An Economic Approach to Roster Management for College Football Teams

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May 17, 2025

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Introduction

Overview

College football coaches in today's game are faced with a difficult optimization problem: How do I balance playing time to maximize wins, develop talent for the future, and keep everyone happy? An oft-used economic model may provide some insight.

WARNING

This presentation is an exercise in applied economic modeling. It will be light on data, and focus instead on the systematic approach to a problem that economics can provide. There will be light math involved.

Along the way, I'll use these alert boxes to identify insights from the model that provide opportunities for your analytics teams to estimate key parameters.

Model-based Thinking

What is a **model**?

Statistics and Data science

In **statistics and data science**, a model is a *data generating process, some assumptions, and a statistical estimator*

Economics

In **economics**, a model is a mathematically-defined system designed to identify important facts and features of the world. It is a *simplification of reality*.

Generally concerned with **marginalism**: how does utility/output change when decisions are made or things go wrong?

Setting up the Model

College Football Teams as Firms

- College football teams are firms:
  - Use **labor** (players), **capital** (snaps played at different levels of quality), and **technology** (facilities, strategy, conditioning, coaching, analytics) to produce **wins**.
- Firms (teams) seek to maximize wins using players, subject to constraints.
  - Concrete constraints: 11 players on the field, Roster limit, Fixed schedules
  - Abstract constraints: limited time to installing plays, developing players, transfer portal departure, recruiting/talent acquisition, strength of competition

Takeaway

Teams employ players via snaps to produce wins, but must strategize not only for this season, but future seasons.

The Production Function

How do teams translate snaps, investment in facilities, strength and conditioning programs, into wins?

College Football Players as Households

- College football players are households
  - Consume playing time, develop for the future.
  - Balancing incentives of maximizing personal relative to team success (bowl-opt outs)
  - Player contribution is **weakly increasing** with experience
  - Hold talent constant, more experienced players will contribute more to their teams
  - Hold experience constant, more talented players will contribute more to their teams

Takeaway

Players work to receive time in the program, and with that time they can play on the field or develop for the future.

Development Curves

What are the expected contribution rates of players along their career? How does heterogeneity - in player position and experience, in team scheme and level of competition - affect those expected development rates?

The Solow Model

- Well-known framework for understanding how firm decisions and household preferences affect an economy's output.
- "Fundamental Equation": Relating savings today to output tomorrow
  - $\dot{k} = sAk^{\alpha} - (\delta + n)k$
  - Links production across periods and consumer preference to firm output
- Limitation: Savings - the decision about what resources to dedicate to the future - are **exogenous**, determined outside the model

A Useful Extension: Overlapping Generations

Developed (most notably) by Paul Samuelson in 1958
Two key features:

- Different Kinds of Households
- Endogenous Savings Function

Overlapping Generations

Environment

- Consider consecutive discrete time periods t, $t+1$, $t+2$,...
  - Seasons or development windows for teams
- N total players: *prospects* or *starters*
- Total number of players in a period: $N_p + N_s$
- Players "live for two periods"
  - Enter as a prospect, matriculate to starter, then graduate
  - Abstracting away from potential for roster growth for now
- Economy is populated by a single team T
- Team uses factors of production to produce wins
  - Could NFL Draft Picks, Conference Championships, Playoff Appearances

Players 1

Players

- Enter as prospect with baseline of 0 playing time
- **Key Decision**
  - Whether to give prospect playing time (immediate contribution) or develop him (future contribution)
  - Assume prospects are all of a similar quality, and they can either play in a given period or choose to improve that quality through development.
  - Coach is 'benevolent dictator'
- Development, s_t turns into productive snaps in time period $t+1$. The player uses the rest of his time playing snaps and producing wins
- Starters do not develop (controversial assumption!)

Players 2

Inherent budget constraint on both prospects and starters $\text{Time}_i = \text{Playing Time}_{it} + s_{it}$, where $\text{Playing Time}_{i,t+1} = R_{t+1} + (1-\delta) * s_{it}$ A starter's productive capital (read: snaps) is a function of the choices of his development as a prospect, and the team's ability to improve players throughout their career (R_{t+1}).

Takeaway

Coaches choose to play players early, or they choose to develop them for the future, and a player's development can be improved by the team's efforts to develop prospects.

Coaching and Development

- Can we estimate effect of coaching on converting quality snaps to wins?
- Can we remove assumption that starters don't develop and capture temporal improvement of players throughout their careers?

Consumption Choices

Young players pick development time as to maximize the discounted sum of their utility.

$$\max_{s_t} \mathsf{U} = \mathsf{u}(\text{Playing Time}_t) + \beta \mathsf{u}([R_{t+1} + \delta] s_t)$$
$$\mathsf{u}'(\text{Playing Time}_t) = \beta([R_{t+1} + \delta] s_t) \mathsf{u}'(\text{Playing Time}_{t+1})$$

- If a coach chooses to play a prospect less (decreases playing time in period t and increases development time in period t), he decreases the player's lifetime utility by the left-hand side of the equation. We'll call that the **marginal cost of developing a prospect.**
- What's the benefit to developing a prospect? Quality of playing time in period t+1 increases by the right hand side. That's the **marginal benefit of developing a prospect.**

Players Summary

- ECON 101: We want marginal cost to equal marginal benefit
- Have a framework to evaluate they effects on a player, and even to solve for an optimal level of development to maximize utility.
- Defined relationship between a coach's choice to develop a player or play him as a prospect and winning.
- Problems:
  - What is utility? Result dependent on functional form
  - Teams care about players, but more strongly about program performance

Functional Form

How we define the returns to playing time for players is a huge component of the usefulness of this model, and an obvious entry point for contracts, market value, incentive structures, and more.

Teams 1

$$\text{Wins}_t = A_t F(K_t, N_t)$$

- Wins today are a function of how good we are at converting player-snaps into wins, and which players we play, and what their level of development.
- Teams choose which players to play and what opportunities they give young players to maximize wins.

Profit Maximization

From a standard profit maximization sense, firms will earn 0 profits when they are maximizing their production function. In the example of college football teams, we can think of 0 wins as the "ceiling" of a team, and any deviations from optimal will result in a reduction of wins.

Teams 2

Maximizing a team's production fucntion gives us two important results:

- The team specific ability to convert player snaps into wins, R depends on **technology** and **wins today**.
- Opportunities we can give prospects to develop is determined by **technology** and **wins today**

Investment into Facilities

Numerous examples of specific investment into technology and facilities improving performance (Jayden Daniels at LSU). Now that we can tie this into the development curve of a college player, more important than ever to understand the returns to money spent on facilities.

Equilibrium

Equilibrium I

- Typical OLG equilibrium characterized by 9 equations
- Key facet is optimal level of prospect development to maximize sum of discounted future wins, based on past wins, team-specific ability to convert snaps to wins, technology, and current level of development.

$$\text{Playing Time}_{prospects,t} + \text{Playing Time}_{starters,t} + K_{t+1} - (1+\delta) = N_t + R_t * K_t$$

Playing time for prospects today plus playing time for starters today plus the quality snaps we will play next year is equal to the number of players we play today, how well we develop them, and our ability to convert player snaps into wins. **Key question**: "In equilibrium, how much should I develop my prospects relative to how much I play them?"

The Central Equation

$$k_{t+1} = s(Af(k_t) - Ak_t f'(k_t), Af'(k_t))$$

- The quality of snaps a team can put on the field next season is a function of how much they develop their prospects.
- The optimal level of development (relative to playing time) for prospects depends on
  - How well the team converted player snaps to wins this season
  - How many more wins they would contribute with higher-quality snaps
  - Strategy, Coaching, Facilities, Technology

Summary

Bringing it All Together

This fundamental equation, the linkage of wins today to wins tomorrow, gives us a key direction to begin to peel back layers. From that equation alone, we have several empirical questions we can go to the data and try to answer for teams:

- How good are different teams at converting player snaps to wins?
- How good are teams at developing players? (Returns to development time)
- What is the marginal effect of adding player snaps at different positions?
- What is the marginal effect of adding development at different positions?
- How do time preferences for winning align with development cycles, and what can that tell us about talent acquisition strategies (prospects v portal)?

The Steady State

Restrictions on Utility 1

Log Utility

- Useful representation of preferences
- Diminishing Returns: 0 vs 20 snaps in a game is a huge benefit, 65 vs 67 not so much
- Hot Day in Texas

$$\text{U} = \log(\text{Playing Time}_t) + \beta \log([R_{t+1} + \delta] s_t)$$

Restrictions on Utility 2

Skipping some algebra, this yields an optimal level of development:

$$s_t = \frac{\beta}{1+\beta} w_t$$

- The optimal level of player development this period is a function of that player's opportunity provided by the program (in terms of development and converting snaps to wins) and of how much a program values wins now against wins later.
- Given that the discount factor B is between 0 and 1, $\frac{\beta}{1+\beta}$ will be less than 1, which means **it will always be optimal to develop younger players to some extent**.
- Larger β - value future wins similarly to present wins - means that we will, in the equilibrium, want to develop younger players more.
- Aligns nicely with competitive windows. If we know this season is a rebuilding year, then we value future wins more, and we want to develop our players more.

Restrictions on Production Function 1

- w_t: a player's opportunity provided by the program
- In these growth models, this is the wage, the "cost" of labor.
- w_t: what the team can offer a player - playing time and development.
- Motivating factor for recruits (choosing schools based on how many NFL draft picks they've put out at that position, for example)

Recruiting

What "wages" do recruits most respond to? NIL/Rev Share? Coaching and development? Facility/amenities? Characteristics of school, location? NFL Draft picks produced at that position?

Restrictions on Production Function 2

College football teams convert players (labor) and productive snaps (capital) into wins

$$\text{Wins}_t = Ak_t^{\alpha}$$

- k_t is the productive snaps of each player
- A is the program specific technology
- α is the marginal productivity of quality snaps: how much more wins you get by adding more quality snaps. (Between 0 and 1)

Finding Your Alpha

How do schematic choices, recruiting, and player stability affect a team's ability to turn quality snaps into wins? How do injuries and in-season variance destabilize a team's alpha?

Optimal Player Development

- In equilibrium, $w_t = (1-\alpha)Ak_t^\alpha$.
- Substitution into above equation yields

$$s_t = \frac{\beta(1+\alpha)}{1+\beta}Ak_t^\alpha$$

- The optimal level of player development depends on marginal productivity, team technology, and the level of quality snaps in this period (current success).

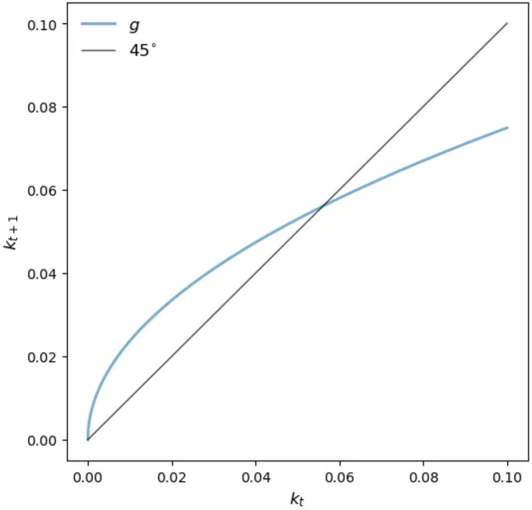
Evolution

- **Central Equation**:

$$k_{t+1} = \frac{\beta(1+\alpha)}{1+\beta} A k_t^{\alpha}$$

- Quality of our team next season depends on:
  - How much we value wins today relative to wins in the future β
  - The marginal productivity of additional quality snaps α
  - Our team technology A (strategy, facilities, strength and conditioning, analytics, etc)
  - The level of quality snaps we put on the field this season k_t
- Not just looking at every season as a random group of unaffiliated players, but instead as a path-dependent sequence where our choices today affect our quality in the future!
- **Crucial** for effective roster management.
- You have to be able to think about the entire horizon, not just live year to year, scrambling for answers.

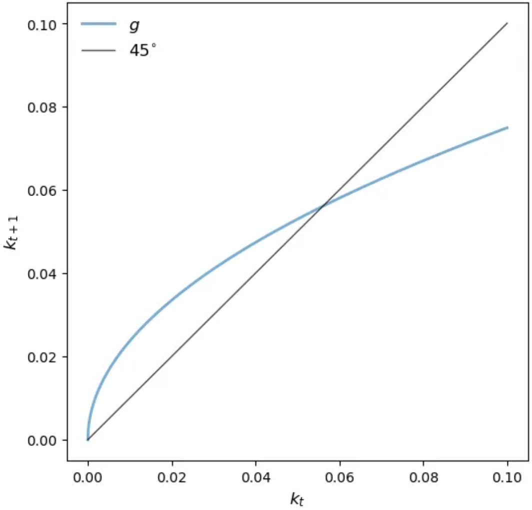
The Steady State



Cycles

- College football success is a multi-year process of development, close losses, and building foundations for the future.
- The Steady State governs how your team is going to peak and rebuild - the level where your productive snaps next season k_{t+1} is the same as your productive snaps this season k_t.

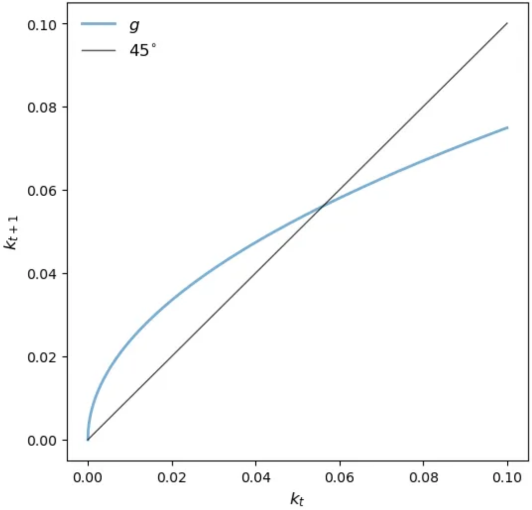
Steady State Dynamics 1



Cycles

- If $(k_t < k*)$, increase development to increase k_{t+1}, which will in turn, push up $k_{t+2}\ldots$ and so on, until you reach that steady state where you're optimizing your development process and consistently competitive across periods.
- If $(k_t > k*)$, you can afford to play prospects more and focus less on development, as you try to optimize for the current competitive window.

Steady State Dynamics 2



Dynamics

- What happens if we improve our team technology by hiring an analytics director?
- What changes if we want to be more competitive in the short-term (decrease our discount factor)?
- What lessons about talent acquisition could we learn by incorporating team-specific marginal productivity?

Discussion and Extensions

Summary

- Completed an example of model-based thinking and demonstrated how it can help solve real problems for football teams and front offices.
- Formalized the idea of diminishing returns to playing time (for players) and productive snaps (for teams).
  - “We are not collecting talent; we’re building a team" - Bill Belichick
- Introduced the idea of the steady state and found an equation to help us understand development cycles.
- Identified key elements of the model that could direct the efforts of analysts to improve team strategy.

Possible Extensions

- Not all snaps are created equal - s_t becomes a position-specific vector of development to optimize
- Incorporate probability of transfer into steady state - high performers might leave good lower-level schools, low playing time players might leave good schools.
- Decomposing marginal productivity into offense and defense
- Value of depth vs elite talent - player development and quality are uncertain

Thank you!

If you'd like these slides, or to discuss this further, don't hesitate to reach out!

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