positive effect on point totals is confined to the early stage of the career. In fact, for veteran players it appears that small birth cohort size is associated with greater point totals, reversing the trend early in the career. However these estimates need to be taken in context. The majority of players do not reach 10 or even 6 years in the league. As seen in Table 1 row 12, just over half the NHL sample (53 percent) play only 3 seasons or less in the league and this rises to 75 percent when the player sample is on the cusp of free agency at 7 years in the league. In short, given that the clear majority of NHL players spend less than 7 years in the league, the estimated point totals are in accordance with the view that large birth cohorts are, on average, of higher quality than their small birth cohort counterparts.

As a further check Table 4 replaces individual point totals with a players' plus/minus record (this is the net point difference based on whether a player was on the ice when a goal was scored for or against) for each player. The results confirm the view that NHL players born when there is more competition in the form of a larger birth cohort tend to be better on average than those born in smaller (less competitive) birth years. The effects relative to the mean plus-minus value of 1.54 are even more impressive than the point totals. Even after adjusting for the full set of characteristics and team effects, there is a near doubling of the overall plus/minus record (2.24) amongst those players born into above average birth cohorts relative to small birth cohort players. This time as well the effect, though it varies across career stage, is always positive.

5.3 Added Checks

Further evidence on the possible channels associated with these large and significant salary losses and performance gains comes from Table 5 where we examine the likelihood that a player born into a larger-than-average cohort is drafted into the NHL or becomes a team captain. Essentially most players enter the league via the draft.[12] In the NHL it is particularly large (300 players) and deep in that there are 12 rounds of drafting. If not drafted a player must often play in lower level professional leagues for some time before getting noticed by major league teams. This could perhaps be one mechanism that accounts for the low entry stage (rookie) salaries amongst large birth cohort players. Using only the relevant covariates from the previous analysis –we use characteristics (such as body/mass indicator, country of origin and forward dummy) that would have been visible to the team at the time of draft -- we find that there is a 9 percentage point reduction in the probability of being drafted for players born into larger than average birth cohorts (Table 5 column 2).

When we explore intangible quality or hard-to-observe aspects of a player such as potential leadership skills (Table 5 columns 3 and 4), we find that there is indeed evidence of a large birth cohort effect. Becoming a captain of a team in the NHL is a rare event, only 4 percent of the sample ever goes on to become a team captain (there is typically only 1 captain on a team and the average roster on an NHL team is 20 players), yet even after adjusting for player characteristics, a large cohort player is nearly 90 percent more likely (3.5 percentage points higher relative to the mean probability of 4 percent) to become a team captain than lower-than-average birth cohort

[12] The draft is an annual meeting in which every franchise of the NHL selects players (in ascending order based on past season performance) from the amateur leagues where they meet draft eligibility requirements.

players. This last finding is perhaps not surprising since we anticipate a likely correlation in observed quality to map over into these less visible attributes of player performance.

6. Relative Age (Birth Month) and Player Outcomes

Models of relative age tend to focus on the probability of entry into the NHL, which is higher for early-born players, in keeping with our earlier theoretical discussion. Instead, we focus here on the prediction that, *conditional on being good enough to enter the NHL*, your overall ability (and hence performance) should be greater the lower your relative age. In other words players born later in the calendar year should display better performance than their earlier-born counterparts because those players are being selected from the top tail of ability whereas those born earlier in the year include both top and mid-to-bottom tail performers (see Figure 4). This owes simply to the 11 month advantage (at the maximum) that a January born youth has over December born equivalents.

Table 6 reports earnings estimates for the relative age variable (a dummy that takes on the value 1 if a player is born between January and April and 0 otherwise) using a specification identical to the one used in Table 2. We find those who are born later in their cohort suffer a wage penalty of around 3 percent, but this salary gap widens over the course of the career. This is perhaps reflective of the true ability of an early-born player becoming less noisily visible to teams and coaches. The more time they have to observe an early born player, the less any initial physical or mental advantage becomes relative to their later-born counterparts. Since player free-agency (after 7 years) is often the time when early contracts get renegotiated, this could explain the large negative hit that January-to-April born players take in their late prime and veteran careers in columns 1 through 4.

A more interesting and theoretically consistent set of findings appear in Tables 7 and 8 where point totals and plus/minus records are significantly and consistently lower amongst players with higher relative age (birth months falling between January and April) than amongst those born in May to December. Players born in the early part of the year are drafted on the basis of a potential 11 month calendar advantage in physical and mental development which likely masks a true ability distribution that is drawn from the middle and lower tails. The widening in the point losses the longer a January-to-April born plays in the league may reflect the effects of true underlying quality coming to the fore over time.

Yet in Table 9 column 2 we see that NHL teams are indeed biased in favour of early-birth month players given that the probability of being drafted is 3 percent higher (2.4 percentage points relative to a mean of 78.7 percent). Once again, this ‘initial’ advantage is not seen in a later-stage career outcome such as being awarded the team captaincy. Here we see that (column 4) a player born between January and April has a 12 percent reduced chance (0.5 percentage points less likely to be named a captain relative to the 4 percent chance observed in the data).

These findings suggest that a higher relative age (being born early in the calendar year), gives players of average or below average quality a greater chance of being drafted and making it into the NHL. But it does not lead to higher earnings and is associated with significantly lower performance that widens as careers progress from rookie to veteran status in the league. Indeed there seems to be a significant realignment of salaries downwards after early born players reach free-agency, perhaps compensating a team for their noisy signal of quality at an earlier age.

6.1 Does Relative Age (Birth Month) Moderate the Effect of Large Birth Cohort Size?

Next we investigate if downward earnings adjustments owing to large birth cohort size effects are moderated by relative age. If those advantages, already detailed in the text, that come from being born early in the year insulate a January-born player more than one born in December, we should see a smaller negative earnings coefficient on the Large Birth Cohort dummy for player with lower relative ages.

Table 10 runs the same earnings estimation as was used in Table 2 row 1 column 4, only this time separately by relative age categories, in order to see if there is any differential cohort size effect. The table shows that the earnings losses from being born into a large birth cohort are 10 percentage points lower for those born in January to April than they are for those born in September to December final column). This means that although an early birth month player still suffers a salary loss if born during a baby-boom birth year, the majority of the overall negative large birth cohort effect is coming from the 'youngest' calendar year months (i.e., those born May to August and September to December).

7. Do Results Differ During League Expansions and in the Post-Lockout Era?

Finally in Table 11 we look at how planned league expansions, which exogenously raise the demand for hockey talent as well as the 2004-05 lockout which imposed the first ever salary cap in the NHL, might have affected salaries for large birth cohort players.

First we divide the sample into the pre and post season-ending lockout periods, 1990-91 to 2003-04 seasons and the 2005-06 to 2007-08 seasons respectively. Figure 6 charts the evolution of average player salaries over this entire period and we see that the 2004-05 lockout does indeed produce a reduction in levels of pay but crucially no abatement in the growth trajectory. Collapsing the data into these two periods we then estimate our standard panel data earnings regressions, with full controls, found in column 4 of Table 2. Table 11 columns 1 and 2 show that the lockout served to recalibrate earnings towards large birth cohort players relative to small birth cohort players. There is likely a simple reason for this. In the post lockout aftermath there was a substantial lowering in overall pay levels and in the dispersion of pay. Top salaries were effectively constrained (at least in the three seasons we observed following the lockout) and this is where some of the players facing lower competition due to small birth cohort sizes, were forced to renegotiate salaries with team owners alongside better quality higher birth rate counterparts.

Table 11 also reports the difference between NHL earnings during seasons in which there were league expansions (6 in total) as compared to seasons in which there none. Based on a labour demand curve which is shifting outward with each league expansion, we would expect any potential negative effects owing to competitive crowding and/or lower bargaining power for players born into large birth cohorts to be positively moderated. This is borne out for the average large birth cohort player who receives an 8.8 percent earnings premium if playing in the league during an expansion. For early-career players (less than 3 years in the league) born into large birth cohorts, a league expansion turns into a whopping 45 percent premium. This positive league expansion effect does not seem to carry over into late-stage and veteran salaries: if anything they suffer relatively more perhaps because they are locked into longer term contracts and are not in a position to negotiate freely at such an advantageous time whereas a new entrant into the league is.

7. Conclusions

Consistent with the previous literature looking at general labour market outcomes, we find that professional hockey players born in times of higher birth rates suffer significant earnings losses relative to those born into smaller birth cohorts. Earnings are roughly 22% lower in the first three seasons for a player born in a higher than average birth rate cohort (>17.35), which is a level much lower than that seen at the height of the largest baby boomers in our sample. This effect persists but narrows from years 4 to 6 and then achieves parity in 7-9 years (the typical free agency window). But this catch-up period is not sufficient to make up for the earnings losses over the average span of a career of 4.5 years which is 18 percent.

We then examine the channels through which unusually large birth cohorts could potentially affect career outcomes, focusing on career length (games played), performance (point totals for non-goalies) and potential league expansions that occurred post most baby-boom entry into the league. We find that the earnings losses amongst large birth cohorts are accounted for by a combination of reductions in games played and league expansions that improved the bargaining power of player entrants born in years with relatively small birth cohort sizes. As our theoretical intuition would suggest, we find no effect due to lower performance of large birth-cohort players: if anything the opposite was true in that performance was on average higher for players born during these above average birth cohort years.

The answer to our second question runs counter to the thrust of a majority of the literature in this area pointing to significant advantages accruing to higher relative age. Whilst our data clearly confirms a higher prevalence of early birth month players in the NHL (far higher than the probability of being born in the general population) the career performance of these players is in fact significantly worse than later-birth month players. Though January-to-April born players have about a 2 percentage-point salary advantage in the first part of their career, this effect does not persist past the free agency years, when there is in fact a significant negative relationship between earlier relative age and earnings of 9 percent. Moreover, relative age is inversely related to point totals for non-goalies and career length as measured by total games played. Beyond this, the probability of captaincy in a team is also inversely related to relative age. A player born in the latter half of the year (from July to December) is 5 percentage points more likely to be a team captain than a player born in the first half (from January to June).

The fact that later born players outperform their early born counterparts is consistent with a number of theories that have been advanced in different contexts such as schooling and educational attainment. Selection into the NHL for those born in younger relative age categories is considerably harder given that these players have had to compete against more physically and mentally mature early born counterparts. Since most hockey players are born in jurisdictions where amateur team play is governed by calendar year births, those with initial physical and mental advantages are given preferential attention and opportunities. If a younger player can not only overcome these initial disadvantages but perhaps gain from having performed alongside more capable peers, then they should be expected to outperform the average player, who is typically drawn from older relative age categories (i.e., born between January and April).

Somewhat surprisingly, given the above findings, we find that those players with higher relative age (born in the first quarter of the calendar year) are relatively sheltered from the negative effects of greater cohort competition. A player that is born early (January to April) experiences significantly lower earnings losses than a player that is born late in the year (September to December) even if both were born in large birth cohorts. This means that players with greater relative age increase their chances of getting into the NHL and also have a slight advantage if born into a large birth cohort over their later born (younger) counterparts.

The final set of results concerns the multiple league expansions that occurred during our sample period and after the 2004-05-season-ending-lockout. First we find that league expansions are significant predictors of earnings differentials and growth for players. Moreover, these exogenous shifts in demand for player talent benefit early career players (but not veterans) born into larger birth cohorts as one might come to expect, given the opportunity to capitalize in a new negotiation with a new team based on a higher performance record for the average player. Second, we present evidence that the imposition of the first ever salary cap on teams -- which would presumably have slowed earnings growth and perhaps muted any differentials noted above – produced a reversal in the sign of the negative association with the large cohort pre-lockout period. We do not think that these changes are associated with an exogenous increase in the underlying demand for professional players since league size remained constant during this period. This may instead be due in part to the decrease in higher birth rate cohorts relative to the average major, although this is probably only part of the story. Therefore, it appears that the lockout was less of an issue overall for all players regardless of birth cohort and relative age, than we would have expected given the salary cap and other concessions players made to ownership in an effort to restrain salaries and ostensibly to improve competitive balance in the league.

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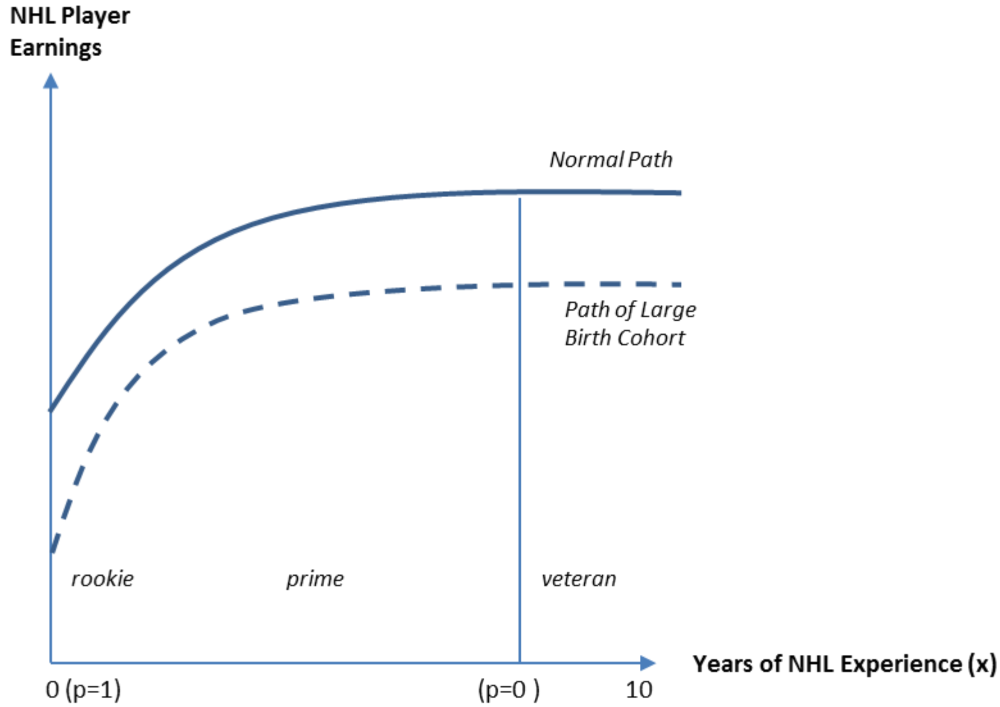

Figure 1: Hypothetical contrast between career earnings paths of NHL players from normal and unusually large birth cohorts.

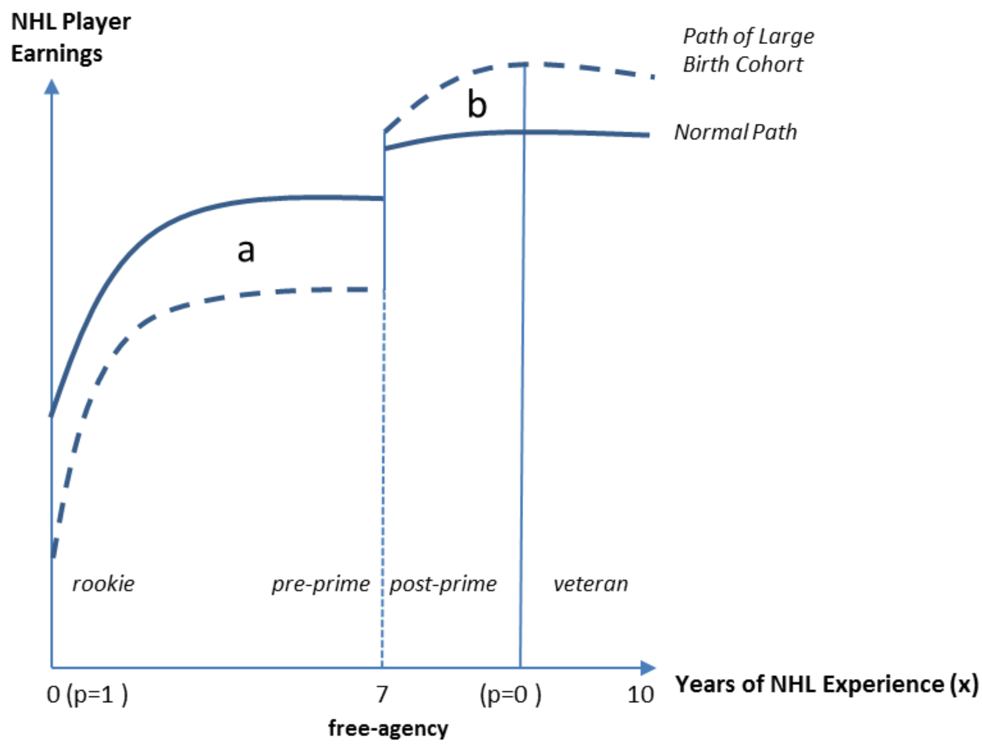

Figure 2: Hypothetical contrast between career earnings paths of NHL players from normal and unusually large birth cohorts, with free agency occurring after 7 years' experience.

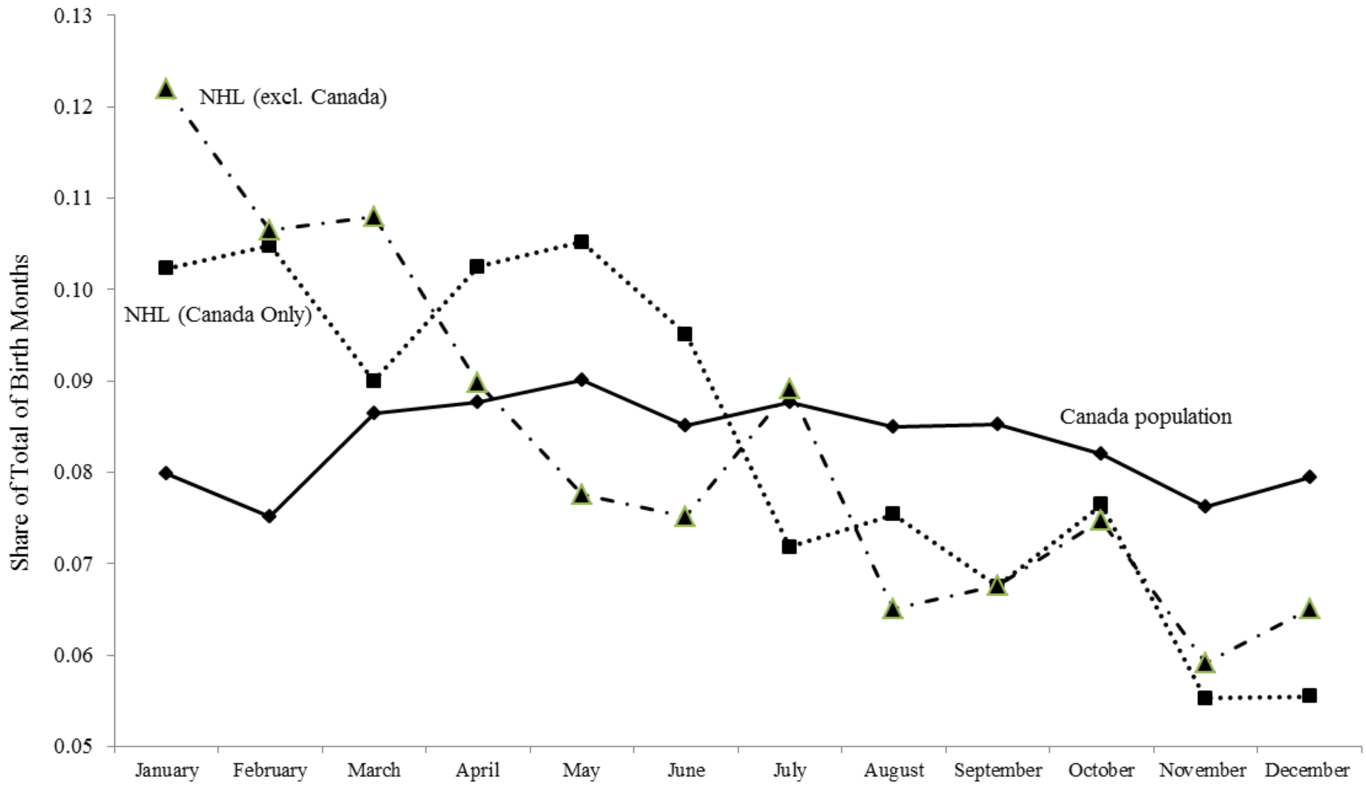

Figure 3: Seasonality of births for NHL players and Canadian population as a whole, 1991-2008 averages.

Sources: NHL player birth month located from official league site: http://www.nhl.com/ice/playerstats.htm. Canadian population birth month data from Statistics Canada, *Live Births, By Month, Canada, Provinces and Territories*: http://data.gc.ca/data/en/dataset/d976763b-5d5e-442e-8f31-48f9102ac66c

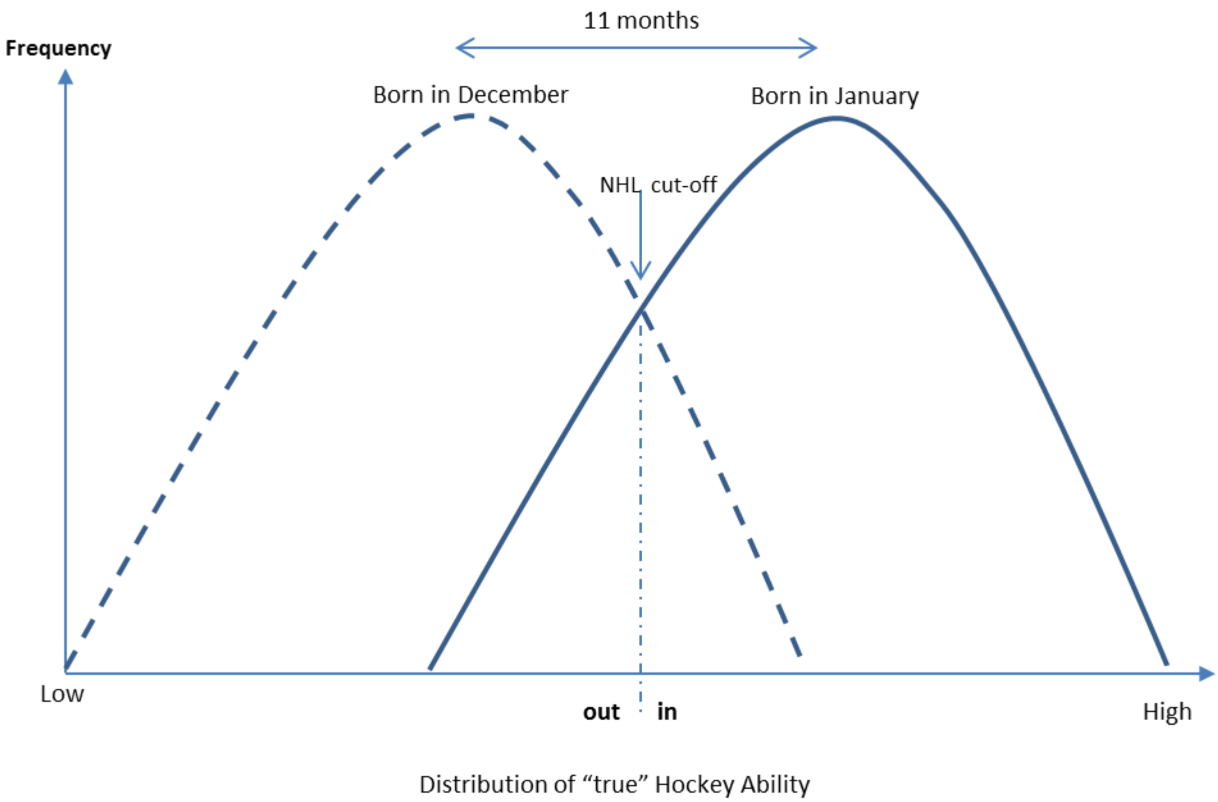

Figure 4: Illustration of the maturity advantage of youth hockey players born in January versus those born in December in the same calendar year and with similar distribution of ability.

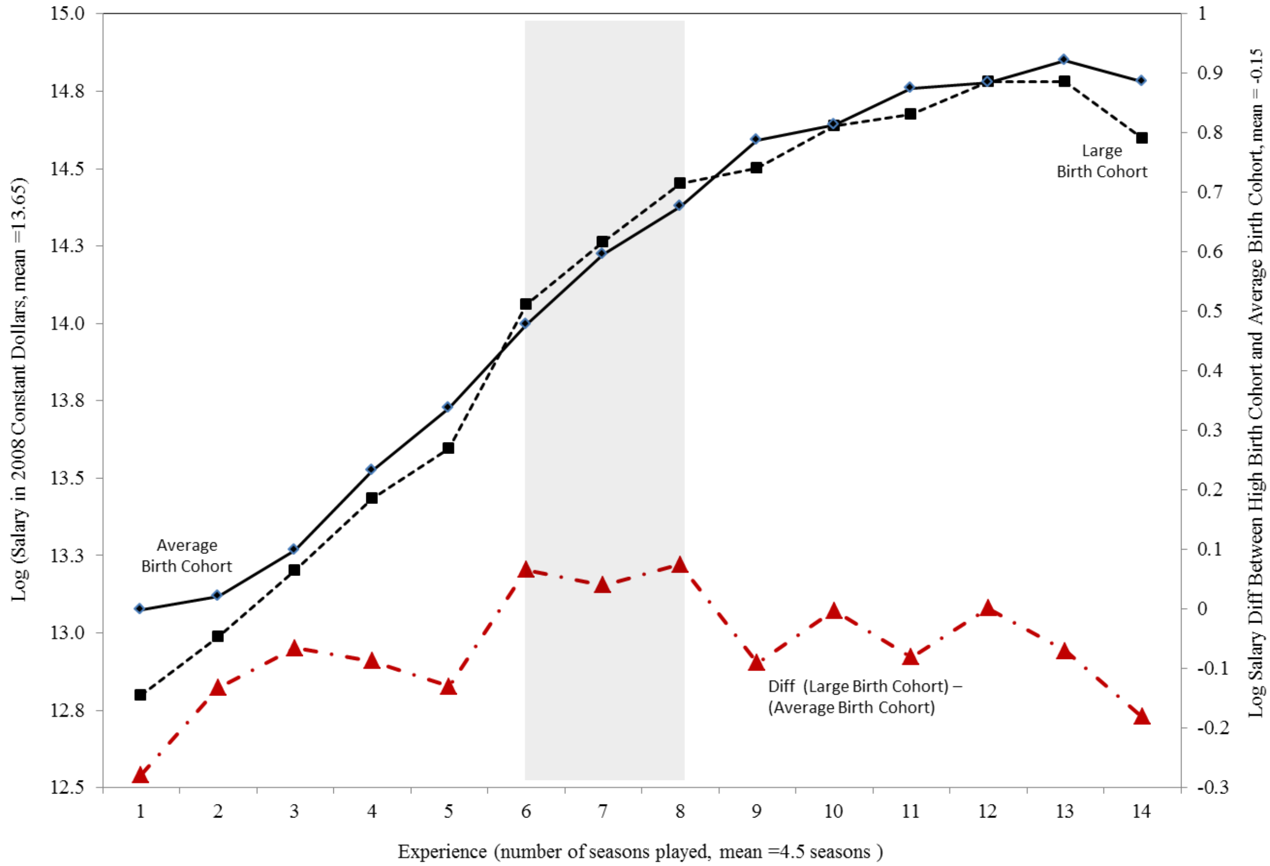

Figure 5: Unadjusted career earnings paths of NHL players from normal and unusually large birth cohorts, with free agency occurring after 7 years' experience.

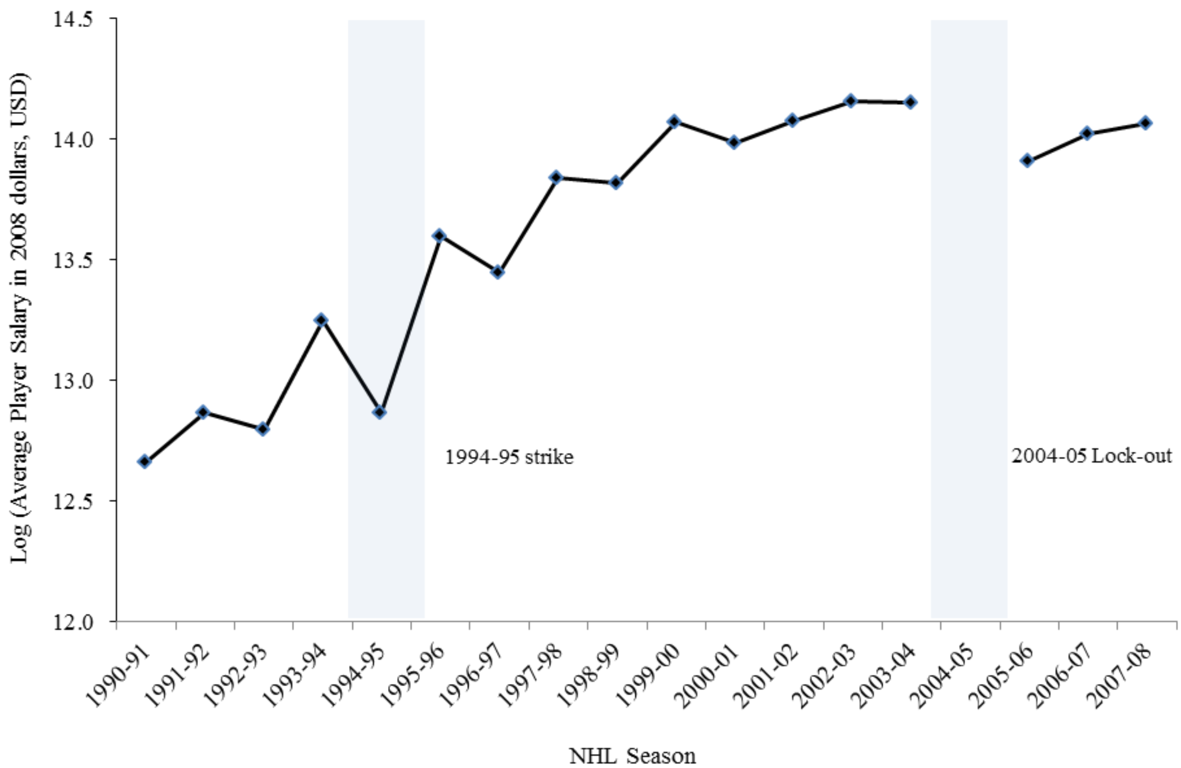

Figure 6: The evolution of average NHL player salaries, 1990-91 to 2007-08 (in 2008 Constant USD dollars)

Table 1: Summary Statistics for Pooled NHL Player Sample, 1990-2008

Variable	Mean	Std.Dev	Min	Max
Dependent				
1. Salary (2008 USD dollars)	1,334,304	1,591,470	16095.82	2.20e+07
2. Log Salary	13.65	.901	9.68	16.90
3. Player performance: Point totals (per season)	24.26	23.77	0	163
Plus/minus (per season)	1.54	10.77	-50	60
Independent				
4. Birth Rate (per 1000 of population)†	17.35	3.29	11	28.5
5. Birth Month (1-12)	5.84	3.41	1	12
Control Variables				
6. Age (yrs)	27.07	4.36	18	45
7. Birth Year	1971.5	6.11	1951	1989
8. Height (inches)	72.85	2.07	61	81
9. Weight (lbs)	200.16	15.56	150	263
10. Body Mass Ratio (weight/height)	2.74	.169	.233	3.95
10. Experience (years in league)	4.4	3.21	1	17
11. Games played (per season)	47.5	24.04	1	82
Other Variables (Dummies Only)				
12. Experience: Rookie <3 yrs	0.531	0.49	0	1
Early Prime 4 to 6 yrs	0.256	0.43	0	1
Late Prime 7 to 9 yrs	0.131	0.33	0	1
[Veteran 10yrs>=]	0.075	0.26	0	1
12. Captain	.040	.196	0	1
13. Drafted [Non-drafted]	.787	.394	0	1
14. Position				
[Defence]	.315	.464	0	1
Forward	.587	.492	0	1
Goalie	.096	.295	0	1
15. Country of Origin				
[Canada]	.598	.490	0	1
United States	.155	.362	0	1
Czech Republic	.059	.237	0	1
Russia	.055	.228	0	1
Sweden	.046	.211	0	1
Finland	.029	.168	0	1
Slovakia	.019	.135	0	1
Former Soviet Republics‡	.017	.128	0	1
Rest of Europe	.016	.125	0	1
Rest of World	.005	.125	0	1

Notes: The sample is the combined data set described in the text. The sample includes all player positions (including goalies) with potential experience 1 to 17 seasons and with a valid annual earnings observation (>0 in 2008 dollars). The regression samples exclude goalies. Sample sizes vary because of missing variables. †Birth rate is crude birth rate measured for every player's birth country and year of birth.‡ These include Latvia, Lithuania, Ukraine, Kazakhstan, and Belarus.

Table 2: The Effect of Large Birth Cohort on NHL Player Salaries, 1990-2008

	All Player Observations, 1990-2008			
	Log(Salary) Mean =13.65 (1)	Log(Salary) Mean =13.65 (2)	Log(Salary) Mean =13.65 (3)	Log(Salary) Mean =13.65 (4)
[Small Birth Cohort] Large Birth Cohort† (avg. career length = 4.4 yrs)	-0.197*** (.029)	-0.209*** (.019)	-0.184*** (.019)	-0.179*** (.019)
By career stage =				
Rookie <3yrs	-0.195*** (.031)	-0.276*** (.023)	-0.255*** (.023)	-0.215*** (.023)
Prime 4 to 6yrs	-0.178*** (.037)	-0.136*** (.027)	-0.112*** (.026)	-0.073** (.027)
Prime 7 to 9 yrs	-0.169*** (.047)	-0.077** (.035)	-0.043 (.034)	-0.012 (.034)
Veteran 10yrs>=	-0.316*** (.053)	-0.177*** (.047)	-0.141*** (.044)	-0.117*** (.044)
Player Performance ‡	No	Yes	Yes	Yes
Other controls	No	No	Yes	Yes
Team fixed effects	No	No	No	Yes
Between R^2	0.328	0.503	0.555	0.582
Overall R^2	0.409	0.547	0.570	0.587
Total Observations	8992	8795	8785	8785
Number of players	2036	1993	1990	1990

*** p<0.01, ** p<0.05, * p<0.1

Notes: All regressions are random effect models. Standard errors are in parentheses. The sample is the panel data set described in the text, exclusive of all goalies. Observations are player-season cells. Estimates exclude players without earnings. The controls are a body mass indicator (weight/height), forward dummy and country of origin. In team fixed effects we exclude the team with highest average payroll (New York Rangers). †An indicator coded 1 if crude birth rate is 17.35 or higher in country of origin at time of birth and 0 otherwise -- below average Small Birth Cohort size (<17.35) is the excluded reference category. The estimate parameters by career stage are relative to Small Birth Cohort *Rookies <3yrs*, Small Birth Cohort *Prime 4 to 6yrs*, etc., ‡ Measured as point totals in a given season.

Table 3: The Effect of Large Birth Cohort on NHL Player Performance, 1990-2008

	All Player Observations, 1990-2008			
	Points (per season) Mean =24.6 (1)	Points (per season) Mean =24.6 (2)	Points (per season) Mean =24.6 (3)	Points (per season) Mean =24.6 (4)
[Small Birth Cohort] Large Birth Cohort[†] (avg career length= 4.6 yrs)	5.21*** (.718)	1.87*** (.454)	2.29*** (.457)	1.89*** (.474)
By career stage =				
Rookie <3yrs	9.65*** (.671)	4.00*** (.486)	4.41*** (489)	3.98*** (.023)
Prime 4 to 6yrs	-1.19 (.845)	0.326 (.613)	0.959 (.026)	0.598 (.026)
Prime 7 to 9 yrs	-5.48*** (1.06)	-4.11*** (.781)	-3.38*** (.779)	-3.72*** (.708)
Veteran 10yrs>=	-10.07*** (0.728)	-7.55*** (1.02)	-6.76*** (1.02)	-7.02*** (.900)
Games played (per season)	No	Yes	Yes	Yes
Other controls	No	No	Yes	Yes
Team fixed effects	No	No	No	Yes
Between R^2	0.058	0.586	0.621	0.623
Overall R^2	0.045	0.474	0.526	0.534
Total Observations	12110	12110	12098	12098
Number of players	2655	2655	2651	2651

*** p<0.01, ** p<0.05, * p<0.1

Notes: All regressions are random effect models. Standard errors are in parentheses. The sample is the panel data set described in the text, exclusive of all goalies. Observations are player-season cells. Columns 1-4 also include all players regardless of earnings data. In controls we include a body mass indicator (weight/height), forward dummy and country of origin. In team fixed effects we exclude team with highest average payroll (New York Rangers). [†]An indicator coded 1 if crude birth rate is 17.35 or higher in country of origin at time of birth and 0 otherwise -- below average Small Birth Cohort size (<17.35) is the excluded reference category. The estimated parameters by career stage are relative to Small Birth Cohort counterparts; so Small Birth Cohort *Rookies <3yrs*, Small Birth Cohort *Prime 4 to 6yrs*, etc., ‡ Measured as point totals in a given season.

Table 4: The Effect of Large Birth Cohort on NHL Player Performance, 1990-2008

	All Player Observations, 1990-2008			
	Plus/minus (per season) Mean =1.54 (1)	Plus/minus (per season) Mean =1.54 (2)	Plus/minus (per season) Mean =1.54 (3)	Plus/minus (per season) Mean =1.54 (4)
[Small Birth Cohort] Large Birth Cohort† (avg career length= 4.6 yrs)	2.55*** (.718)	2.21*** (.202)	2.60*** (.216)	2.24*** (.220)
By career stage =				
Rookie <3yrs	3.53*** (.266)	3.50*** (.263)	3.89*** (.274)	3.55*** (.277)
Prime 4 to 6yrs	1.77*** (.344)	1.30*** (.341)	1.69*** (.349)	1.34*** (.350)
Prime 7 to 9 yrs	1.09*** (.999)	0.171 (.461)	0.586 (.697)	0.242 (.465)
Veteran 10yrs>=	1.83*** (.622)	.823 (.616)	1.30** (.619)	0.775 (.618)
Games played (per season)	No	Yes	Yes	Yes
Other controls	No	No	Yes	Yes
Team fixed effects	No	No	No	Yes
Between R^2	0.027	0.083	0.083	0.125
Overall R^2	0.015	0.045	0.051	0.075
Total Observations	12110	12110	12098	12098
Number of players	2655	2655	2651	2651

*** p<0.01, ** p<0.05, * p<0.1

Notes: All regressions are random effect models. Standard errors are in parentheses. The sample is the panel data set described in the text, exclusive of all goalies. Observations are player-season cells. Columns 1-4 also include all players regardless of earnings data. In controls we include a body mass indicator (weight/height), forward dummy and country of origin. In team fixed effects we exclude team with highest average payroll (New York Rangers). †An indicator coded 1 if crude birth rate is 17.35 or higher in country of origin at time of birth and 0 otherwise -- below average Birth Cohort size (<17.35) is the excluded reference category. The estimated parameters by career stage are relative to Small Birth Cohort counterparts; so Small Birth Cohort *Rookies <3yrs*, Small Birth Cohort *Prime 4 to 6yrs*, etc., ‡ Measured as point totals in a given season.

Table 5: The Effect of Large Birth Cohort on Other NHL Player Outcomes, 1990-2008

	All Player Observations, 1990-2008			
	Pr(Drafted) Mean =.787 (1)	Pr(Drafted) Mean =.787 (2)	Pr(Captain) Mean =.04 (3)	Pr(Captain) Mean =.04 (4)
[Small Birth Cohort] Large Birth Cohort†	-0.097*** (.008)	-0.092*** (.009)	0.028*** (.004)	.029*** (.004)
Other Controls	No	Yes	No	Yes
Pseudo R^2	0.027	0.039	0.015	0.161
Total Observations	12369	12357	12369	12179

*** p<0.01, ** p<0.05, * p<0.1

Notes: All regressions are *probit* models reporting the marginal effects. The sample is the panel data set described in the text that includes all non-goalies. Observations are player-season cells. Columns 1-4 include all players regardless of earnings data. In other controls we include body mass indicator (weight/height), country of origin, forward dummy and cumulative experience measure which is a count of seasons in league. † An indicator coded 1 if crude birth rate is 17.35 or higher in country of origin at time of birth and 0 otherwise -- below average Small Birth Cohort size (<17.35) is the excluded reference category.

Table 6: The Effect of Relative Age (Birth Month) on NHL Player Salaries, 1990-2008

	All Player Observations, 1990-2008			
	Log(Salary) Mean =13.65 (1)	Log(Salary) Mean =13.65 (2)	Log(Salary) Mean =13.65 (3)	Log(Salary) Mean =13.65 (4)
[Low Relative Age] High Relative Age† (Born Jan-Apr)	-0.073*** (.027)	-0.032* (.019)	-0.029* (.017)	-0.027* (.017)
By career stage =				
Rookie (<3yrs)	-0.0288 (.025)	-0.018 (.026)	-0.023 (.021)	-0.020 (.021)
Prime (4 to 6yrs)	- 0.061** (.029)	-0.031 (.026)	-0.039 (.025)	-0.039 (.024)
Prime (7 to 9 yrs)	-0.124*** (.035)	-0.089*** (.033)	- 0.097*** (.032)	-0.096*** (.031)
Veteran (10yrs>)	- 0.086* (.044)	-0.053 (.042)	-0.060 (.041)	-0.056 (.045)
Player Performance‡	No	Yes	Yes	Yes
Other controls	No	No	Yes	Yes
Team fixed effects	No	No	No	Yes
Between R^2	0.307	0.452	0.511	0.523
Overall R^2	0.409	0.529	0.558	0.552
Total Observations	8994	8797	8787	8785
Number of players	2037	1994	1991	1990

*** p<0.01, ** p<0.05, * p<0.1

Notes: All regressions are random effect models. Standard errors are in parentheses. The sample is the panel data set described in the text, exclusive of all goalies. Observations are player-season cells. Columns 1-4 also exclude players without earnings. In controls we include a body mass indicator (weight/height), forward dummy and country of origin. In team fixed effects we exclude team with highest average payroll (New York Rangers). †An indicator coded 1 if a player is born in the first quarter of the calendar year and 0 for those born between May and December (excluded reference category). The estimated parameters by career stage are relative to earlier born counterparts; so May to December born *Rookies <3yrs*,etc are excluded reference categories., ‡ Measured as point totals in a given season.

Table 7: The Effect of Relative Age (Birth Month) on NHL Player Performance, 1990-2008

	All Player Observations, 1990-2008			
	Points (per season) Mean =24.6 (1)	Points (per season) Mean =24.6 (2)	Points (per season) Mean =24.6 (3)	Points (per season) Mean =24.6 (4)
[Low Relative Age] High Relative Age† (Born Jan-Apr)	-2.03*** (.718)	-0.946** (.406)	-0.940** (.384)	-0.975*** (.387)
By career stage =				
Rookie <3yrs	-1.62*** (.600)	-0.42 (.431)	-0.41 (.411)	-0.47 (.041)
Prime 4 to 6yrs	-2.91*** (.786)	-1.83*** (.567)	-1.78*** (.550)	-1.80*** (.551)
Prime 7 to 9 yrs	-3.31*** (.786)	-2.34*** (.734)	-2.32*** (.720)	-2.33*** (.721)
Veteran 10yrs>	-2.35* (1.32)	-2.61*** (.962)	-2.59*** (.950)	-2.61*** (.950)
Games played (per season)	No	Yes	Yes	Yes
Other controls	No	No	Yes	Yes
Team fixed effects	No	No	No	Yes
Between R^2	0.161	0.594	0.629	0.632
Overall R^2	0.035	0.474	0.525	0.539
Total Observations	12113	12113	12100	12098
Number of players	2657	2657	2652	2651

*** p<0.01, ** p<0.05, * p<0.1

Notes: All regressions are random effect models. Standard errors are in parentheses. The sample is the panel data set described in the text, exclusive of all goalies. Observations are player-season cells. Columns 1-4 also include all players regardless of earnings data. In controls we include a body mass indicator (weight/height), forward dummy and country of origin. In team fixed effects we exclude team with highest average payroll (New York Rangers). † An indicator coded 1 if a player is born in the first quarter of the calendar year (January to April) and 0 for those born between May and December (excluded reference category). The estimated parameters by career stage are all relative to earlier born counterparts; so *May to December born Rookies <3yrs*,etc are excluded reference categories., ‡ Measured as point totals in a given season.

Table 8: The Effect of Relative Age (Birth Month) on NHL Player Performance, 1990-2008

	All Player Observations, 1990-2008			
	Plus/minus (per season) Mean =1.54 (1)	Plus/minus (per season) Mean =1.54 (2)	Plus/minus (per season) Mean =1.54 (3)	Plus/minus (per season) Mean =1.54 (4)
[Low Relative Age] High Relative Age† (Born Jan-Apr)	-0.609*** (.186)	-0.459*** (.184)	-0.512*** (.185)	-0.505*** (.185)
By career stage =				
Rookie <3yrs	-0.699*** (.256)	-0.533** (.253)	-0.574*** (.361)	-0.646*** (.251)
Prime 4 to 6yrs	-0.494 (.366)	-0.283 (.361)	-0.346 (.361)	-0.273 (.359)
Prime 7 to 9 yrs	-0.712 (.513)	-0.651 (.506)	-0.725 (.506)	-0.542 (.502)
Veteran 10yrs>	-0.097 (.680)	-0.205 (.670)	-0.245 (.670)	-0.252 (.665)
Games played (per season)	No	Yes	Yes	Yes
Other controls	No	No	Yes	Yes
Team fixed effects	No	No	No	Yes
Between R^2	0.018	0.051	0.056	0.107
Overall R^2	0.013	0.034	0.038	0.075
Total Observations	12155	12113	12100	12098
Number of players	2655	2657	2652	2651

*** p<0.01, ** p<0.05, * p<0.1

Notes: All regressions are random effect models. Standard errors are in parentheses. The sample is the panel data set described in the text, exclusive of all goalies. Observations are player-season cells. Columns 1-4 also include all players regardless of earnings data. In controls we include a body mass indicator (weight/height), forward dummy and country of origin. In team fixed effects we exclude team with highest average payroll (New York Rangers). † An indicator coded 1 if a player is born in the first quarter of the calendar year (January to April) and 0 for those born between May and December (excluded reference category). The estimated parameters by career stage are all relative to earlier born counterparts; so *May to December born Rookies <3yrs*,etc are excluded reference categories., ‡ Measured as point totals in a given season.

Table 9: The Effect of Relative Age on Other NHL Player Outcomes, 1990-2008

	All Player Observations, 1990-2008			
	Pr(Drafted) Mean =.787 (1)	Pr(Drafted) Mean =.787 (2)	Pr(Captain) Mean =.041 (3)	Pr(Captain) Mean =.041 (4)
[Low Relative Age] High Relative Age[†] (Born Jan-Apr)	0.027*** (.007)	0.024*** (.007)	-0.007** (.003)	-0.005* (.003)
Other Controls	No	Yes	No	Yes
Pseudo R^2	0.010	0.027	0.015	0.027
Total Observations	12372	12359	12372	12181

*** p<0.01, ** p<0.05, * p<0.1

Notes: All regressions are *probit* models reporting the marginal effects. The sample is the panel data set described in the text that includes all non-goalies. Observations are player-season cells. Columns 1-4 includes all players even those without earnings. In other controls we include body mass indicator (weight/height), country of origin, and forward dummy. [†]An indicator of crude birth rate of 17.5 per 1000 per population or higher for birth rate, Small Birth cohort size (<17.5) is excluded reference category

Table 10: The Effect of Large Birth Cohort on NHL Player Salaries By Relative Age, 1990-2008

	Dependent Variable: Log(Salary) Mean =13.65				
	By Relative Age (birth quarter)				
	Born January to April	Born May to August	Born Sep to Dec	Differences (t-stats)	
	(1)	(2)	(3)	(1)-(2)	(1)-(3)
[Small Birth Cohort] Large Birth Cohort† (avg. career length = 4.4 yrs)	-0.141*** (.031)	-0.161*** (.035)	-0.243*** (.038)	-0.020 (0.645)	-0.102*** (2.91)
By career stage =					
Rookie <3yrs	-0.128*** (.040)	-0.177*** (.047)	-0.185*** (.050)	-0.049 (1.160)	-0.057 (1.207)
Prime 4 to 6yrs	-0.034 (.047)	-0.081 (.063)	-0.170*** (.057)	-.047 (0.903)	-0.136*** (2.72)
Prime 7 to 9 yrs	0.010 (.058)	0.083 (.065)	-0.215*** (.070)	-0.073 (1.211)	-0.205*** (3.36)
Veteran 10yrs>	-0.208*** (.076)	-0.264*** (.077)	-0.176* (.092)	-0.064 (0.842)	0.032 (0.400)
Player Performance ‡	Yes	Yes	Yes		
Other controls	Yes	Yes	Yes		
Team fixed effects	Yes	Yes	Yes		
Between R^2	0.516	0.487	0.533		
Overall R^2	0.522	0.505	0.532		
Total Observations	3520	2904	2361		
Number of players	825	638	527		

*** p<0.01, ** p<0.05, * p<0.1

Notes: All regressions are random effect models. Standard errors are in parentheses. The sample is the panel data set described in the text, exclusive of all goalies. Observations are player-season cells. Columns 1-4 also exclude players without earnings. In controls we include a body mass indicator (weight/height), forward dummy and country of origin. In team fixed effects we exclude team with highest average payroll (New York Rangers). †An indicator coded 1 if crude birth rate is 17.35 or higher in country of origin at time of birth and 0 otherwise -- below average Small Birth Cohort size (<17.35) is the excluded reference category. The estimate parameters by career stage are relative to Small Birth Cohort *Rookies <3yrs*, Small Birth Cohort *Prime 4 to 6yrs*, etc., ‡Measured as point totals in a given season.

Table 11: The Effect of Large Birth Cohort on NHL Player Salaries Pre-Post Lockout and League Expansion, 1990-2008

	Dependent Variable: Log(Salary) Mean =13.65					
	By Lockout and League Expansions					
	2004-05 Lockout			League Expansion Years∗		
	Pre Mean=13.57	Post Mean=14.00	Diff (t-stat) =0.43	No Mean =13.34	Yes Mean =14.04	Diff (t-stat) = 0.68
	(1)	(2)	(2)-(1)	(3)	(4)	(4)-(3)
[Small Birth Cohort] Large Birth Cohort† (avg. career length = 4.4 yrs)	-0.127*** (.021)	0.470*** (.098)	0.597*** (6.97)	-0.141*** (.028)	-0.053* (.029)	0.088*** (3.14)
By career stage =						
Rookie <3yrs	-0.119*** (.026)	-0.090 (.165)	0.029 (.966)	-0.434** (.031)	0.025 (.033)	0.459*** (6.12)
Prime 4 to 6yrs	-0.050* (.029)	0.026 (.132)	0.076** (2.32)	-0.124*** (.076)	-0.161*** (.039)	-0.035 (0.777)
Prime 7 to 9 yrs	-0.078** (.058)	0.100 (.127)	0.178** (2.28)	-0.005 (.063)	-0.071 (.052)	-0.066 (1.10)
Veteran 10yrs>	-0.350*** (.052)	-0.006 (.094)	0.344*** (3.82)	-0.044 (.058)	-0.362*** (.089)	-0.318*** (467)
Player Performance ‡	Yes	Yes		Yes	Yes	
Other controls	Yes	Yes		Yes	Yes	
Team fixed effects	Yes	Yes		Yes	Yes	
Between R^2	0.516	0.646		0.633	0.473	
Overall R^2	0.522	0.585		0.599	0.573	
Total Observations	7041	1744		5330	3455	
Number of players	1617	869		1750	1250	

*** p<0.01, ** p<0.05, * p<0.1

Notes: All regressions are random effect models. Standard errors are in parentheses. The sample is the panel data set described in the text, exclusive of all goalies. Observations are player-season cells. Columns 1-4 also exclude players without earnings. In controls we include a body mass indicator (weight/height), forward dummy and country of origin. In team fixed effects we exclude team with highest average payroll (New York Rangers). †An indicator coded 1 if crude birth rate is 17.35 or higher in country of origin at time of birth and 0 otherwise -- below average Small Birth Cohort size (<17.35) is the excluded reference category. The estimate parameters by career stage are relative to Small Birth Cohort *Rookies <3yrs*, Small Birth Cohort *Prime 4 to 6yrs*, etc., ‡Measured as point totals in a given season.∗Six league expansions occurred in total prior to the start of the 1991-92, 1992-93, 1993-94 seasons and again in 1998-99, 1999-2000, 2000-01.

Appendix Table 1

Unweighted Sample Coverage: Birth Month and NHL Experience (years)

	Years in League											
Birth Month	1	2	3	4	5	6	7	8	9	10	11+	Total
Jan-April	584	641	571	484	399	332	270	221	162	122	270	4,056
May-Aug	436	498	455	384	341	280	230	191	147	115	229	3,306
Sep-Dec	361	402	360	314	265	220	181	149	1114	86	165	2,617
Total	1,381	1,541	1,386	1,182	1,005	832	681	561	423	323	664	9.979

Notes: An observation here is a player-year. This table includes only valid earnings observations, defined as a player with experience 1 to 17 seasons with positive annual earnings in 2008 constant dollars. Birth month is the month of birth of the player. Experience is a count of number of seasons observed between1990-91 and 2007-08 seasons.

Appendix Table 2

Unweighted Sample Coverage: Birth Rate and NHL Experience (years)

Birth Rate	Years in League 1	2	3	4	5	6	7	8	9	10	11+	Total
Low (<15)	490	600	562	472	378	309	254	189	135	93	169	3,651
Avg (15-17.5)	381	449	413	347	316	270	218	199	151	130	309	3,183
High (>17.5)	511	491	411	363	311	253	209	173	137	100	186	3,145
Total	1,380	1,540	1,386	1,182	1,005	832	681	561	423	323	6664	9,979

Notes: An observation here is a player-year. This table includes only valid earnings observations, defined as a player with experience 1 to 17 seasons with positive annual earnings in 2008 constant dollars. Birth rate is the crude birth rate in the player's year and country of birth. Experience is a count of number of seasons observed between1990-91 and 2007-08 seasons.

Appendix 1

Data Sources

Our key dependent variable is individual player salaries. The USA Today Sports Salaries Database (http://content.usatoday.com/sportsdata/hockey/nhl/salaries/team/) provides player salaries by player by team going back to 2000. For earlier seasons we rely on a time-intensive search of the HockeyZonePlus database which allows one to view the salary history of an individual player since player salaries became public in 1989[13], by entering the player's last name (http://www.hockeyzoneplus.com/bizdb/nhl-salaries-search.htm). Historical player demographic and performance data was obtained from the official NHL league website (http://www.nhl.com/ice/playerstats.htm). Birth rate data was obtained from the United Nations Statistics Division's *Demographic Yearbook* (http://unstats.un.org/unsd/demographic/products/dyb/dyb2.htm) which provides crude birth rate data for the countries and the birth years present in our sample of players (1951-1989). Despite having 46 birth countries in our sample of NHL players, we collected birth rate data only for the following countries/regions (Canada, US, Sweden, Russia, Finland, Czech Republic, Slovakia, Former Soviet Republics, and Rest of Europe). A few players born in places like Jamaica or South Korea etc. where there is no history of amateur hockey, were tracked down and found to have been players brought up in Canada or the US and hence assigned birth rates for those countries in the sample period.

[13] This was the result of a demand made by the national Hockey League Players Association (NHLPA) in one of the first rounds of bargaining that did not involve Alan Eagleson as head of the NHLPA. Pay secrecy clearly favoured the NHL owners and this move was one reason NHL player salaries began to slowly converge to the rest of the North American player salaries in the 1990s and 2000s. Eagleson was convicted of fraud and collusion with owners in restraining player salary demands.

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